

SECRET
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**DETECTION
AND
SIGHTING RADAR
ПРС-3
Technical Description
VOLUME I**

The Technical Description of radar MPC-3 is to be used for studying the radar by the technical and flying personnel of Air Force units utilizing the radar.

The Technical Description consists of three volumes.

The first volume contains general information on the radar, its functional description, description of its composition and constructional design, and description of the functional diagrams of the radar channels.

The second and the third volumes contain comprehensive description of the radar units.

The book contains 102 pages.

CONVENTIONAL DESIGNATIONS AND ABBREVIATIONS USED IN
THE DESCRIPTION

УИЧ - intermediate frequency amplifier (IFA)
УИЧ-10 - IFA-10
УИЧ-30 - IFA-30
ИВАИЧ - automatic frequency control preamplifier (AFCPA)
ИВИЧ - intermediate frequency preamplifier (IFPA)
СДЧ - remote control system (RCS)
УИТ - direct current amplifier (DCA)
АИЧ - automatic frequency control (AFC)
АФЧ - automatic gain control (AGC)
РФЧ - manual frequency control (MFC)
РФЧ - manual gain control (MGC)
ТН - television sight (TS)
ТХН - bore-sighting gauge (BSG)
СЧВ - intercommunication system (ICS)
КНЧ - tail gun mount (TGM)
СОБ - defensive armament system (DAS)
R - resistor
L - inductance
C - capacitor
Л_д - delay line
Д_р - choke
Т_р - transformer
M - electric motor
СН - selsyn
P - relay
Ш - plug connector
B - switch and selector switch
ББ - computer unit
БК - limit switch
ГК - contact group
Б - interlocking
БМ - mechanical interlocking
Д_р - fuse
Л - electron tube
НН - neon lamp
НН - incandescent lamp
РЗН - receiver protection discharger (RPD)
Д - crystal detector
СБ - selenium rectifier
ИИ - measuring instrument
КТ - test point
МЧ - magnetic amplifier
ЗМЧ - amplidyne
СЧ - servo-amplifier (SA)
КК - test contact
f_{сч} - centre frequency of magnetron (f_{сч})
f_{нч} - lower frequency of magnetron (f_{нч})
f_{вч} - upper frequency of magnetron (f_{вч})

Δf_m	- magnetron frequency change band (Δf_m)
f_{BK}	- upper frequency of klystron (f_{uk})
f_{HK}	- lower frequency of klystron (f_{lk})
Δf_k	- klystron frequency change band (Δf_k)
f_{CK}	- rate of radiator rotation, scanning frequency (f_{sc})
f_n	- synchronizing pulse repetition frequency (f_r)
T_1, T_2	- delay time of ultrasonic line ЛЗЗ-З
$\tau \Delta f_m$	- time of magnetron frequency change ($\tau \Delta f_m$)
P_{KMP}	- pulse power of transmitter (P_{pls})
P_{CP}	- average power of transmitter (P_{av})
МЛЗ	- measuring delay line
УДС	- damping signal amplifier (DSA)
УЛЗ	- ultrasonic delay line
К	- button
ИИ	- indicator
УО	- control winding
РД	- rheostat pickoff
У	- assembly
УК	- ultrasonic calibrator (UC)

Note. The numerical values of the parameters designated conventionally by letters are presented in the Radar Operating Instructions.

I. GENERAL INFORMATION ON RADAR

A. PURPOSE

Tail detection and sighting radar NPC-3 is designed for installation in jet bombers and serves for:

- detection of air targets abaft the aircraft;
- lock-on of the selected target, automatic tracking of it and supplying the computer with data required for solving the air firing problem (these data are: the angular coordinates of the target, the angular speed, the target range, and the range derivative).

B. OPERATING PRINCIPLE

In the aircraft defensive armament system, radar NPC-3 carries out successively the task of scanning (observation of the air situation abaft the aircraft) and the task of sighting (directing the antenna head to the target located in the scanned area, target lock-on and angle and range tracking). It also supplies the computer with the target data (its angular coordinates, angular speed, range, and closing speed).

Corresponding to these tasks, radar NPC-3 has the following three modes of operation: the mode of space scanning, the mode of directing the antenna to the target, and the mode of target lock-on and angle and range tracking.

The design of the radar antenna makes it possible to fulfil the task of space scanning and the task of sighting successively.

The scanning of space is effected by means of spiral movement of the antenna beam (Fig. 1) due to rotation and simultaneous deflection of the reflector from the rotation axis (from the zero position). In the mode of scanning, the antenna of the radar scans the space within a 70° solid angle (Fig. 2).

At the operator's will, the scanned area in azimuth may be enlarged automatically by an angle of 20° or manually by an angle of 30° due to shifting the scanning axis to the right and to the left with respect to the aircraft flight direction (Fig. 3).

The area scanned by the radar (with the solid angle being at least 70°) is divided into the following three zones: zone I of 0 to 12° with respect to the scanning axis; zone II of 12 to 24° with respect to the scanning axis; zone III of 24 to 36° with respect to the scanning axis (Fig. 4).

If a target appears in the radar control area, the screen of the indicator displays a mark of the target with that of the scanned zone (Fig. 5).

The target marks caused by friendly aircraft are accompanied on the indicator screen by mark FRIEND (СВОЙ): the wider mark which is farther than the target mark.

Hence, with the aid of the indicator screen, it is possible to determine:

- the direction to the target with respect to the scanning axis (according to the radial direction from the centre of the screen to the target mark);
- the scanned zone in which the target is located;
- the distance to the target;
- the national identity of the target;
- a possible lock-on range according to the lock-on range mark.

After a target is detected, the antenna head can be directed to it either manually by the operator with the aid of the indicator screen or automatically.

When directing manually, the operator, using the indicator screen, determines the national identity of the target and its position in space, and then depresses the action switch.

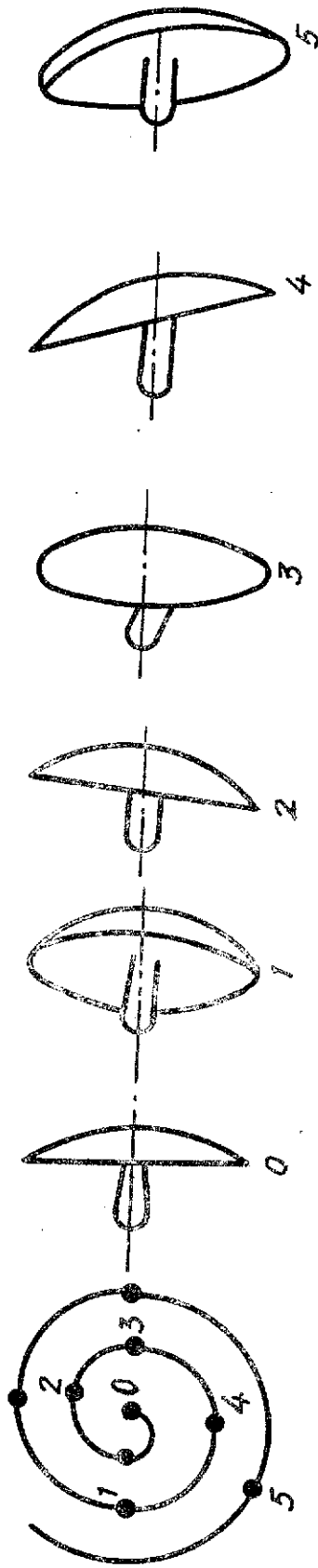


FIG. 1. SHAPING OF SPIRAL MOVEMENT OF ANTENNA BEAM

0 - zero position of reflector; 1 - reflector deflected to the left, beam deflected to the left; 2 - reflector deflected upwards, beam deflected upwards; 3 - reflector deflected to the right, beam deflected to the right; 4 - reflector deflected downwards, beam deflected downwards; 5 - reflector deflected to the left and downwards, beam deflected to the left and downwards

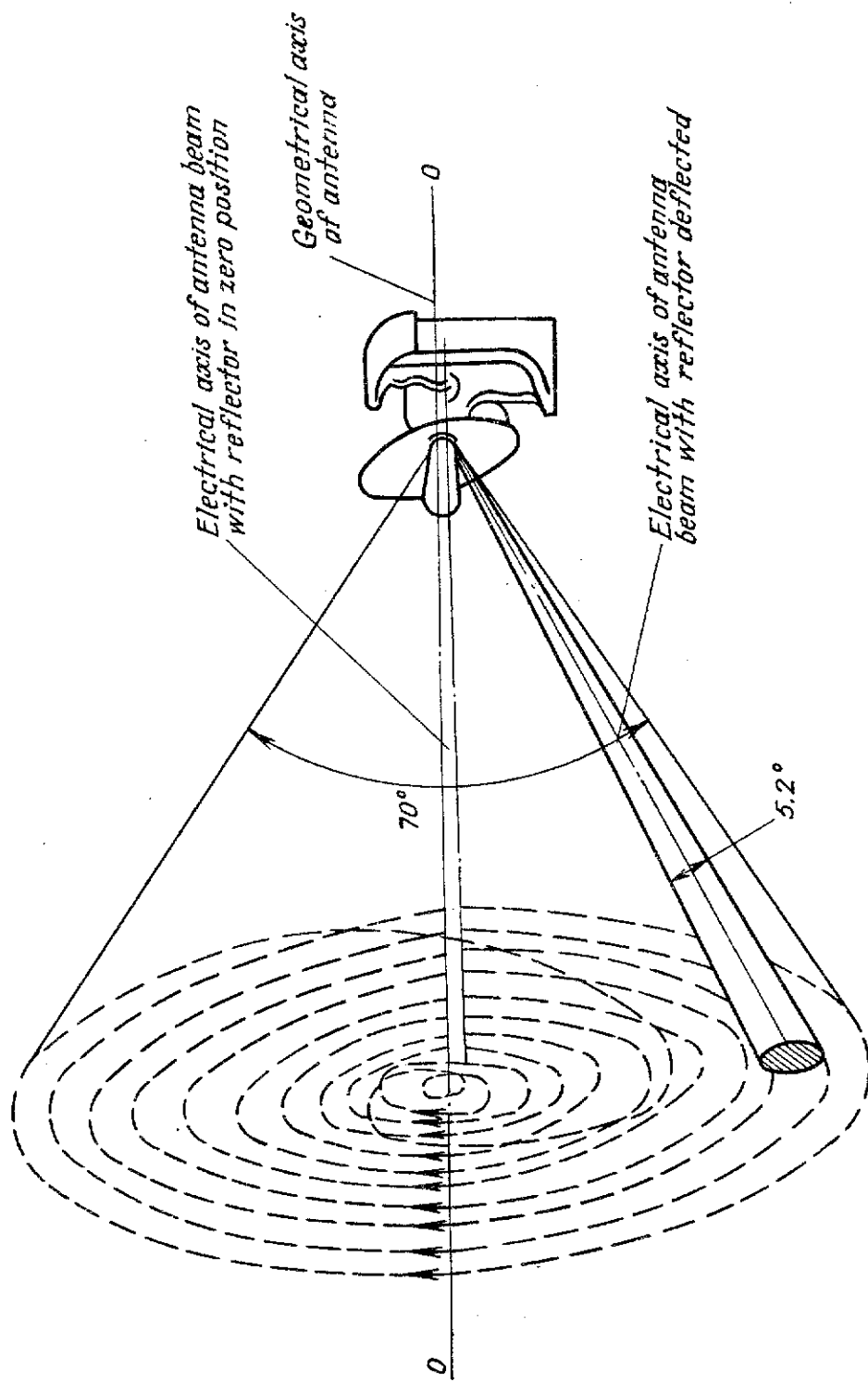


FIG. 2. RADAR IIIC-3 SCANNING DIAGRAM

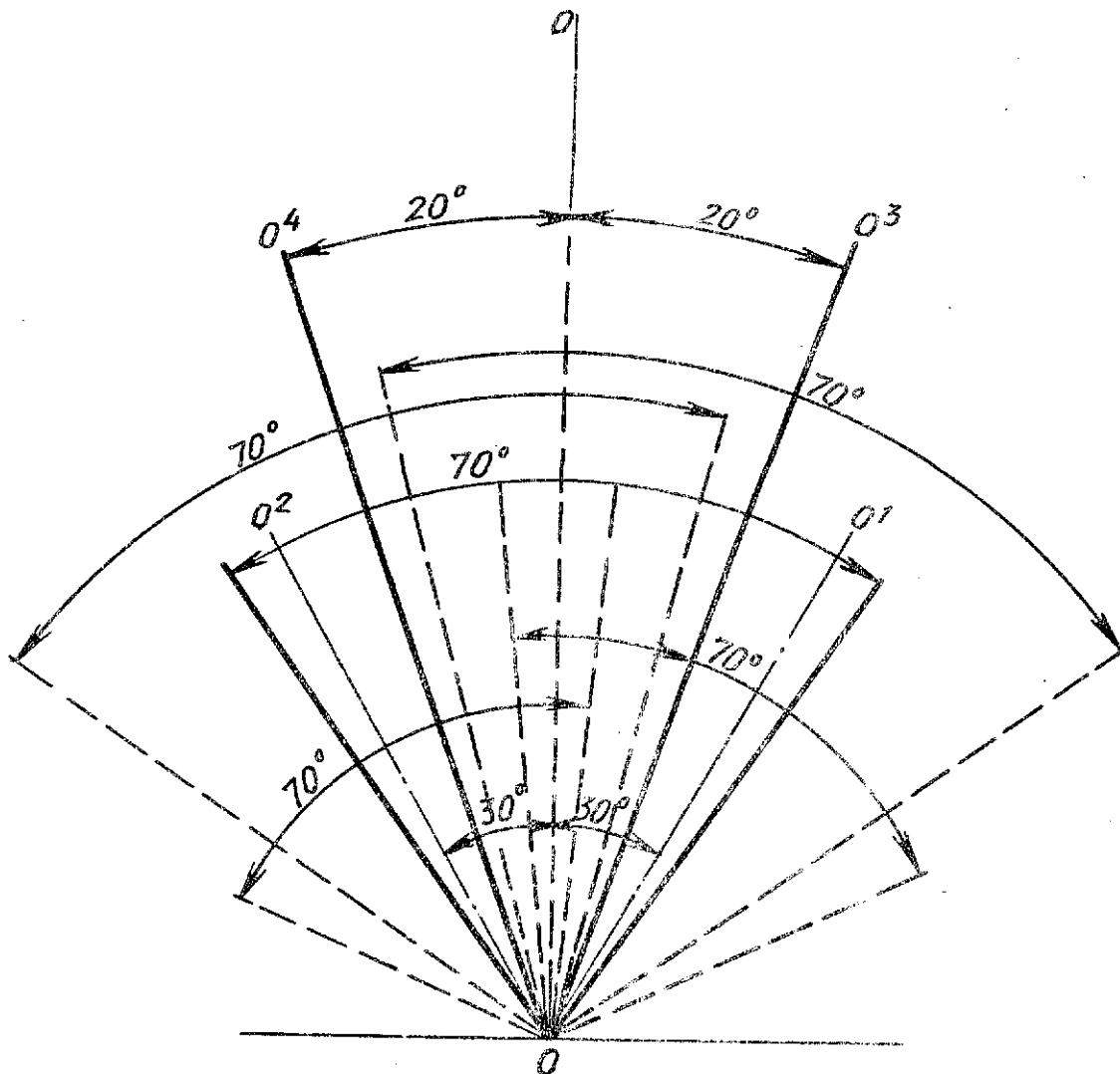


FIG. 3. SHIFTING OF RADAR ИРС-3 SCANNED AREA

00 - axis of central scanned area (along aircraft axis); 00¹ - axis of scanned area shifted manually to the right through 30°; 00² - axis of scanned area shifted manually to the left through 30°; 00³ - axis of scanned area shifted automatically to the right through 20°; 00⁴ - axis of scanned area shifted automatically to the left through 20°

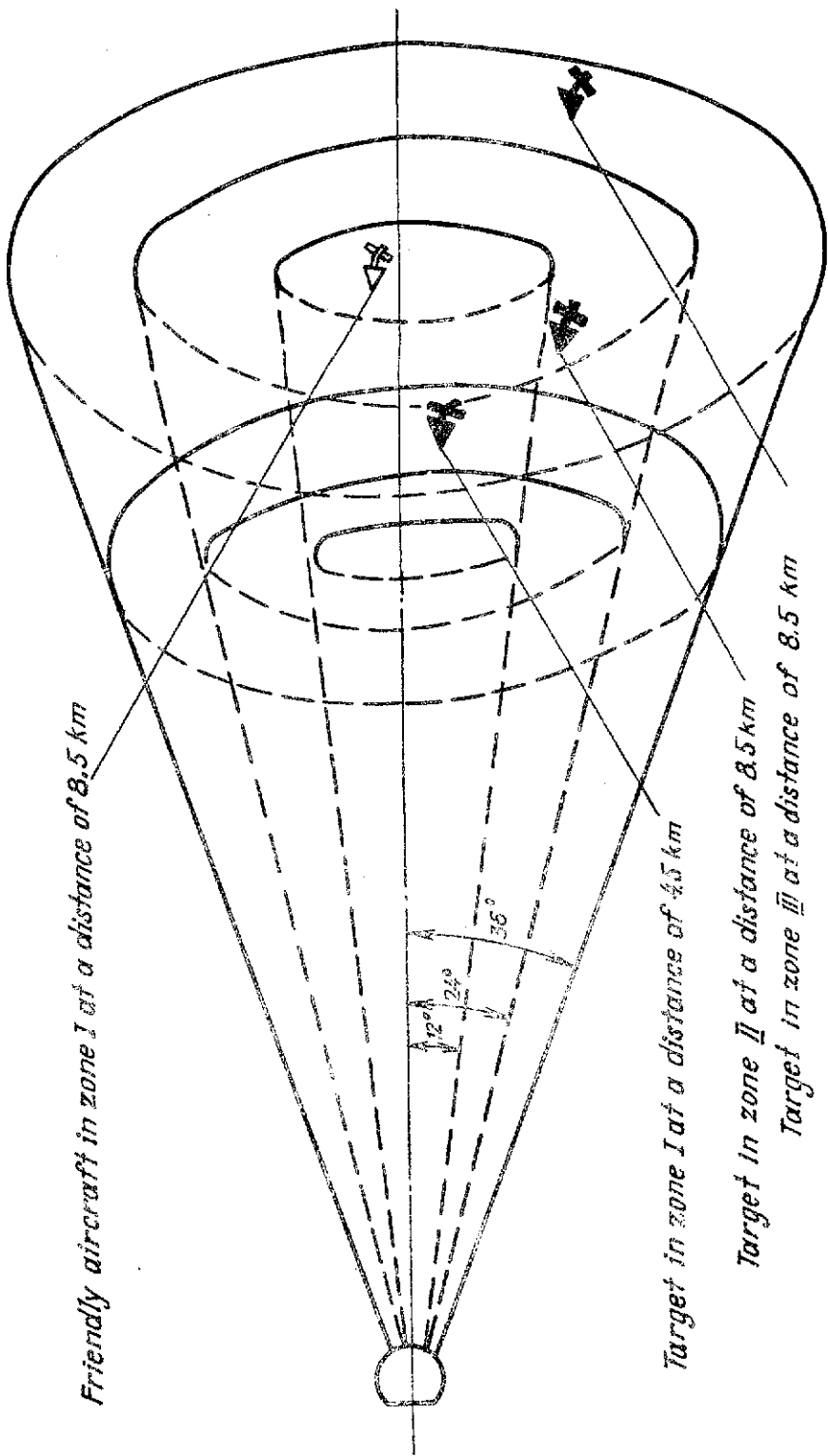


FIG. 4. RADAR SCANNED AREA DIVIDED INTO THREE ZONES

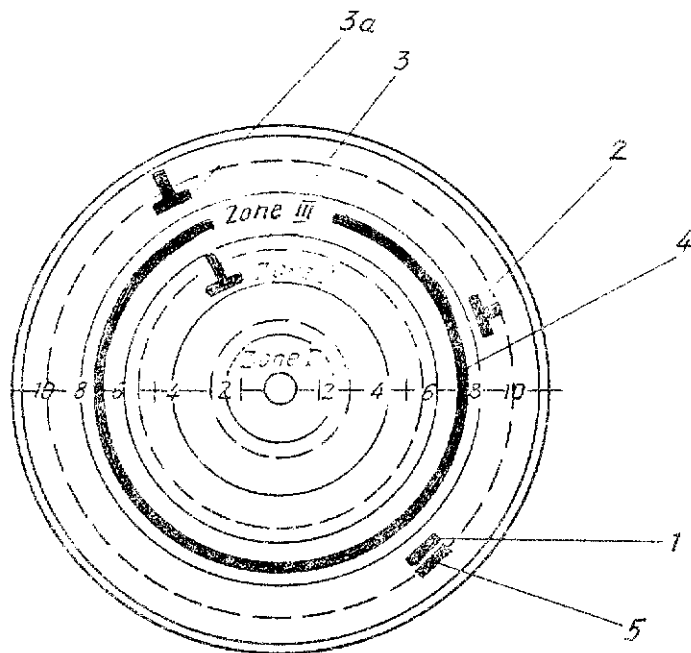


FIG. 5. APPEARANCE OF INDICATOR SCREEN IN SCANNING MODE
 1 - mark of friendly target in zone I; 2 - mark of target in zone II; 3, 3a - marks of targets in zone III; 4 - lock-on range mark; 5 - friendly target identification mark

The marks and the targets are shown in accordance with Fig. 4.

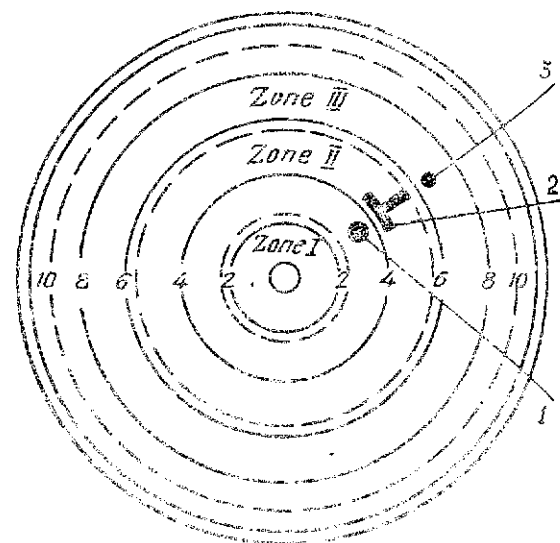


FIG. 7. APPEARANCE OF INDICATOR SCREEN IN MODE OF MANUAL ANTENNA POSITIONING

1 - mark of antenna head axis, 2 - mark of target in zone III (seen due to afterglow of CRT); 3 - dot "middle of zone" into whose CRT mark 1 should be brought to lock on the target

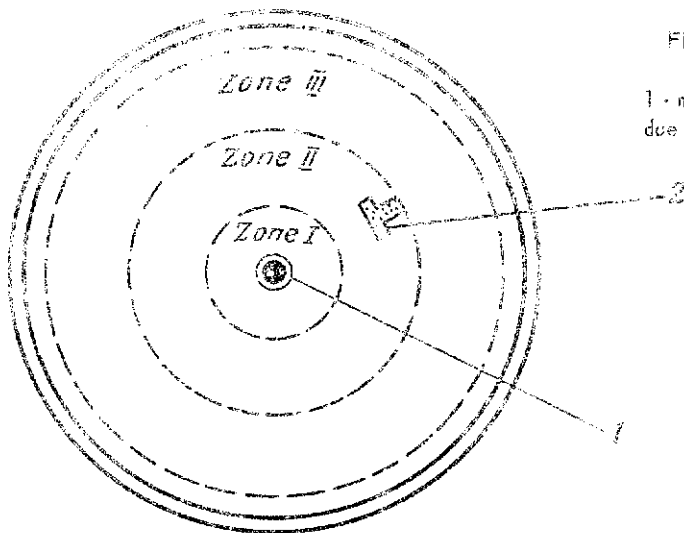


FIG. 6. APPEARANCE OF INDICATOR SCREEN IN MODE OF MANUAL ANTENNA POSITIONING

1 - mark of antenna head axis at instant of positioning; 2 - mark of target in zone III (seen due to afterglow of CRT)

In this case, the reflector of the antenna is attracted to the zero position, and the radiator of the antenna starts rotating. This means that the antenna head stops its scanning function and starts its sighting function.

As a result, the indicator screen will start displaying an antenna-positioning mark in the form of a bright dot.

The target mark, in this case, will remain in view due to the afterglow of the indicator cathode-ray tube (Fig. 6).

In this mode of operation, the entire scale of the indicator corresponds to 70° of the solid angle in which the space is scanned, and is divided by two circumferences into three zones which correspond to the three space-scanning zones. The centre of the scale corresponds to the axis of the scanned area.

The operator turns the handles and the control panel of TI-1A in such a way as to move the antenna-positioning mark from the centre in the direction of the target, which has been selected for lock-on, to the middle of the zone whose mark followed up the target when scanning (Fig. 7).

After directing the antenna head to the target, the lock-on of the target occurs and its angle and range tracking begins.

The angle tracking of the target is based on the principle of equisignal Alcock, which is obtained due to the rotation of the antenna radiator deflected through a certain angle from the rotation axis (Fig. 22).

The measurement of the target range depends on the pulse principle of radar operation. The distance to the target is determined by the time required for the pulse sent by the radar to travel to the target and to return to the radar after being reflected from the target.

The lock-on of the target is indicated by lamp LOCK-ON (ЗАХВАТ), which starts glowing (the lamp is located on the indicator), and also by the locked-on target mark which appears on the screen. In this case, the indicator starts to operate in the mode of locked-on target indication (Fig. 8).

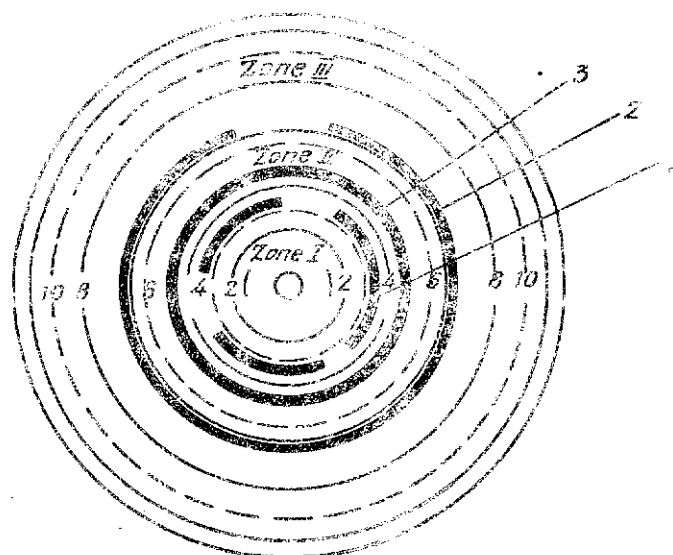


FIG. 8. APPEARANCE OF INDICATOR SCREEN IN MODE OF TARGET TRACKING

1 - mark of locked-on target; 2 - mark of lock-on range; 3 - mark of target in area scanned by antenna

The mark of the locked-on target is displayed on the indicator screen in the form of a ring divided into three arcs.

The marks of other targets situated in the area scanned by the antenna beam in the tracking mode have the shape of circumferences.

When the target approaches the range of aimed fire, lamp FIRE (ОГОНЬ) on the indicator starts glowing.

The opening of fire is effected by means of depressing button FIRE (ОГОНЬ). The fire can also be opened automatically, if switch FIRE (ОГОНЬ) is set to position AUTOMATIC (АВТОМАТ) and if the target is located at the aimed fire range.

If it is necessary to stop target tracking, button TARGET RELEASE (ОСВОБОДИТЬ) is to be depressed. The handles and the control panel are returned to the zero position and the action switch is released. The radar passes to the scanning mode of operation.

In order that the antenna head may be directed to the target automatically, the operator switches the radar over to the mode of automatic positioning.

When a target appears in the scanned area, the antenna head is directed to the target automatically (without assistance of the operator). In this case, the antenna head stops its scanning function and begins its sighting function, and the lock-on and automatic angle and range tracking of the target take place.

When radar ИРС-3 operates jointly with the identification system of the СР30-2 set, then no possibility is provided for directing the antenna to friendly aircraft automatically.

To exclude the possibility of locking on the ground when the aircraft flies at low altitudes, the radar is provided with setting of lock-on limitation.

The limitation of lock-on is set by the operator making use of knob LOCK-ON RANGE (ЗАМБН. ЗАХБ.) and the lock-on range mark on the indicator screen; the mark is of the shape of a ring with a darkened sector in its upper part (Fig. 3).

If the mark of the ground or aircraft (target) is situated farther than the lock-on range mark, these objects cannot be locked on.

Radar ИРС-3 is provided with protection against deliberate jamming. This protection is effected by means of changing the magnetron frequency.

The magnetron has 12 fixed frequencies for tuning.

Change-over from one fixed frequency to another can be effected either manually or automatically.

In the automatic change-over mode, the magnetron frequency changes without assistance of the operator if jamming appears.

In the manual change-over mode, knob FREQUENCY CHANGE (ИЗМЕНЕНИЕ ЧАСТОТЫ) is to be depressed.

The radar is also provided with protection against nonsynchronous pulse jamming. This protection is effected by means of selecting the target pulses according to the transmitted pulse recurrence frequency. The description of the selection method will be presented below.

In the defensive armament system of the aircraft, radar ИРС-3 operates in combination with television sight ТН-1А and sighting-and-computing units, and it is also coupled with the identification system (set СР30-2). In this system, control of the tail gun mounts can be effected by means of:

- (a) radar ИРС-3 (the RADIO /РАДИО/ mode);
- (b) television sight ТН-1А (the OPTICS /ОПТИКА/ mode);
- (c) radar ИРС-3 when the antenna head is directed to the target by television sight ТН-1А (the ANTENNA POSITIONING /НАВОДКА/ mode);
- (d) television sight ТН-1А when the target range and the closing speed are determined by radar ИРС-3 (the OPTICS - RANGE FINDER /ОПТИКА - ЗАМБНОМЕР/ mode).

II. MAIN TACTICAL AND TECHNICAL CHARACTERISTICS OF RADAR

A. TACTICAL CHARACTERISTICS

(a) The range of detection of attacking jet fighters is 6500 m with the closing speed being 100 m/s.

(b) The scanned area is not less than 70° of solid angle.

The scanned area axis may be shifted in azimuth through $\pm 30^\circ$ manually and through $\pm 20^\circ$ automatically.

(c) The time of scanning the area is 2.7 to 3 s.

(d) The range of lock-on of the identified target is 3000 m with a probability of not less than 95 per cent and a relative closing speed of 100 m/s.

(e) The radar provides automatic tracking of targets within angles of $\pm 35^\circ$ in angular height and within angles of $\pm 65^\circ$ in azimuth.

(f) The mean-square error in determining the target position during automatic tracking and in introducing the data into the computer should not exceed 3 thousandths of the distance at ranges of 400 to 3000 m with the relative angular rate being 0 to 0.3 rad/s and the angular acceleration up to 0.5 rad/s^2 . The error is determined on the weapon.

(g) The ranges that can be supplied to the computer are 350 to 4000 m.

(h) The maximum error in determining the target range and in introducing it into the computer does not exceed 40 m for distances up to 2000 m, and 70 m for distances up to 4000 m.

(i) The radar can produce a range derivative in the limits from 0 to 300 m/s. The accuracy of generation of the range derivative is not worse than 30 m/s within 0 to 300 m/s.

(j) The screen of the indicator makes it possible:

- to determine roughly the range to the target within 350 to 4500 m with the maximum error being not more than 450 m, and at distances from 4500 to 10,000 m with the maximum error not exceeding 10 per cent of the distance in question;

- to determine the position of the target in space with respect to the geometrical axis of the antenna with the aid of the marks of the zones in the mode of scanning;

- to determine the angular position of the locked-on target to an accuracy of $\pm 9^\circ$ with knob INDICATION ON (BKL. VHEMK.) depressed;

- to determine the national identity of the target with the aid of mark FRIEND.

(k) The minimum range of the radar (its dead area) does not exceed 350 m.

B. TECHNICAL CHARACTERISTICS

(a) The range of magnetron frequency change is Δf_m .

(b) The average power of the transmitter is not less than P_{av} .

(c) The synchronizing pulse repetition frequency is f_p .

(d) The sensitivity of the receiving channel, as measured by the disappearance of the signal in noise, is not less than 98 dB with respect to 1 mW.

(e) The beam width of the directivity pattern at the level of 0.5 is as follows:

- $5.2 \pm 0.8^\circ$ in plane H;

- $5.2 \pm 0.8^\circ$ in plane E.

(f) The duration of the transmitted pulse of the radar is $0.45 \pm 0.05 \mu\text{s}$.

III. FUNCTIONAL DESCRIPTION OF RADAR

Synchronization of operation of all the radar components is effected by a master blocking oscillator.

The pulse recurrence frequency of the master blocking oscillator is stabilized by an ultrasonic delay line (VMS). The blocking oscillator is started by its own pulse delayed in the delay channel by the ultrasonic line.

The master blocking oscillator shapes so-called sweep triggering pulses which trigger the range sweep circuit and the synchronizing pulse shaping circuit. The latter generates synchronizing pulses which start the submodulator.

The submodulator generates pulses which trigger the modulator of the magnetron oscillator. The magnetron oscillator generates high-power radio-frequency pulses of a 0.45- μ s duration, whose repetition frequency is equal to that of the synchronizing pulses.

The radio-frequency energy of the transmitter is supplied through antenna switch RECEIVE - TRANSMIT (ПРПЕМ - ПЕРЕДАЧА) and through the waveguide system to the antenna, which radiates the radio-frequency energy into space.

The antenna has a reflector which bunches the radiated energy into a narrow beam. Scanning of space is effected due to a spiral movement of the antenna beam.

Such a movement of the antenna beam, as was stated earlier, is obtained by means of rotation of the antenna reflector and of its simultaneous deflection from the rotation axis.

The deflection of the reflector is performed by an electromechanical system which consists of commutator EI-6 linked mechanically with the reflector deflecting mechanism and of a reflector deflection control circuit which connects successively the electric magnets of the couplings serving for deflecting the antenna reflector and returning it to the zero position.

When the radio-frequency energy pulses travel through the waveguide line to the antenna, a small part of their energy is branched into the balance mixer of the automatic frequency control circuit (AFC) of the klystron local oscillator. The AFC circuit maintains the frequency of the klystron local oscillator 30 MHz higher than that of the magnetron oscillator.

If a target is present in the scanned area, the radio-frequency pulses reflected from it are received by the antenna and supplied through the waveguide line and antenna switch RECEIVE - TRANSMIT to the balance signal mixer in which they are converted into intermediate-frequency pulses.

After the radio-frequency pulses are converted into the 30-MHz intermediate-frequency pulses (the 30-MHz frequency is equal to the frequency of the klystron local oscillator minus the frequency of the R.F. pulse reflected from the target), and after the intermediate-frequency pulses are amplified by the intermediate-frequency preamplifier (ИВНЧ), the target signals, in the form of intermediate-frequency pulses are supplied to the IFA-30 main amplifier (УМН-30).

In order to provide a constant amplification factor of the intermediate-frequency preamplifier and, consequently, a constant level of the basic noise at the IFA-30 output, use is made of automatic gain control in the intermediate-frequency preamplifier. Such a control is performed by a noise AGC circuit.

To improve the anti-jamming ability of the radar, the IFA-30 is triggered by means of the reception keyer only for the time of reception (65 \pm 5 μ s).

The signal amplified by the IFA-30 is converted into a video pulse by the second detector, then it is amplified by the video amplifier and supplied to the circuit of protection against nonsynchronous pulse jamming (to the delay channel and to the coincidence circuit).

To protect the receiving channel against the action of deliberate jamming, the radar is provided with automatic change-over of the magnetron operating frequency. An increase of noise at the receiver output due to the presence of jamming causes the jamming recorder circuit to operate. The latter in its turn makes the magnetron change its frequency. The magnetron frequency is repeatedly changed by the frequency change mechanism until the jamming effect disappears at all or until its presence does not interfere with the radar operation. Provision is also made for manual change of the magnetron frequency at the operator's will, and this is effected by depressing button FREQUENCY CHANGE.

Protection against nonsynchronous pulse jamming is effected by means of selecting the pulses according to the recurrence frequency. This method consists in the fact that all the signals arriving at the receiving channel of the radar pass to the coincidence circuit by the following two paths: (1) directly and (2) through the ultrasonic delay line which delays the signal for the synchronizing pulse recurrence period.

If the direct and delayed signals arrive at the coincidence circuit simultaneously, which is the case for the target pulses, then they can pass through this circuit.

In such a condition, the signals of pulse jamming whose recurrence period is not equal to the recurrence period of the pulses transmitted by the radar cannot pass to the output of the receiver (from the coincidence circuit). From the output of the coincidence circuit, the target signals are supplied to the target and mark pulse mixer in which they are combined with the pulses of zone marks and of lock-on range marks and, when the target is locked on, with the pulses of locked-on target marks taken from the respective circuits. Besides, if the radar operates jointly with set CP30-2, applied to the target and mark pulse mixer from the FRIEND mark circuit are the pulses serving for determining the national identity of the aircraft (the marks of the friendly aircraft).

The target and mark pulses amplified by the video amplifier are supplied to the cathode of the cathode-ray tube of the indicator.

The range sweep circuit produces a linear voltage which, in the mode of scanning, is supplied to the rotor of rotary transformer BT1-3 mechanically coupled with the antenna reflector rotation axis.

The mutually-perpendicular linear voltages picked off the stator windings of the rotary transformer are supplied to the deflection coils of the indicator to produce a radial-circular sweep on the indicator screen.

Such is the way of synchronizing the direction of the antenna beam to the target with respect to the scanning axis and the direction from the centre of the screen to the target mark.

In scanning, the target marks can be observed on the screen in the form of bright arcs whose distance from the centre of the screen makes it possible to determine the target range, while the direction from the centre of the screen to the target mark makes it possible to determine the direction to the target from the scanning axis (Fig. 13).

If targets are located in the zone from 12° to 24° with respect to the scanning axis, the target marks on the indicator screen are accompanied by additional radial marks (zone marks) with a duration of $4 \mu\text{s}$ (600 m on the indicator scale). And if targets are in the zone between 24° and 36° with respect to the scanning axis, these marks have a duration of $10 \mu\text{s}$ (1500 m). The mark of a target situated in the zone from 0 to 12° with respect to the scanning axis is not accompanied by the zone mark.

The identification mark makes it possible to distinguish friendly targets from hostile targets. It is shaped from the signal coming from set CP30-2 by the identifi-

cation mark circuit. Set CP30-2 is started by a pulse of the synchronization system when switch INTERROGATION (ОНРОС) is turned on. The reply signal of the identification set appears only when the target is friendly. When the identification system operates the friendly target marks on the indicator screen are accompanied by additional wide marks situated farther than the main marks.

The lock-on range mark on the screen is displayed in the form of a ring with a darkened arc in the upper part.

When locked on, all the targets situated in the area scanned by the antenna are displayed on the indicator screen in the form of rings, the ring of the tracked target being divided into three arcs.

Provision is made in the radar for manual and automatic shift of the scanned area in azimuth by means of coupling a differential selsyn between the TH-1A transmitting selsyn and receiving selsyn CH1-6 of the antenna. The manual shift is effected with the aid of knob ZONE SHIFT (ЗОНЕ ШИФТ) by means of turning the rotor of differential selsyn CH6-1 through an angle of $\pm 30^\circ$.

The automatic shift of the scanned area through an angle of $\pm 20^\circ \pm 3^\circ$ is effected with the aid of the scanned area azimuth automatic shift control circuit which, in synchronism with the deflection of the reflector, connects chokes to the open ends of the stator windings of selsyn CH6-1.

When the antenna head passes from the mode of space scanning to the mode of directing the antenna to the target, the antenna stops its scanning function and starts the sighting function, which means that the deflection of the reflector from its rotation axis (the axis of the antenna head) discontinues (the rotating reflector is kept in the zero position) while the radiator starts rotating, its axis being deflected with respect to the antenna head. The direction of the sighting antenna head to the target can be effected both manually by the operator and automatically.

When the antenna head is manually directed to the target, the indication of the antenna-positioning mark on the indicator screen is effected by means of supplying the deflection coils of the cathode-ray tube with the voltage taken from the positioning potentiometers which are mechanically coupled with the TH-1A control panel.

For manual direction of the antenna head to the target, use is made of synchronous coupling between the azimuth and tilt transmitting selsyns mechanically linked with the TH-1A control panel and the receiving selsyns of the antenna (azimuth selsyn CH1-6 and tilt selsyn CH1-5).

When the handles and the control panel of TH-1A are rotated, voltages are set up across the rotors of the receiving selsyns. The amplitude and the phase of the voltages depend on the direction of the antenna-positioning knob rotation.

These voltages are amplified by the antenna-positioning voltage amplifier and supplied to the input of the azimuth and tilt commutators which also receive the rectangular pulses of the reference voltage multivibrators. As a result of interaction between the voltages picked up from the rotors of selsyns CH1-6 and CH1-5 and the reference voltage pulses in the azimuth and tilt commutators, the outputs of the latter produce rectified voltages whose value and sign depend on the value and the direction of rotation of the TH-1A control panel and handles.

The output voltages of the commutators are amplified by the direct current amplifiers (VHT) and by the amplidyne (3MV), and they are supplied to azimuth and tilt electric motors M1-2 and M1-1. The electric motors rotate the sighting antenna head until the voltage across the rotors of selsyns CH1-5 and CH1-6 becomes equal to zero, i.e., until the antenna is brought into coincidence with the positions of the handles and the control panel of TH-1A.

To provide stability in operation of the antenna-positioning electromechanical system, use is made of a damping system consisting of damping signal amplifiers (VDC) through which a negative feedback is effected between the amplidyne and the direct current amplifiers.

At some instant, when directing the antenna to the target, the radio beam encounters the target and the pulses reflected from the target get through the antenna to the input of the receiving channel.

Just like in the mode of scanning, the reflected pulses are converted into intermediate-frequency pulses, amplified in the IFA-30, detected, and amplified by the video amplifier.

From the output of the jamming rejection circuit, they are supplied to the automatic angular lock-on device, while from the output of the video amplifier they are supplied through the range selector to the input of the error signal separation circuit.

The automatic angular lock-on device receives also a lock-on range pulse. It is due to this pulse that the automatic lock-on device is caused to function only by the pulses of such targets which are situated within the lock-on range. The lock-on range is set by the operator with the aid of knob LOCK-ON RANGE (ДАЛЬНО. ЗАХВ.) depending on the level of the interfering effect produced by the reflections from ground objects. The automatic lock-on device functions and switches over the radar from the antenna-positioning mode to the tracking mode. The functioning of the automatic lock-on device is indicated by lamp LOCK-ON (ЗАХВАТ), which starts glowing, and by the change-over of the indicator from the mode of the antenna head axis indication (in case of manual antenna positioning) to the mode of tracked target indication.

When the target is locked on in angular coordinates, relay P3V of the automatic angular lock-on device operates. Manual positioning selsyns CH1-6 and CH1-5 get disconnected from the antenna control circuits and the control of the antenna is passed to the target angle tracking circuit, with the reflector movement control circuit keeping the reflector in the zero position. The radiator of the antenna continues rotating.

When the radiator is rotating, the antenna beam describes in space a conical surface whose axis coincides with the reflector axis (Fig. 22).

In this case, the target which is not located on this axis is illuminated during a single revolution of the beam by pulses of electromagnetic energy whose intensity varies.

Therefore the amplitude of the reflected signal also varies. The amplitude varies according to a periodic law which is almost like the sinusoidal law, the amplitude variation frequency (the modulation frequency) being equal to radiator rotation rate f_{sc} .

It is obvious that the farther the target is shifted with respect to the axis of the scanning cone (the reflector axis), the greater is the pulse modulation depth. The phase of the reflected pulse amplitude envelope is determined by the direction in which the target is shifted from the equisignal direction: downwards, to the left, to the right, etc. (Fig. 23). When receiving reflected radio pulses whose amplitude changes with time, the output of the receiver video amplifier produces video pulses whose amplitude varies according to the same law which governs the variation of the amplitude of the radio pulses at the input of the receiver.

These video pulses pass through the range selector and then they are converted in the error signal separation circuit into an alternating voltage whose frequency is equal to the rate of the antenna beam rotation and whose amplitude and phase are

determined by the angular shift of the target with respect to the equisignal direction. This voltage is called the error signal. If the amplitude of the reflected pulses does not vary with time, which is the case when the target is situated in the equisignal direction there will be no error signal.

The error signal voltage is amplified and converted into two opposite-phase voltages supplied through the P3V angular lock-on relay to the azimuth and tilt commutators.

Mounted on the antenna radiator rotation axle are two magnets of inductors. The coils of the inductors are 90° apart and produce two pulses whose recurrence frequency is equal to radiator rotation rate f_{sc} . The pulses of the inductors trigger the azimuth and tilt reference voltage multivibrators.

The rectangular pulses of the multivibrators are supplied respectively to the azimuth and tilt commutators.

As a result of interaction between the error signal and the reference voltage pulses in the commutators, the outputs of the latter put out rectified voltages whose value and sign depend on the extent and the direction to which the target is shifted from the reflector axis.

The voltages from the outputs of the azimuth and tilt commutators are amplified by the direct current amplifiers (VHT) and by the amplidynes (3MY) and then supplied to the azimuth and tilt electric motors rotating thereby the antenna head in the direction of error signal decrease, i.e., in the direction of bringing the antenna head into line with the direction to the target. To eliminate self-oscillations of the antenna head in the angle tracking mode, use is made of a damping system consisting of damping signal amplifiers (VDC). Through this system, a negative feedback is effected between the amplidynes and the direct current amplifiers.

In order to provide a reliable accurate tracking of the target, the receiving channel should transfer the modulation of the target signals without distortion of its phase and modulation factor under any conditions and in case of any variations of the amplitude of the signal caused by the target being tracked. For this purpose, the radar uses selected-target pulse AGC (pulse AGC). The pulse AGC changes the IFA-30 amplification depending on the mean amplitude of the tracked target signal, provides a distortionless passage of the modulated target pulses through the receiving channel, and suppresses any parasitic modulation of the error signal (i.e., the modulation by a frequency which differs from f_{sc}).

The automatic antenna positioning is performed in the following way. Mounted on the antenna are reflector rotation transmitting rotary transformer BT1-2 and reflector deflection transmitting rotary transformer BT1-1 which, with their signals summed up, put out the coordinates of the reflector and, consequently, the position of the beam in space with respect to the antenna head axis.

In addition, there are antenna head position pickoffs: two potentiometers R1-1 (of tilt) and R1-2 (of azimuth).

The coordinates of the reflector and of the antenna head are supplied to the azimuth and tilt phase detectors where they are summed up and converted into direct voltages whose values determine the complete coordinates of the beam in azimuth and tilt with respect to the aircraft axis, and these voltages are supplied to the memory circuits.

The target pulses are supplied to the hostile target generating circuit. When a hostile target is detected in the scanned area, this circuit produces a hostile target pulse and sends it to the automatic antenna-positioning device. The latter operates, starts thereby the azimuth and tilt target coordinate memory circuits, changes the

antenna operation from scanning to sighting, and couples antenna control to the memory circuit.

For memorizing the voltages corresponding to the beam coordinates, the memory circuits are conductive only for a few milliseconds when the beam is directed to the target; they send these voltages to the direct current amplifier circuits through compensating positioning potentiometers R1-3 (of tilt) and R1-4 (of azimuth) installed on the antenna.

The sliders of compensating potentiometers R1-3 and R1-4 are mechanically linked with the antenna head.

The automatic antenna-positioning circuit operates in such a way that a single definite position of the compensating potentiometer slider and, consequently, a definite position of the antenna head at which there is no unbalance between the currents of the direct current amplifiers correspond to a definite memorized voltage and, consequently, a definite position of the target with respect to the scanning axis.

As long as there is no such a correspondence, there will be an unbalance between the currents of the direct current amplifiers, and the electric motors will rotate the antenna head (until it gets directed to the memorized position of the target).

When the antenna head gets directed to the target, the angular lock-on of the target will occur and the system will start tracking the target.

With the target being tracked, the angular position of the antenna head (i.e., the angular coordinates of the target) is introduced into the computer with the aid of four transmitting selsyns CH1-1 through CH1-4 which are coupled with the antenna head azimuth and tilt reducers.

After the target is locked on in angular coordinates, the range finder starts operating, which serves for determining the target range (the distance to it) and the closing speed of the target (the range derivative).

The range finder is an electronic follow-up system consisting of an integrator, a range pulse generator, target pulse and range pulse coincidence circuits, and a derivative circuit.

There are the following mutual functional relations in the range finder.

The value by which the so-called range pulses shaped by the range pulse generator are delayed with respect to the start pulses corresponds to the value of the integrator output voltage. Thus, as the integrator output voltage changes, the delay of the range pulses changes, too.

When the automatic angular lock-on device functions, its relay P3V switches on the range search circuit which causes the integrator output voltage to vary in accordance with the sawtooth law.

In this case, the range pulses start changing, from one repetition period to another, their delay with respect to the start pulses within the limits from 2 to 40 μ s.

The range pulses seem to be moving along the time axis within these limits.

If the range pulses and the target pulses applied to the automatic range lock-on device coincide with each other (which will obviously occur if the delay of the range pulses is equal to that of the target pulses with respect to the start pulses), then the automatic range lock-on device will operate. As a result, the integrator starts being controlled by the coincidence circuits, which means that the range finder passes from the search mode to the mode of target tracking in range.

In the tracking mode, the range finder operates as follows.

The range pulse (the so-called first range pulse) is applied to the first-pulse coincidence circuit. The range pulse delayed by 0.5 μ s in the delay line (the so-called

second range pulse) is applied to the second-pulse coincidence circuit. Applied to both coincidence circuits also is the target pulse.

If the target pulse coincides with the range pulses, the output of the coincidence circuits produces two pulses whose duration and amplitude are determined by the accuracy with which the first or the second range pulse coincides with the target pulse. These pulses are applied in opposite polarities to the input of the difference detector of the derivative circuit. The difference detector separates a voltage proportional to the difference between the values of these pulses. This voltage controls integrator operation through the amplifier of the derivative circuit.

In this case, the integrator operates as follows. The voltage at the output of the integrator grows if the target pulse coincides with the first range pulse to a greater extent than with the second range pulse, i.e., when the target approaches. The target pulse therewith seems to be coming on to the first range pulse. It is obvious that the higher is the closing speed of the target, the better the target pulse coincides with the first range pulse, the greater will be the control voltage taken from the difference detector, and the quicker the integrator output voltage will increase.

As the output voltage increases, the delay of the range pulses with respect to the start pulses decreases, i.e., the range pulses move in the NEARER (БЛИЖЕ) direction, thereby tracking the target.

If the closing speed of the target is equal to zero, the voltage across the difference detector output is also equal to zero and the range voltage does not change. In this case, the range pulses do not change their delay with respect to the start pulse.

Hence, in the mode of target tracking in range, the output voltage of the integrator is a voltage directly proportional to the range (it is called "range voltage").

The output voltage of the difference detector is directly proportional to the closing speed. It is amplified and used as a range derivative voltage (closing speed voltage).

If the range lock-on relay (PЗЛ) operates, the range voltage is applied to the range follow-up system where, in accordance with this voltage, electric motor МЛ-1 turns the sliders of the range potentiometers. The resistance, proportional to the target range, is introduced with the aid of the potentiometer sliders into the appropriate devices of the aircraft armament system.

If a necessity arises to start tracking another target located in the same direction but at a different distance, then the operator sets switch NEARER - FARTHER (БЛИЖЕ - ДАЛЬШЕ) to the respective position.

As a result, the automatic range lock-on device is switched off, while the range finder circuitry provides a free movement of the range pulses until the desired target is locked on, i.e., the search in range begins.

When the range lock-on relay operates in order to actuate the pulse AGC and to provide shaping of the mark of the locked-on target in range, the range indication circuit shapes a pulse which coincides in time with the locked-on target pulse.

When the target is locked on, the hostile target separation circuit puts out a voltage of +230 V which is applied to the automatic fire-control device to prepare it for operation.

In addition, when the range lock-on relay operates, a range voltage is also applied to the automatic fire-control device. And when the target approaches to the aimed fire range, the automatic fire-control device operates and starts periodically (for the time of 1 to 2 seconds, at intervals of 1 to 2 seconds) delivering a voltage of +27 V to the fire-opening circuit.

When knob INDICATION ON is depressed, indication of the angular position of the locked-on target is effected with the aid of the degree scale of the indicator by applying a voltage proportional to the deflection of the locked-on target from the aircraft flight direction to the deflection coils of the cathode-ray tube, the voltage taken from potentiometers R1-13 and R1-14.

The generation of the target angular speeds by radar HPG-3 is effected with the aid of the angular-speed gyro pickoffs installed on the gyro platform. The gyro platform provides movement of the gyro pickoffs with angular speeds corresponding to the angular speeds of the target relative movement. For this purpose, control of the gyro platform is effected from the radar antenna tracking the target through the selsyn synchronous follow-up system. The movable part of the gyro platform provides movement of the angular-speed gyro pickoffs in two planes (horizontal and vertical) with the aid of the respective drives (of azimuth and tilt) which are independent of each other.

The radar antenna mounts transmitting selsyns for angular position of the antenna head in azimuth (CH1-2, CH1-4) and in tilt (CH1-1, CH1-3) which are mechanically coupled with the respective reducers of the antenna. The stators of these selsyns are electrically connected with those of the respective receiving selsyns (CH19-1, CH19-2 for azimuth and CH19-3, CH19-4 for tilt) installed on the gyro platform.

The azimuth and tilt drives are constructed on the principle of a two-channel system, which means that the selsyn coupling between the gyro platform and the antenna is effected through coarse and fine channels. Mounted on the antenna and on the gyro platform are selsyns with a gear ratio of 1 : 1 (CH1-1, CH1-2 and CH19-1, CH19-3) for the coarse channel, and selsyns with a gear ratio of 1 : 31 (CH1-3, CH1-4 and CH19-2, CH19-4) for the fine channel. The fine channel provides a high accuracy with which the movable part of the gyro platform follows the antenna head, but it admits false matched positions (which occur every $11^{\circ}36'$). The coarse channel serves for eliminating these false matchings. Change-over from one channel to the other is effected by a selection circuit.

The azimuth drive and the tilt drive are identical, therefore described below will be only the azimuth one. When the antenna head tracks a target in azimuth, the rotors of the azimuth transmitting selsyns rotate, producing an electric error signal in the circuit of the receiving selsyn rotors. The error signal is proportional to the angle of rotation of the antenna head in azimuth.

The error signal is amplified by the respective amplifiers (the fine channel amplifier, the coarse channel amplifier, the power amplifier) and then it is supplied to the electric motor of the gyro platform azimuth drive. The electric motor turns the movable part of the gyro platform, on which the gyro pickoffs are mounted, in the direction of decrease of the error signal, and continues to turn it until the error signal becomes equal to zero, i.e., until the gyro platform movable part is in the position matched with the antenna head position. The angular-speed gyro pickoff responds only to the angular speed of movement in azimuth and supplies the computer of the aircraft armament system with a current proportional to the angular speed of the antenna head movement in azimuth.

Hence, in the mode of target tracking by the antenna, the gyro pickoffs put out the relative angular speed of the target.

IV. COMPOSITION AND CONSTRUCTIONAL DESIGN OF RADAR

Radar NPC-3 consists of 25 constructionally completed units which are electrical connected between one another by a system of cables (unit 2DK-15). The radio-frequency units are connected between one another by means of waveguides.

The arrangement of the equipment in the units takes into account the functional relation between separate components of the radar.

Used as a basis for the constructional design of the radar is the principle of combining the circuits and assemblies in functional channels with due regard for arranging the radar in aircraft with the cable system having the minimum length and quantity of wires. The units of the radar have abbreviated designations which are inscribed on the Manufacturer's name plates of the units and in the technical documents for example: 2DK-1, DK-19, 2AP17-9A, etc.

The number that follows the dash in these designations denotes the unit number in the radar, for example: 2DK-1 is the first unit in radar NPC-3.

The assemblies, tubes, parts and other items installed in the units are designated by letters which denote the abbreviated names of the items, by figures which denote the number of the unit in which the item is installed, and by the reference number of the item according to the schematic diagram of the unit, for example: CH1-2 is the second selsyn in unit 2DK-1, R10-9 is the ninth resistor in unit 2DK-10, etc.

Radar NPC-3 includes the following units:

- Unit 2DK-1 (the antenna) which contains mechanisms and motors for turning the antenna head, for rotating and deflecting the reflector, for rotating the radiator, selsyns for directing the antenna and generating angular positions of the target, antenna-positioning and indication potentiometers and rotary transformers.
- Unit 2A2 (the transmitter) which contains a magnetron oscillator and a modulator.
- Unit 2DK-3 (the receiving, jamming rejection and synchronization unit) in which are installed components serving for intermediate-frequency amplification, anti-jamming protection, synchronization, and automatic gain control.
- Unit 2DK-3 which contains 14 separate electrical-circuit assemblies having their own designations.
- Unit 2DK-4 (the indicator) which is composed of a cathode-ray tube with focusing and deflecting coils, and a video amplifier.
- Unit 2DK-5 (the connection box) which contains components for switching the circuits serving for control, monitoring, antenna positioning, tracking, coupling of the radar with sight TI-1A, and delivery of data to the computer.
- Unit 2DK-6 (the control panel).
- Unit 2DK-7 (the control and monitoring panel) on which are arranged radar controls, a measuring instrument, and switches which make it possible to check operation of all the channels of the radar.
- Unit 2AP17-9A (the amplidynes).
 - Unit 2DK-10 (the angle tracking unit). Mounted in this unit are: automatic angular lock-on device, error signal separation circuit, azimuth and tilt commutators, reference voltage multivibrators, antenna-positioning voltage amplifiers, change-over multivibrator, direct current amplifiers, and damping signal amplifiers.
 - Unit 2DK-11 (the range unit). Mounted in this unit are: range pulse generator, coincidence circuit, range derivative circuit with difference detector, integrator, range search and search starting circuit, range selector, speed selector, lock-on indication circuit, automatic lock-on device, and range follow-up system.

- Unit ДК-12 - the supply unit with rectifiers and electronic stabilizers of voltages: +230 V (st.), -230 V (st.), +300 V (st.).

- Unit 12A (the indicator supply unit with +6000-V and +600-V rectifiers).

- Unit 2ДК-13 (the mark and range sweep unit of the indicator). Mounted in this unit are: circuits shaping the zone, identification, lock-on range marks and the marks of locked-on targets, mixer of mark and target pulses, hostile target generating circuit, range sweep generator, and synchronization and brightening circuit.

- Unit 20K (the high-voltage rectifier of voltage 17 kV for supplying the magnetron).

- Unit 2ДК-22 (the radio-frequency receiving unit). The unit includes: discharger, signal and automatic frequency control balance mixers, klystron local oscillator, intermediate-frequency preamplifier, automatic frequency control preamplifier, and automatic frequency control system.

- Unit 2ДК-24 (the box of supply circuit fuses).

- Unit 2ДК-25 (the waveguide line).

- Unit 2ДК-26 (the klystron supply unit with -300-V and -600-V rectifiers).

- Unit ДК-28 - the supply unit with rectifiers and stabilizers of voltages: +120 V (st.), +150 V (st.), -150 V (st.); and a stabilizer of voltage 115 V, 380 to 900 Hz.

- Unit 2ДК-29 (the automatic antenna-positioning unit). Mounted in this unit are: control and lock-on circuits, memory circuits, tilt and azimuth phase detector, automatic fire-opening circuit, and scanning circuit.

- Unit ДК-19 (the gyro platform). Arranged in this unit are gyro pickoffs for target angular speeds in azimuth and in tilt.

- Unit ДК-30 (the unit of amplidyne which amplify the signals sent to the gyro platform).

- Unit ДК-31 (the connection box which couple the angular speed generating units with the defensive armament system).

- Unit ДК-32 (the gyro platform amplifier).

As to their construction, the units are composed either of separate removable standard assemblies or of separate removable mounting panels.

The mounting panels are fastened to the frame of the chassis. The chassis has a removable cover and a bottom. Unit 2ДК-3 represents constructionally a framework whose upper portion mounts removable standard assemblies.

All the units in which electron tubes are used, and also unit 2ДК-7 are mounted on shock-absorbing frames with shock absorbers, type АД.

- Unit 2A2 and unit 2ДК-22 are mounted on a common shock-absorbing frame.

Antenna unit 2ДК-1 is coupled with units 2A2 and 2ДК-22 with the aid of waveguide line 2ДК-25.

These units (2ДК-1, 2A2, 2ДК-22, and 2ДК-25) and unit 20K are pressurized, and in flight at an altitude higher than 3 km additional pumping is needed for them.

All the control and check members of the radar are arranged in units 2ДК-6, 2ДК-7 and 2ДК-4. The fuses of the supply circuits are located in fuse box 2ДК-24 which has blown-fuse indicating lamps.

V. SYNCHRONIZATION AND NONSYNCHRONOUS
PULSE JAMMING REJECTION CHANNEL

A. PURPOSE

The synchronization and nonsynchronous pulse jamming rejection channel is designed for timing the operation of the radar devices, for synchronizing the CP30-2 set identification system, and for protecting the automatic devices and the indication channel against nonsynchronous pulse jamming.

B. MAIN TECHNICAL CHARACTERISTICS

- (a) The synchronizing pulse repetition frequency is f_T .
- (b) The passing-through of nonsynchronous pulse jamming at frequencies up to 6000 Hz is excluded. The passing-through of jamming having frequencies higher than 6000 Hz is possible only at such frequencies multiple of the radar pulse recurrence frequency. In this case, the pass-band does not exceed 2 per cent of the jamming pulse recurrence frequency.
- (c) The amplitude of the master blocking oscillator pulses is not less than 60 V with a duration of not less than 10 μ s.
- (d) The amplitude of the sweep triggering pulses is not less than 40 V.
- (e) The amplitude of the synchronizing pulses is not less than 70 V with a duration of 1 to 4 μ s.
- (f) The amplitude of the start pulses is $130 \begin{smallmatrix} +50 \\ -20 \end{smallmatrix}$ V with a duration of $0.6 \pm 0.1 \mu$ s.
- (g) The amplitude of the negative gate pulses is not less than 30 V with a duration of $65 \pm 5 \mu$ s.
- (h) The amplitude of the target pulses sent to the automatic lock-on devices (connectors 63 and 67) is not less than 25 V with a duration of not longer than 1 μ s.
- (i) The amplitude of the target pulses sent to the indication channel (connector 63) is not less than 20 V with a duration of not longer than 1 μ s.

C. CHANNEL COMPOSITION

The channel is composed of:

- (a) master blocking oscillator circuit (assembly 308 in unit 2DK-3);
- (b) sweep triggering pulse generator circuit (assembly 408 in unit 2DK-3);
- (c) sweep and synchronizing pulse shaping circuit (in unit 2DK-13);
- (d) start pulse shaping circuit (in unit 2A2);
- (e) negative gate pulse shaping circuit (assembly 208 in unit 2DK-3);
- (f) 10-MHz exciter circuit (assembly 4H3D in unit 2DK-3);
- (g) ultrasonic delay line V13 (μ s3-3 in unit 2DK-3);
- (h) 10-MHz intermediate-frequency amplifier (assembly 508 in unit 2DK-3);
- (i) commutator (assembly 108 in unit 2DK-3);
- (j) delayed-signal video amplifier and cathode follower circuit (assembly 408 in unit 2DK-3);
- (k) coincidence circuit (assembly 3H3D in unit 2DK-3);
- (l) 10-MHz intermediate-frequency amplifier (IPA-10) automatic gain control circuit (assembly 1H33 in unit 2DK-3).

D. DESCRIPTION OF FUNCTIONAL DIAGRAM

The operation and interaction of the components of the synchronization and jamming rejection channel is explained by the channel functional diagram and by the time relationship diagram (Fig. 11). The main components of the synchronization channel (Fig. 9) are as follows:

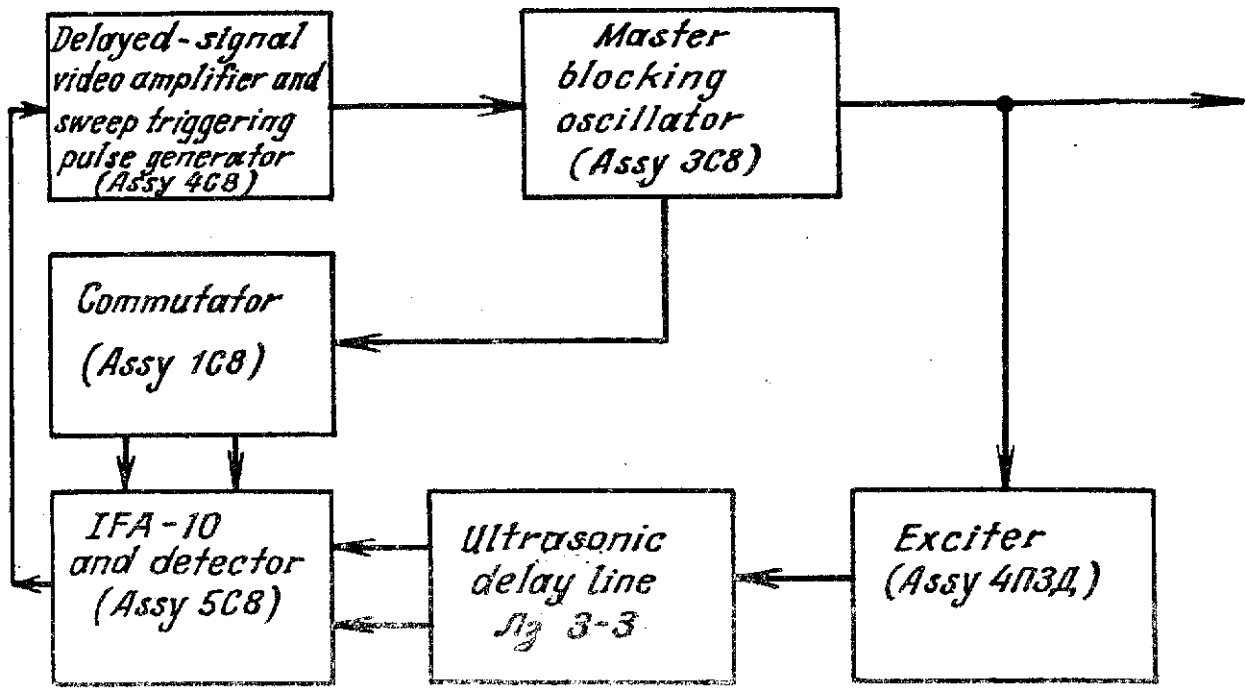


FIG. 9. MASTER BLOCKING OSCILLATOR SYNCHRONIZATION DIAGRAM

- the master blocking oscillator (assembly 3C8 in unit 2DK-3) which generates positive and negative pulses with an amplitude of not less than 60 V and a duration of not less than 10 μ s. The blocking oscillator is started by its own pulse passing through a pulse delay circuit;

- the exciter (assembly 4П3Д);
- the ultrasonic delay line (ЛЗ-3);
- the 10-MHz intermediate-frequency amplifier (IFA-10, assembly 5C8);
- the video amplifier and cathode follower (in assembly 4C8).

The positive pulses of the master blocking oscillator (assembly 3C8) are applied to the exciter (assembly 4П3Д).

The exciter generates radio pulses of a frequency of 10 MHz, whose duration is equal to that of the blocking oscillator pulses. The exciter pulses are applied to the input of ultrasonic delay line ЛЗ-3 which uses two inputs and delays these pulses by T_1 and T_2 μ s. To compensate the attenuation in the line, the radio pulses are supplied to the 10-MHz frequency amplifier (assembly 5C8) where they are amplified and converted into video pulses which are amplified in assembly 4C8 and used to start the master blocking oscillator. For synchronizing the radar with periods T_2 and T_1 successively, only one of the pulses delayed by the delay line should be at the IFA-10 output. For this purpose, the IFA-10 input (assembly 5C8) is commutated by the commutator (assembly 1C8) pulses whose duration is T_2 and T_1 . The commutator is caused to operate by the trailing edge of the multivibrator (in assembly 3C8) pulse which cuts off the blocking oscillator for 250 \pm 50 μ s. If it is necessary to conceal the recurrence frequency swing for the sake of radiocamouflage, the commutation of the IFA-10 inputs can be cut off by means of switch B3-1 SWING - OFF (КАЧАНИЕ - БЕКЛ.), and in this case the synchronization of the radar is provided with period T_1 (Fig. 11).

Since the blocking oscillator own period is selected to be longer than the delay time of the ultrasonic delay line, the blocking oscillator period depends on the delay time of the ultrasonic delay line.

In order to maintain a constant amplification factor of IFA-10, use is made of an automatic gain control circuit whose operation depends on the pulse of the master blocking oscillator. When the IFA-10 AGC circuit (assembly 1П3) receives simultaneously both the master blocking oscillator pulses coming from assembly 3C8 and the delayed pulses coming from assembly 5C8, its output produces a negative voltage proportional to the amplitude of the IFA-10 output voltage.

This voltage is supplied to assembly 5C8 to maintain the amplification factor constant.

The positive pulses of the master blocking oscillator are used for shaping the sweep triggering pulses.

The sweep triggering pulse shaping circuit (assembly 4C8) shapes positive pulses of a 40-V amplitude. The positive sweep triggering pulses are supplied to unit 2DK-13 where they are applied to the range sweep shaping multivibrator.

The pulses pass from the multivibrator to the synchronizing pulse shaping circuit. The synchronizing pulse is shifted by 20 \pm 4 μ s with respect to the sweep triggering pulse so as to make the sweep zero coincident with the beginning of transmitter radiation.

From unit 2DK-13 the synchronizing pulses are supplied through connection box 2DK-5 to unit 2A2 where they are amplified by the starting amplifier and are used for starting the submodulator.

The submodulator generates start pulses with an amplitude of 130 $\begin{matrix} +50 \\ -20 \end{matrix}$ V and a duration of 0.6 \pm 0.1 μ s.

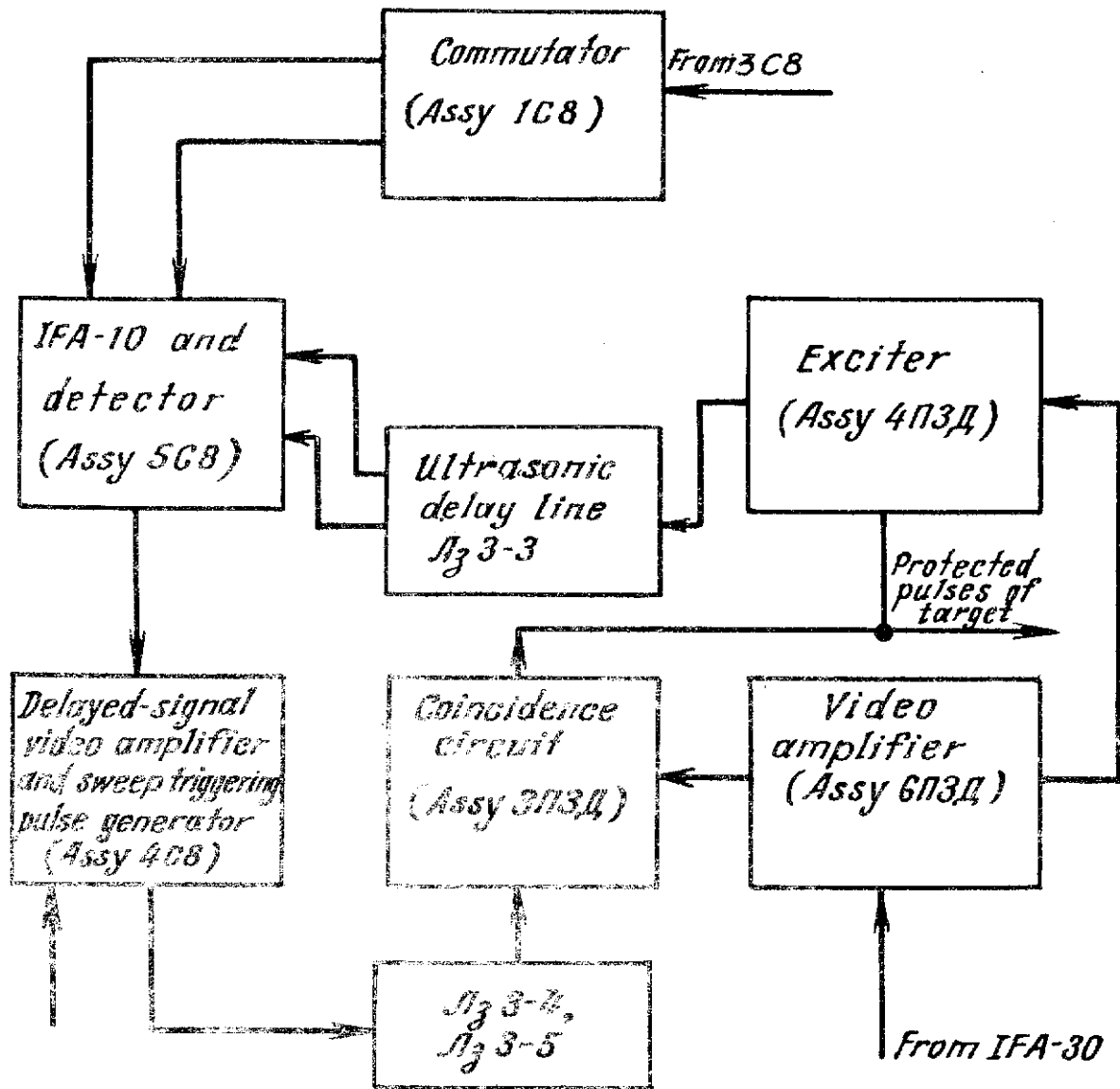


FIG. 10. DIAGRAM OF NONSYNCHRONOUS JAMMING REJECTION IN RADAR

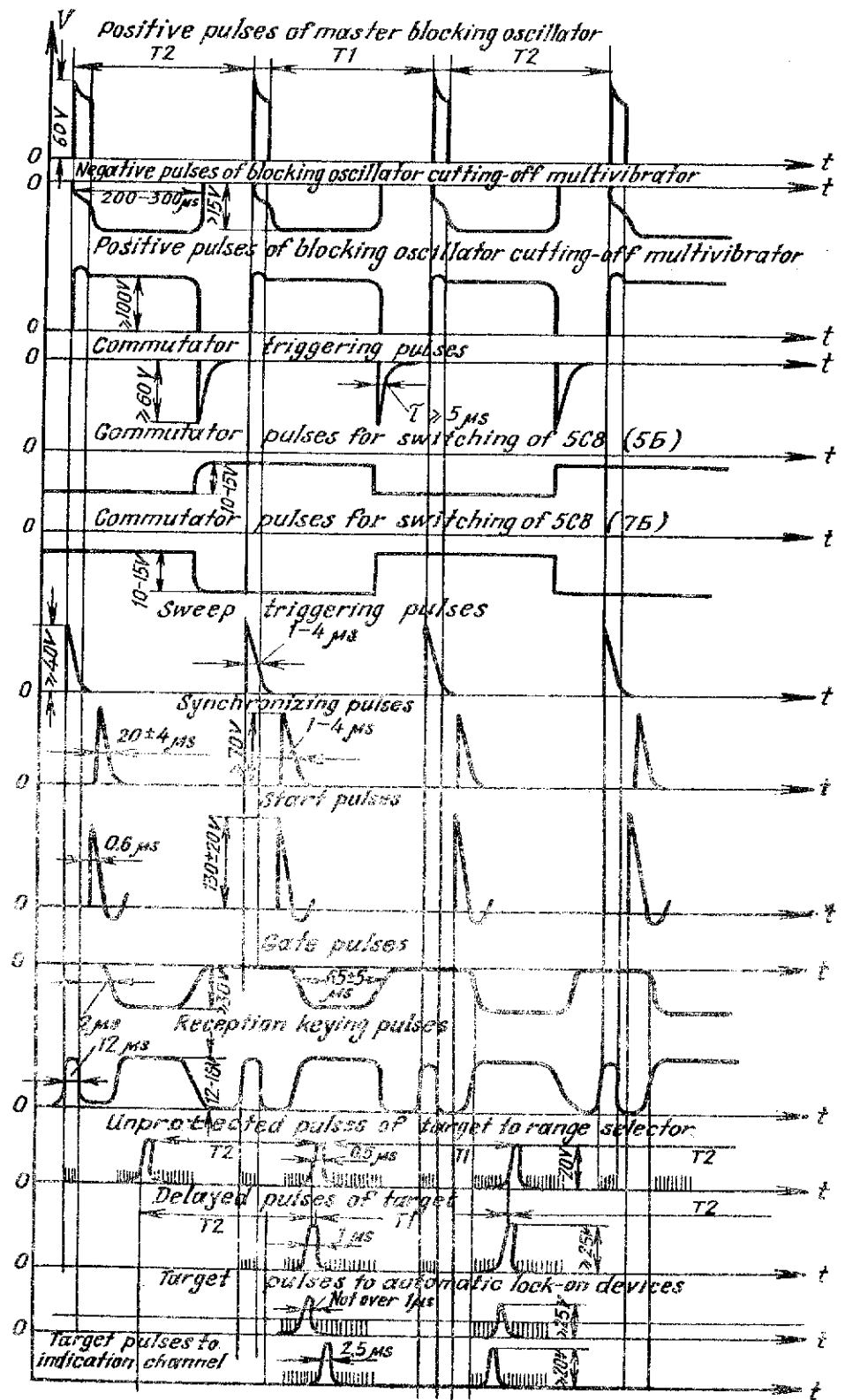


FIG. 11. TIME RELATIONSHIP DIAGRAM

The start pulse from unit 2A2 is supplied through the contacts of relay P5-11 (unit 2DK-5) to unit 2DK-3 for starting the lock-on range pulse shaping circuit (assembly 6ПЗД), and through line №3-7 (which delays the beginning of the reception with respect to the time of radiation of the transmitted signal) it is supplied for triggering the negative gate pulse multivibrator (assembly 2С8). In the monitoring mode, it is supplied through the contacts of relay P5-12 to the monitoring pulse shaping circuit. In addition, the start pulse is supplied to unit 2DK-22 for cutting off the intermediate-frequency preamplifier for the time when the transmitted pulse is radiated and the AFC circuit is started, to unit 2DK-11 for starting the range pulse generator, to unit 2DK-29 to be applied to the dangerous range generator, and to set CHQ-3.

The protection of the radar against nonsynchronous pulse jamming and against mutual interference of radar stations depends on the principle of time selection.

The pulses from the video amplifier (assembly 6ПЗД) are applied to one of the inputs of the coincidence circuit (assembly 3ПЗД), while to the other input of the coincidence circuit the same pulses are applied and delayed for one period in the delay circuit (assemblies 4ПЗД, № 3-3, 5С8, 4С8, № 3-4 and № 3-5, see Fig. 10).

The operating condition of the coincidence circuit is such that the signals may appear at its output only when the target pulses at the coincidence circuit inputs coincide with each other in time. Delay lines № 3-4 and № 3-5 are needed for compensating for the shift of the delayed target pulse with respect to the pulse arriving directly from the video amplifier (assembly 6ПЗД).

The necessity for compensating for this shift is explained by the existence of a certain advance of the delayed target pulse due to the fact that the blocking oscillator is triggered by the front edge of the trigger pulse. From the output of the coincidence circuit, the target pulses are supplied to the automatic range lock-on device (unit 2DK-11) and to automatic angular lock-on device (unit 2DK-10) through delay line №3-6 and the cathode follower (assembly 2С8), to unit 2DK-13, and to the exciter (assembly 4ПЗД) for summation. Delay line №3-6 compensates for the delay of the identification pulses arriving from set CP30-2.

Since a certain loss of sensitivity occurs in the coincidence circuit, unit 2DK-3 uses a repeated summation circuit: the protected signals from the output of the coincidence circuit are again delivered to the input of the exciter (assembly 4ПЗД) where they are summed up with the unprotected pulses arriving from the video amplifier (assembly 6ПЗД).

It is due to such a summation that the sensitivity loss is compensated for and the relation $\frac{\text{signal}}{\text{noise}}$ is increased.

VI. RADIO-FREQUENCY AND AUTOMATIC
FREQUENCY CONTROL CHANNEL

A. PURPOSE

The radio-frequency and automatic frequency control channel performs the following functions:

- (a) generation of powerful radio pulses;
- (b) reception of the radio pulses reflected from target and conversion of them into pulses of intermediate frequency;
- (c) maintenance of constancy of the receiving channel intermediate frequency;
- (d) detection of noise jamming effect on the receiving channel, and change-over of the magnetron and klystron frequencies.

B. MAIN TECHNICAL CHARACTERISTICS

- (a) The operating frequency range of the magnetron oscillator is Δf_m .
- (b) The duration of radio pulses is $0.45 \pm 0.05 \mu s$ at the level of 0.5 amplitude.
- (c) The radio pulse repetition frequency is f_r .
- (d) The pulse power of the transmitter is P_{pls} .
- (e) The sensitivity of the receiving channel, as measured by the disappearance of the signal in noise, is not less than 98 dB with respect to 1 mW.
- (f) The klystron frequency change range is Δf_k .
- (g) The intermediate frequency is 30 ± 0.5 MHz.
- (h) The accuracy of maintaining the intermediate frequency constant by the automatic frequency control circuit is not worse than ± 0.5 MHz.
- (i) The number of the magnetron operating frequencies is 12.
- (j) The total time required for changing the magnetron frequency is not more than $\tau \Delta f_m$.

C. CHANNEL COMPOSITION

The channel is composed of:

- (a) tunable magnetron high-power radio pulse generator (M2-7) with the modulation device (M2-1, M2-2, M2-3, M2-5, M2-6);
- (b) antenna change-over switch (M22-1);
- (c) signal channel radio-pulse frequency balance mixer (M22-1, M22-2);
- (d) tunable klystron local oscillator (M22-2);
- (e) the AFC channel radio-pulse frequency balance mixer (M22-3, M22-4);
- (f) automatic intermediate-frequency control preamplifier АРСРА /ПВАПЧ/ (M25-1, M25-2, M25-3);
- (g) electronic AFC circuit (M26-1, M26-2, M26-3, M26-4, M27-1, M27-2, M27-3, M27-4) which performs electronic tuning of the klystron frequency;
- (h) electromechanical AFC circuit (M27-5, M27-6, M27-7, MV22-1, TP22-2, M24-1) which performs mechanical tuning of the klystron frequency;
- (i) electromechanical search circuit (P22-2, KP23-1, KP2-3) which performs mechanical change of the klystron frequency when the high voltage is switched on and after the magnetron frequency has been changed;
- (j) automatic frequency lock-on device (M25-4, M25-5, M26-5, M26-6, M26-7, P22-1) which switches over the electromechanical automatic frequency control circuit from the search mode to the follow-up mode and vice versa;
- (k) noise jamming recording circuit (assembly 18П3Д in unit 2ДК-3);

- (l) magnetron frequency change device (B7-4, P2-5, M2-2, P5-11, K6-2);
- (m) manual frequency control circuit (P22-4, R7-11, B7-7).

D. DESCRIPTION OF FUNCTIONAL DIAGRAM

The functional diagram of the radio frequency and AFC channel is presented in the Album of Functional Diagrams.

The synchronizing pulses delivered from unit 2DK-13 to unit 2A2 are amplified by the starting amplifier (1/2 of П2-6, П2-5) up to a voltage of 170 V which is sufficient for making the submodulator conductive. In the intervals between the pulses, the submodulator is cut off by a negative voltage of -120 to -130 V.

The pulses arriving from the output of the starting amplifier cause the submodulator to conduct. The output winding of the submodulator pulse transformer produces positive pulses having an amplitude of 900 to 950 V and a duration of 0.5 μ s which are applied to the control grids of the modulator tubes.

Before the arrival of the pulses from the submodulator, the modulator tubes are cut off by a negative voltage (700 - 850 V), and storage capacitor C2-18 is charged from the high-voltage rectifier of unit 2OK. When the positive pulse from the submodulator is applied to the grids of the modulator tubes, storage capacitor C2-18 is discharged through the modulator tubes and magnetron П2-7, the latter generating a powerful radio pulse which is delivered through the waveguide system to the radiator of the antenna.

A part of the energy reflected from the target is received by the antenna and delivered through the waveguide line to the signal frequency balance mixer (П22-1, П22-2), which serves as the input stage of the superheterodyne receiver. In the balance mixer, the frequency of the received radio pulse is mixed with the frequency of the klystron local oscillator (П22-2). As a result, the output of the mixer produces an intermediate-frequency pulse whose frequency is equal to the difference between the frequency of the klystron and that of the arriving signal. This pulse is applied to the intermediate-frequency preamplifier.

Operation of the transmitter and the receiver using the common antenna is provided by antenna switch RECEIVE - TRANSMIT (ПРИЕМ - ПЕРЕДАЧА).

In the course of radar operation, the frequencies of the magnetron and the klystron may vary within an appreciable range. This will result in a change of the difference between them. To maintain the intermediate frequency constant, use is made of an automatic frequency control device in unit 2DK-22.

The magnetron pulse weakened by attenuator AT22-1 by 65 to 70 dB is supplied together with the П22-2 klystron oscillations to the AFC channel balance mixer (П22-3, П22-4). The output of the mixer produces intermediate-frequency pulses which are amplified by the automatic frequency control preamplifier (tubes П25-1, П25-2, П25-3) and applied to the input of the electronic AFC circuit (П26-1, П26-2, П26-3, П26-4, П27-1, П27-2, П27-3, П27-4).

The adjusting voltage from the output of the electronic AFC circuit is applied to the repeller of the klystron to adjust the klystron frequency so as to decrease the error.

The initial tuning of the klystron frequency is provided by the electromechanical search circuit, which consists of search relay P22-2, klystron frequency change mechanism motor reversing contacts KH23-1, and directional search contacts KH2-3. When the magnetron does not generate, the control winding of klystron frequency change electric motor M23-1 is disconnected from the search circuit, since relay P22-1 of the automatic lock-on device is de-energized. When the magnetron is switched on, its current flowing

through the coil of relay P2-1 produces a positive voltage which makes normally cut-off tube $\Pi 26-7$ of the automatic lock-on device conductive. As a result, relay P22-1 operates and the 115-V 400-Hz voltage is applied across the control winding of electric motor M23-1 through contacts 2 and 3 of relay P22-1, contacts 1 and 2 of $\text{K}\Pi 2-2$ and the contacts of search relay P22-2.

Assume that prior to applying the high voltage to the magnetron, relay P22-2 is de-energized, which corresponds to the preceding tuning of the magnetron for increasing its frequency. The motor will start rotating in the direction of the normally open contact of group $\text{K}\Pi 23-1$, changing the frequency of the klystron. If the frequency is not locked in this case, the cam mounted on the klystron frequency change mechanism closes the normally open contact of group $\text{K}\Pi 23-1$, connecting search relay P22-2 to the ground. The relay operates, performing self-locking through its contacts 2 and 9, the normally closed contacts of group $\text{K}\Pi 23-1$ and contacts 3 and 4 of group $\text{K}\Pi 2-3$, and its contacts 11, 5 and 4, 10 invert the phase of the voltage across the control winding of electric motor M23-1. The electric motor starts rotating now in the direction of the normally closed contact of group $\text{K}\Pi 23-1$, the frequency of the klystron again changes and, when the difference between the klystron frequency and the magnetron frequency becomes equal to the intermediate frequency, the automatic lock-on device will de-energize relay P22-1, thereby switching the control winding of electric motor M23-1 from the search circuit to the output of the electromechanical AFC circuit (to output winding 8, 9 of magnetic amplifier $\text{M}\text{V}22-1$).

The electromechanical AFC circuit consists of a servo-amplifier ($\Pi 27-5$, $\Pi 27-6$, $\Pi 27-7$), magnetic amplifier $\text{M}\text{V}22-1$, drive motor M23-1 with the klystron frequency change mechanism. The output winding of magnetic amplifier $\text{M}\text{V}22-1$ is connected with the control winding of motor M23-1 through the normally closed contacts of relay P22-1. If the frequency of the klystron or that of the magnetron changes, the output of the AFC circuit produces an error voltage which is supplied to the repeller of klystron $\Pi 22-2$ and to the input of the servo-amplifier ($\Pi 27-6$). The output voltage of the servo-amplifier is supplied through the magnetic amplifier to the control winding of motor M23-1 of the klystron frequency change mechanism which changes the klystron frequency so as to maintain the constant difference between the frequency of the klystron and that of the magnetron. For stabilizing the servo-amplifier, use is made of a feedback. The feedback voltage is applied from the output winding of transformer $\text{T}\text{p}22-2$ to the servo-amplifier ($\Pi 27-5$), and is adjusted by means of potentiometer R22-28. The electromechanical AFC circuit is switched from the search mode to the follow-up mode by means of the automatic frequency lock-on device ($\Pi 25-4$, $\Pi 25-5$, $\Pi 26-6$, $\Pi 26-7$, P22-1, $\Pi 26-5$).

If the klystron frequency is tuned correctly, the intermediate-frequency pulses are applied from the output of the AFC preamplifier to the input of the lock-on circuit. Tube $\Pi 26-7$ gets cut off, de-energizing the lock-on relay which switches the control winding of motor M23-1 from the search circuit to the output of the electromechanical AFC circuit (to the output winding of magnetic amplifier $\text{M}\text{V}22-1$).

When noise jamming is received by the radar receiving channel a change of the magnetron frequency is effected. The noise jamming voltage is supplied from the output of assembly 6U3A (in unit 2DK-3) to the input of the jamming recording circuit in unit 2DK-3. The jamming recording circuit consists of selector $\Pi 18-1$, video amplifier $\Pi 18-2$, amplitude detector $\Pi 18-3$ and controlling tube $\Pi 18-4$ with P5-11 in the anode circuit. Tube $\Pi 18-1$ is normally cut off through its control and suppressor grids. Tube $\Pi 18-1$ amplifies the jamming signal whose level exceeds the threshold of the jamming recorder operation only during the time of action of the lock-on range pulse. The commutation of the jamming recorder by the lock-on range pulse is required for preventing the jamming indication circuit from operation under the effect of the pulses reflected from

the ground. Switch B7-4 switches the magnetron frequency change from automatic to manual by breaking the anode supply circuit of thyatron M18-4.

When the automatic frequency change is in operation, the recorder is responsive to such noise jamming the amplitude of which exceeds 18 ± 2 V. In this case, the thyatron M18-4 current pulse causes relay P5-11 to operate. One group of contacts of P5-11 (2, 3) is used to actuate relay P2-5 of the magnetron frequency change mechanism. Another group of the contacts (5, 6) breaks the circuit which delivers a start pulse to unit 2DK-3, because of which the receiver becomes cut off.

When operating, relay P2-5 performs self-locking through contacts 1 and 2 and through group KИ2-1. The interlocking circuit remains effective until the magnetron frequency change mechanism performs a certain angle. After the mechanism has performed the complete angle required for the frequency change, this group of contacts removes a voltage of +27 V from relay P2-5 to switch the motor into the dynamic braking condition.

In addition to the above-mentioned contact groups, the magnetron frequency change mechanism has two more groups of contacts KИ2-2 which switch off the transmitter and stop the klystron electromechanical search during the change of the magnetron frequency, and also a group of contacts (KИ2-3) which dictate the direction for the M22-2 klystron electromechanical search.

The directional-search contact group (KИ2-3) consists of two normally open and two normally closed contacts. Depending on the direction in which the magnetron frequency is changed during switching to a new frequency of the program, either one or the other group of contacts functions, breaking or closing the circuit which switches on electromechanical search relay P22-2.

As a result, the search is oriented in the proper direction prior to the switching-on of the transmitter (i.e., at the time when the transmitter is tuned to the new frequency of the program).

In the mode of manual frequency control without switching on the high voltage, the voltage of +27 V is supplied through contacts 3 and 5 of relay P7-1 to relay P22-4. Relay P22-4 operates, and the control grid of tube M27-7 of the servo-amplifier gets connected through contacts 5 and 11 to follow-up potentiometer R23-1 to which a negative voltage is supplied through contacts 2 and 9 of relay P22-4. The error signal taken from potentiometer R23-1 sets the klystron to the middle point of search and holds it there.

In the mode of manual frequency control, contacts 7 and 12 of relay P22-4 switch the klystron repeller from the output of the automatic frequency control circuit to resistor R7-11 FREQUENCY (ЧАСТОТА) which sets the required frequency of the klystron within the generation range.

In the mode of manual frequency change, when knob FREQUENCY CHANGE (K6-2 on unit 2DK-6) is depressed, capacitor C5-1 is connected to divider R5-1, R6-4, which has just been formed up, and starts being charged. The charge current flows through the coil of relay P5-11. The relay operates and the change of the magnetron frequency is effected in the same way as in the automatic mode.

In the AFC SEARCH (ПОИСК АПЧ) mode, resistor R22-14 is grounded through switch B7-7. In this case, the negative voltage of -300 V on the control grid of tube M26-7 decreases, the tube starts conducting and causes relay P22-1 to operate. The relay contacts connect the control winding of the klystron frequency change motor to the frequency search circuit. The AFC SEARCH mode is required for monitoring the operation of the search circuit without switching on the high voltage.

VII. RECEIVING CHANNEL

A. PURPOSE

The receiving channel is designed for converting the signals reflected from the target and received by the antenna into the intermediate-frequency pulses, for amplifying and converting them into target video pulses.

B. MAIN TECHNICAL CHARACTERISTICS

- (a) The amplitude at the unprotected output of unit 2DK-3 is 14 to 26 V.
- (b) The noise level at the unprotected output of unit 2DK-3 (with the AGC operating) is 10 ± 2 V.
- (c) The amplitude of the lock-on range pulses is not less than 55 V.

C. CHANNEL COMPOSITION

The channel is composed of:

- (a) radio-frequency head (in unit 2DK-22);
- (b) intermediate-frequency preamplifier (IFPA, assembly 24N6A in unit 2DK-22);
- (c) 30-MHz intermediate-frequency amplifier (IFA-30) with a detector at its output (assembly 1N6 in unit 2DK-3);
- (d) video amplifier with cathode followers (assembly 6N3A in unit 2DK-3);
- (e) the reception keyer and lock-on range pulse generator (assembly 8N3A in unit 2DK-3);
- (f) noise automatic gain control circuit (assembly 9N3A in unit 2DK-3);
- (g) pulse automatic gain control circuit (assembly 19N8 in unit 2DK-3);
- (h) reference pulse shaping circuit (in unit 2DK-3);
- (i) jamming recording circuit (assembly 18N3A in unit 2DK-3).

D. DESCRIPTION OF FUNCTIONAL DIAGRAM

The operation and interaction of the receiving channel components are explained by the functional diagram and the time relationship diagram (Fig. 12). The conversion of the radio-frequency pulses reflected from targets into the intermediate-frequency pulses is effected with the aid of the radio-frequency head. The intermediate-frequency pulses are supplied from the radio-frequency head to the balanced input of the intermediate-frequency preamplifier (assembly 24N6A). The balanced circuit of the intermediate-frequency preamplifier input makes it possible to decrease the local oscillator noise at the IFPA input and to improve thereby the sensitivity of the receiver in comparison with the ordinary circuit. Besides, to exclude the passage of the transmitted pulse, the IFPA is cut off by the start pulse arriving from unit 2A2.

In the calibration mode, relay P22-5 (in unit 2DK-22) operates, breaking the circuit that delivers the start pulse to the IFPA, and the transmitted pulse needed for calibration passes into the receiving channel.

From the IFPA output, the intermediate-frequency pulses are supplied through coaxial cable 61 to the input of the intermediate-frequency amplifier (assembly 1N6). In assembly 1N6, the intermediate-frequency pulses are amplified, converted into video pulses, and then supplied to the input of the video amplifier (assembly 6N3A). From the output of assembly 6N3A, the target video pulses are supplied to the range unit (2KE-11) to be applied there to the jamming recording circuit (assembly 18N3A), to the noise AGC circuit (assembly 9N3A), to one of the inputs of the coincidence circuit (assembly 3N3A) and to the delay channel (assembly 4N3A, Ma3-3 , assemblies 5C3, 4C3, Ma3-4 , Ma3-5).

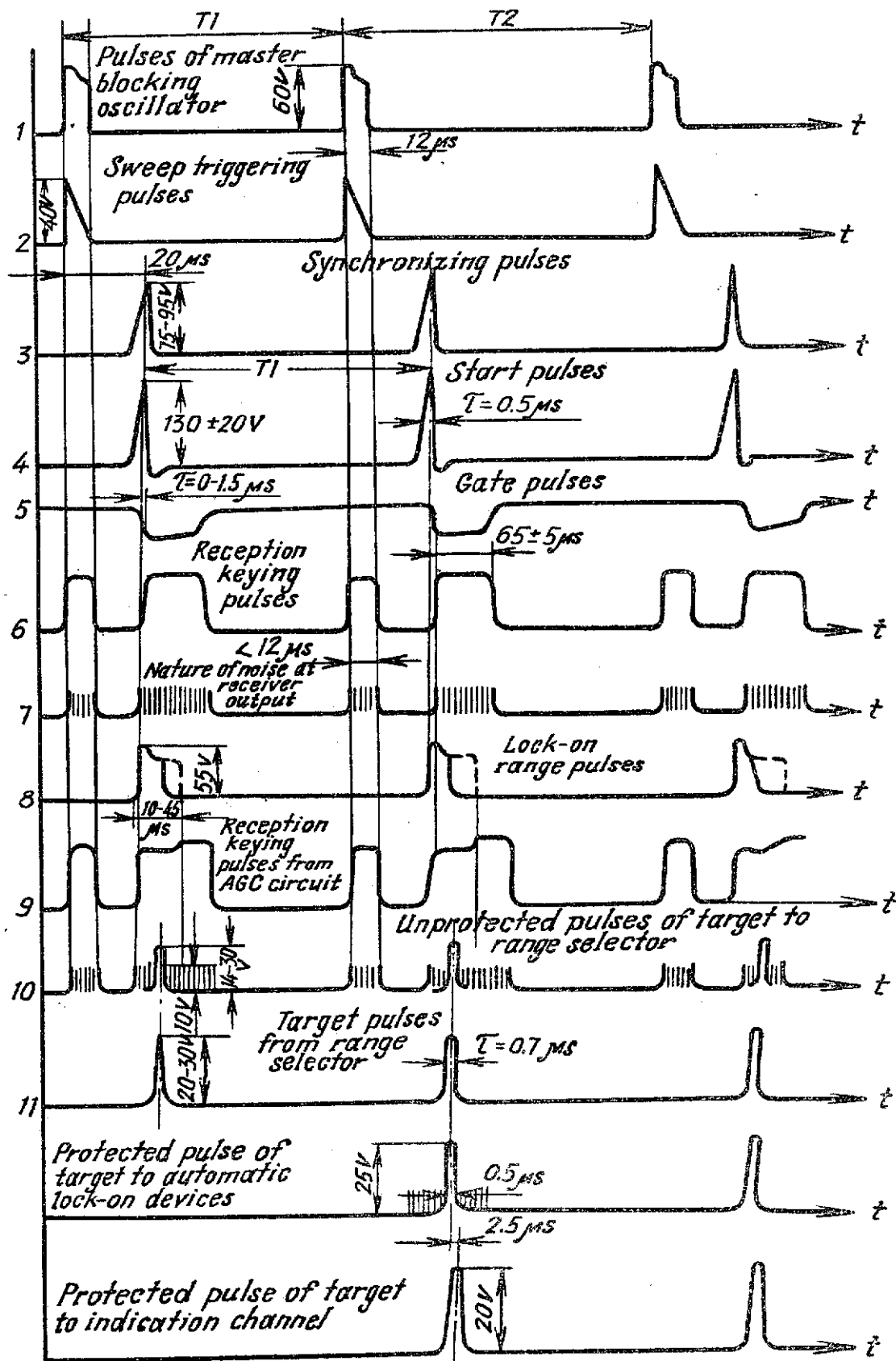


FIG. 12. DIAGRAM OF TIME RELATIONSHIP IN RECEIVING CHANNEL

The intermediate-frequency amplifier (assembly 1N6) is constantly cut off through the control grids of the first four stages by a negative voltage of 8 to 12 V taken from the anode of reception keyer 1B-1 (assembly 8N3A). The IFA-30 is made conductive for the time of noise passage and for the time of reception by the keyer pulses: by the first pulse of a 10- μ s duration - for the passage of the noise necessary for operation of the noise AGC circuit; by the second pulse of a 65 \pm 5- μ s duration - for the time of reception (see Fig. 12 for the diagram of time relationship). To make the IFA-30 conductive for the time of passage of the noise pulse, a negative pulse from the master blocking oscillator (assembly 3C8) is applied to the input of the keyer (assembly 8N3A). To make the IFA-30 conductive for the time of reception by the radar, applied to the input of the keyer are the negative gate pulses from the gate pulse multivibrator circuit (assembly 2C8) which is started by the start pulse delayed by variable delay line 1A3-7. This delay is needed for suppressing the transmitted pulse which has passed through the IFPA.

For reducing the range of variation of the locked-on target signal amplitude at the output of the receiving channel, provision is made for selected-target pulse automatic gain control which influences the grids of the first four tubes of assembly 1N6.

The selected-target pulse is supplied from the range selector through coaxial cable 64 to the selected-target pulse cathode follower (assembly 4C8). The selected-target pulse is widened in assembly 4C8 and supplied to the pulse AGC circuit (assembly 19N8). The control tube of the AGC circuit (1J9-4) is commutated through its control grid by the lock-on range pulse which is shaped by the lock-on range pulse generator.

With the arrival of the target pulses whose amplitude exceeds 20 V (the threshold of the AGC circuit operation), the pulse AGC circuit generates a negative voltage proportional to the signal amplitude. This voltage is applied to the grids of the first four stages of the intermediate-frequency amplifier (assembly 1N6) where it maintains the amplitude of the selected-target pulse at not more than 26 V in case the power of the input signals increases by 50 dB with respect to the threshold of the AGC circuit operation.

When switch MGC - AGC (PPY - APY) of unit 2AK-7 is in the MGC position, the IFA-30 amplification is controlled manually with the aid of the manual gain control circuit (assembly 9N3A). In this case, the selected-target pulse cathode follower (assembly 4C8) is cut off by the negative voltage supplied from unit 2AK-7, and the pulse AGC circuit does not operate. The control grid of the manual gain control tube (1J9-4 in assembly 9N3A) is supplied with a voltage picked off potentiometer R7-12. In this case, picked off the anode load of 1J9-4 is a negative voltage which is applied to the control grids of the first four stages of the IFA-30 (assembly 1N6).

The reception keyer (assembly 8N3A), the pulse AGC circuit (assembly 19N8) and the manual gain control circuit (assembly 9N3A) use a common load. The maintenance of a certain level of noise at the output of the receiving channel is effected by the noise AGC circuit (assembly 9N3A) which stabilizes the amplification factor of the intermediate-frequency preamplifying stages. Applied to one of the inputs of the noise AGC circuit is the noise from the output of the video amplifier (assembly 6N3A), and applied to its other input are the positive pulses of the blocking oscillator. If the noise pulse coincides with the blocking oscillator pulse, the output of the circuit produces a negative voltage proportional to the amplitude of the noise at the output of the video amplifier (assembly 6N3A). This negative controlling voltage of the noise AGC circuit is supplied to the IFPA (assembly 24N6A of unit 2AK-22) to maintain the noise level at the receiving channel output at 10 \pm 2 V. Operation of

the noise AGC circuit depends on a noise pulse of a duration of not less than 10 μ s, which leads the start pulse by 20 \pm 4 μ s, thereby preventing the target pulses from getting into the region of the noise pulse.

For checking the serviceability of the radar with the aid of its monitoring system, unit 2AK-3 is provided with a monitoring pulse shaping circuit.

If relay P5-12 in unit 2AK-5 operates (the monitoring mode), a start pulse from unit 2A2 and a reference voltage from unit 2AK-10 are applied to the test pulse shaping circuit. This circuit shapes two negative test pulses modulated by frequency f_{sc} and supplied to video amplifier 6H3A and through the protection circuit to the automatic lock-on devices and to the indication channel.

A change of the magnetron frequency is effected when the jamming recording circuit (assembly 18H3A) located in unit 2AK-3 is brought into operation by the deliberate noise interference supplied to its input from assembly 6H3A (unit 2AK-3). In this case, relay P5-11 in unit 2AK-5 functions and breaks the circuit which delivers the start pulse to unit 2AK-3, cutting off the IFA-30 for the time of reception.

In order to prevent the automatic lock-on devices and the jamming recording circuit from being operated by the pulses reflected from the ground these pulses are gated by the lock-on range pulses. The lock-on range pulses are shaped by the lock-on range pulse generator located in assembly 8H3A of unit 2AK-3 and started by the start pulse.

The duration of the lock-on range pulse can be adjusted within the limits from 6 - 12 μ s to not less than 45 μ s by means of potentiometer LOCK-ON RANGE (РАМБН. ЗАХВ.) installed in unit 2AK-6.

VIII. INDICATION AND IDENTIFICATION CHANNEL

A. PURPOSE

The indication and identification channel is designed for determining the position of the target with respect to the aircraft flight axis in the antenna scanned area, for displaying the process of directing the antenna to the selected target with the aid of the antenna-positioning mark, as well as for determining the national identity of the target with the aid of identification set CP30-2.

The indication channel provides:

- (a) determination of the target space position:
 - in the scanning mode, the target range is determined within distances from 0 to 10 km; the direction to the target with respect to the scanning axis and the angle between the scanning axis and the direction to the target are determined with the aid of zone marks;
 - in the tracking mode, the target range is determined within the same distances as in the scanning mode; the azimuth and the tilt of the locked-on target are determined with the aid of the antenna head position mark;
- (b) display of the identification signals from set CP30-2;
- (c) determination of the target lock-on range;
- (d) indication of the locked-on target;
- (e) generation of the hostile target pulses and of the +230-V voltage (when a hostile target is locked on) to be sent to the automatic antenna-positioning unit (2AK-29);
- (f) display of the process of directing the antenna to the selected target in the mode of manual antenna positioning with the aid of the antenna-positioning mark.

The appearance of the indicator screen in the scanning mode and in the target lock-on and tracking mode is shown in Figs 5 and 8.

B. MAIN TECHNICAL CHARACTERISTICS

- (a) The range resolution is not worse than 250 m.
- (b) The permissible error in determination of range should not exceed 450 m at distances from 400 to 4500 m and 10 per cent of the range at distances from 4500 to 10,000 m.
- (c) The error in determination of the azimuth and tilt of the locked-on target does not exceed $\pm 5^\circ$ at angles up to $+35^\circ$ and 15 per cent at angles greater than 35° .
- (d) The duration of the zone marks is as follows:
 - for zone I - no mark available;
 - for zone II - 4 μ s (600 m);
 - for zone III - 10 μ s (1500 m).

C. CHANNEL COMPOSITION

Housed in unit 2AK-13 are the following components:

- (a) the circuit for shaping the range sweep voltage, brightening and synchronizing pulses;
- (b) the circuit for generating the hostile target signals in scanning and the +230-V voltage in locking on the hostile target;
- (c) the zone mark shaping circuit;
- (d) the identification mark shaping circuit;

- (e) the locked-on target mark shaping circuit;
- (f) the lock-on range mark shaping circuit;
- (g) the mixer of signals and marks.

Housed in unit 2AK-4 are the following components:

- (a) the cathode-ray tube (I4-1) with deflection yoke;
- (b) the video amplifier-limiter of signals and marks (I4-2).

Housed in unit 2AK-1 are the following components:

- (a) zone mark commutator B1-6;
- (b) rotary transformer BT1-3 which serves for producing a radial-circular sweep;
- (c) antenna head position potentiometric pickoffs R1-13, R1-14;
- (d) locked-on target mark and lock-on range mark commutator B1-7.

Housed in unit 2AK-6 is switch B6-3 INTERROGATION (ONPOC).

Housed in connection box 2AK-5 are the following components:

- (a) relay P5-15 for coupling the supply to the potentiometric pickoffs of TI-1A when the antenna is directed manually;
- (b) relay P5-14 for switching the deflection coils from the stator windings of the sweep rotary transformer to the potentiometric pickoffs of TI-1A when the antenna is directed manually;
- (c) relay P5-8 for coupling the antenna potentiometric pickoffs to the deflection coils when the antenna head position is displayed;
- (d) relay P5-24 for feeding the +230-V voltage to the automatic fire control device of unit 2AK-29 when locking on in range.

D. DESCRIPTION OF FUNCTIONAL DIAGRAM

Range-Sweep, Brightening-Pulse and Synchronizing-Pulse Shaping Circuit

The sweep triggering pulse arriving from unit 2AK-3 (assembly 4C8) triggers the sweep driven multivibrator (I13-1) through the buffer stage (1/2 of I13-2).

The positive pulse of the multivibrator is supplied through the phase-inverter stage (I13-6) to the trapezoidal-voltage generator (1/2 of I13-2) to start it. The generator generates a trapezoidal pulse which is supplied to the two-stage amplifier (1/2 of I13-3 and I13-4) and from the output of the latter the pulse, in the positive polarity, is applied to the circuit of sawtooth current generator I13-5. Connected into the anode circuit of the current generator is the primary winding of matching transformer Tpl3-3.

The secondary winding of the transformer is connected across the winding of the BT1-3 rotary transformer rotor mechanically coupled with the 2AK-1 reflector rotation axle with a gear ratio of 1 : 1.

The stator windings of rotary transformer BT1-3 are connected through the normally closed contacts of relays P5-14 and P5-8 in connection box 2AK-5 to the vertical and horizontal coils (I4-4) of the deflection yoke of indicator 2AK-4.

As the antenna reflector rotates, range-sweep sawtooth currents flow through the deflection coils. These currents are modulated in amplitude by sinusoidal and cosinusoidal envelopes at the frequency of the antenna reflector rotation. In this case, the range sweep line rotates round the centre of the indicator screen in synchronism with the antenna reflector rotation.

For stabilizing the range sweep, the circuit uses a deep voltage feedback. The feedback voltage is picked off potentiometer R13-53 SWEEP AMPLITUDE (AMII. PA3B.) and supplied through the cathode follower (1/2 of I13-8) to the circuit of the amplifier first stage (1/2 of I13-3).

Since the range-sweep voltage is applied across the deflection coils through the rotary transformer, its direct voltage (current) component disappears. Therefore, the sweep line rotates not round its beginning but round the point corresponding to the passage of the sweep current through the zero value. In order to bring the beginning of radiation by the transmitter and that of C-R tube brightening into coincidence with this point, they should be delayed with respect to the beginning of the sweep for a certain time which is determined by the recurrence frequency and the duration of the sweep. The delay and the shaping of the synchronizing pulses and the brightening pulses are effected as follows.

The positive pulse of the range sweep multivibrator ($\Pi 3-1$) is supplied through the phase-inverter stage ($\Pi 3-6$) to the sawtooth voltage generator (1/2 of $\Pi 3-7$), from which the sawtooth voltage is applied to the comparison stage (1/2 of $\Pi 3-7$). The comparison stage shapes a negative brightening pulse delayed with respect to the sweep starting pulse. The value of the brightening-pulse delay with respect to the beginning of the sweep is set by means of adjusting knob SWEEP ZERO (HV1B PA3B.) and is approximately equal to 20 μ s.

The brightening pulse is amplified by the amplifier (1/2 of $\Pi 3-8$) and supplied, in the positive polarity, through the cathode follower (1/2 of $\Pi 3-9$) to the grid of the cathode-ray tube ($\Pi 4-1$ in unit 2K-4) to brighten the tube for the time of the sweep forward motion, starting from the instant when the sweep passes through the centre of the screen. In order that the value of the brightening pulse delay with respect to the sweep triggering pulse will change automatically with the change of the repetition frequency, the sawtooth voltage generator is supplied from the integrator ($\Pi 3-26$) whose direct output voltage varies with variation of the sweep on-off time ratio. The variation of the integrator direct voltage results in a change of the sawtooth voltage steepness, which causes a change of the brightening pulse delay.

For shaping synchronizing pulses (transmitter triggering pulses), use is made of the front edge of the brightening pulse which is supplied through a differentiating network (C13-19, R13-46) for triggering the synchronizing pulse generator (1/2 of $\Pi 3-9$ and 1/2 of $\Pi 3-10$). The generator shapes positive synchronizing pulses which are supplied through the cathode follower (1/2 of $\Pi 3-10$) to unit 2A2 to trigger the submodulator synchronizing pulse amplifier.

Besides, picked off the synchronizing pulse generator through the cathode follower (1/2 of $\Pi 3-18$) and the contacts of relay P13-2 is the pulse to trigger set CP30-2.

Zone Mark Shaping Circuit

Indication of the target angular position in the mode of scanning is effected with the aid of zone marks which are located behind the target marks and are of the shape of narrow dashes. The entire scanned area is divided into three zones (Fig. 13). When the target passes through the first zone, there is no mark behind the target mark. The duration of the second-zone mark is 4 μ s (600 m), and that of the third-zone mark is 10 μ s (1500 m). Shaping of the zone marks is effected in the following way.

Packets of target pulses from the output of receiving unit 2K-3 (assembly 2C8) are supplied to unit 2K-13 to be applied to the storage circuit through the minimum and maximum limiter. The storage circuit (1/2 of $\Pi 3-14$) utilizes each packet of target pulses (the number of pulses in a packet varies from 8 to 25) to shape a wide positive pulse whose duration is equal to that of the packet. Through the amplifier (1/2 of $\Pi 3-14$), this pulse triggers the sawtooth voltage generator (1/2 of $\Pi 3-15$) whose sawtooth pulse is applied to the grid of the normally cut-off tube (1/2 of $\Pi 3-15$) of the comparison stage. Picked off the comparison stage is a negative pulse

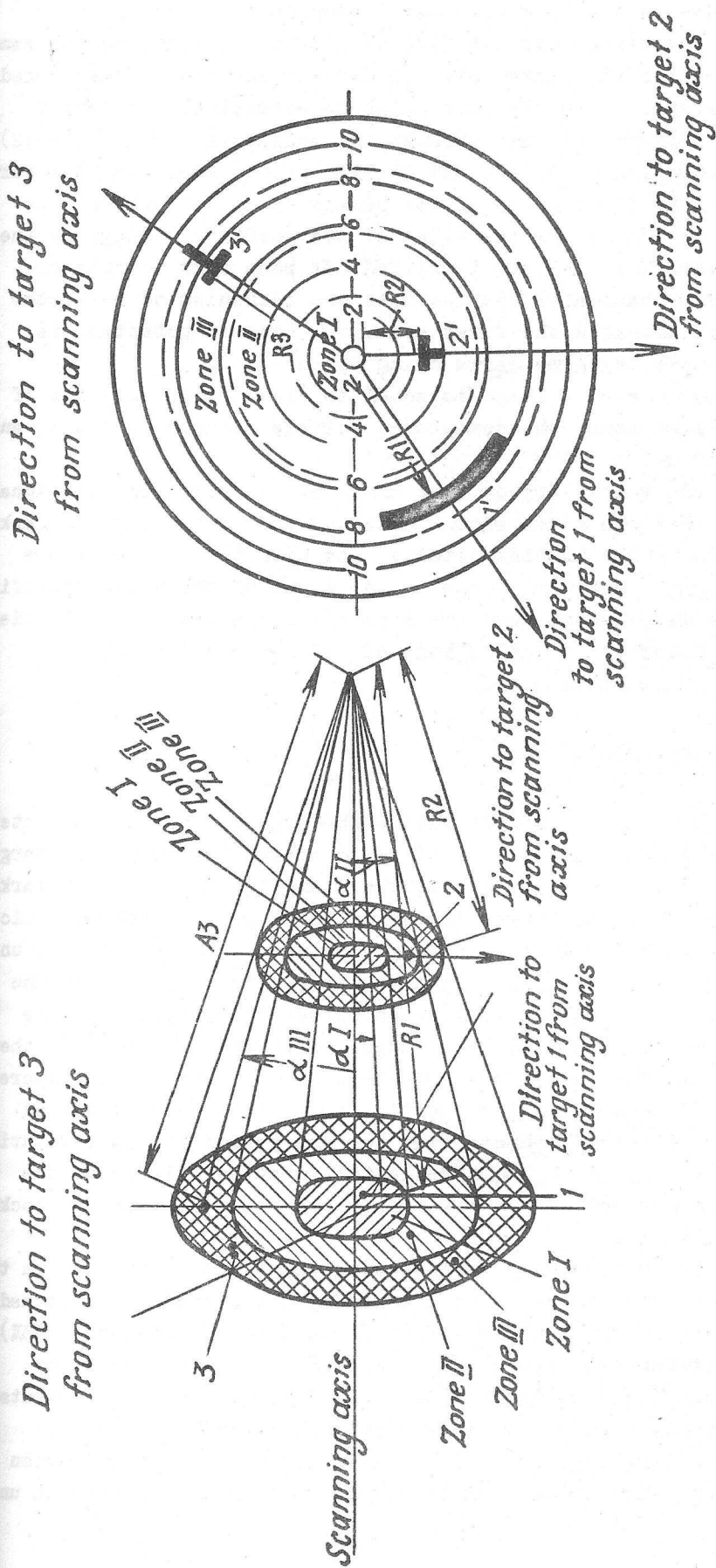


FIG. 13. DETERMINATION OF TARGET COORDINATES ON INDICATOR SCREEN IN SCANNING MODE

1 - target in zone I; 2 - target in zone II; 3 - target in zone III;
 αI - angle between the scanning axis and the direction to the target in zone I ($6 \pm 6^\circ$); αII - angle between the scanning axis and the direction to the target in zone II ($18 \pm 6^\circ$); αIII - angle between the scanning axis and the direction to the target in zone III ($30 \pm 6^\circ$);
 R1, R2, R3 - slant ranges to targets 1, 2, 3; 1' - mark of target 1 in zone I (without the zone mark); 2' - mark of target 2 in zone II (the duration of the zone mark is $4 \mu s$, i.e., 600 m); 3' - mark of target 3 in zone III (the duration of the mark of zone III is $10 \mu s$, i.e., 1500 m)

which is shifted with respect to the first pulse of the packet by 3 to 5 pulses. This pulse is differentiated and, now in the form of a negative-polarity 1- μ s duration gate pulse, is applied to the comparison circuit (1/2 of $\Pi 13-16$). Applied to the same circuit are the target pulses which are picked off the divider located in the locked-on target signal suppression stage. While the gate pulse is effective, the target video pulses pass from the coincidence circuit through the amplifier (1/2 of $\Pi 13-12$) for triggering the multivibrator (1/2 of $\Pi 13-12$ and $\Pi 13-13$) which generates zone mark pulses delayed with respect to the first pulse of the packet by 3 to 5 pulses. The duration of the zone marks is determined by the value of the positive voltage on the first anode of the multivibrator. This voltage is picked off zone mark commutator B1-6 located in unit 2AK-1 and mechanically coupled with the mechanism of reflector deflection. When the antenna illuminates the first zone, the chassis potential is applied to the multivibrator anode, with no marks being produced.

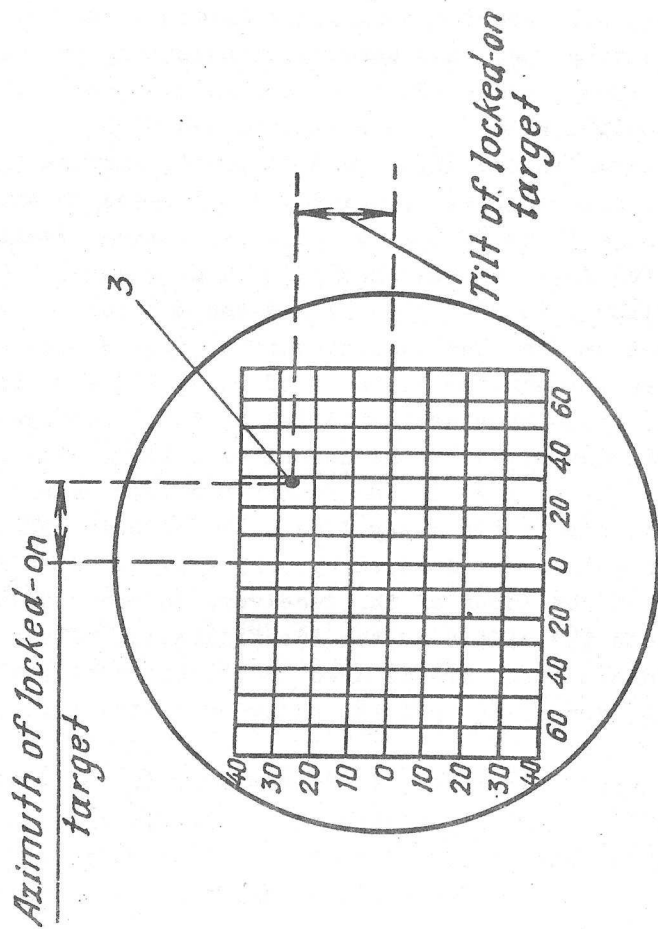
In the second zone, the commutated voltage is equal to +120 V, the duration of the marks being 4 μ s. In the third zone, the commutated voltage amounts to 300 V, and the duration of the marks to 10 μ s.

From the second anode of the multivibrator, the marks are supplied to the signal and mark mixer ($\Pi 13-19$) where they are mixed with the target and identification marks arriving from the identification pulse shaping circuit, and with the lock-on range pulses. From the mixer, the signals and marks come to the input of the video amplifier limiter ($\Pi 4-2$) located in unit 2AK-4 where they are limited in the maximum, amplified and then sent in the negative polarity to the cathode of the cathode-ray tube to modulate the electron beam in brightness.

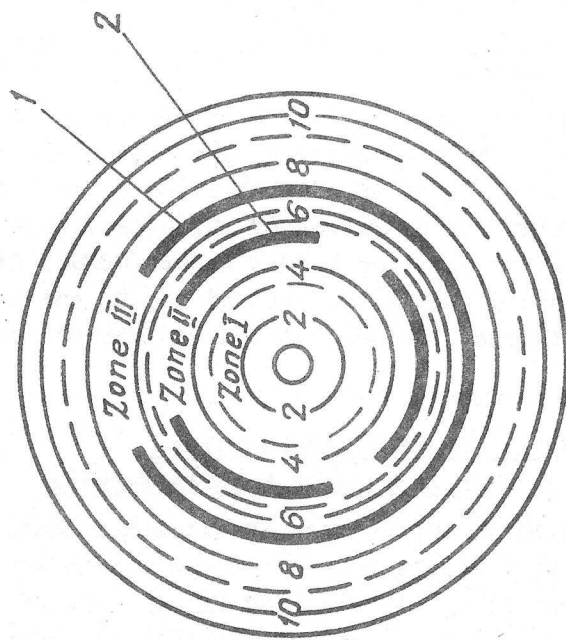
Circuit for Shaping Locked-On Target Mark and Lock-On Range Mark

In case of angular lock-on, all the targets within the area scanned by the antenna are displayed on the indicator screen in the form of solid rings. The locked-on target mark is represented by a ring broken by three unbrightened arcs (Fig. 14). This mark is shaped in the following way. When the target is locked on in range, lock-on indication pulses coinciding in time with the locked-on target pulses are supplied from unit 2AK-11 to the commutating stage (1/2 of $\Pi 13-18$) through delay line $\Pi 13-3$. From the output of the commutating stage, the lock-on indication pulses are supplied to the locked-on target suppression circuit ($\Pi 13-17$). Also supplied to this circuit are the target pulses from unit 2AK-3. In this case, the locked-on target signals are suppressed by the lock-on indication pulses and do not pass to the mixer. The commutating stage is cut off by the voltage of -150 V three times for the period of one revolution of commutator B1-7 mechanically coupled with the reflector rotation axle, with the lock-on indication pulses being not applied to the suppression circuit, and the locked-on target signals passing to the mixer.

The lock-on range mark makes it possible to determine the range of locking on the targets with the aid of the indicator screen. For triggering the circuit, use is made of the trailing edge of the lock-on range pulse shaped in unit 2AK-3 (assembly 8П3А). This pulse is applied to the differentiating stage (1/2 of $\Pi 13-11$) to trigger, by means of its trailing edge, the blocking oscillator (1/2 of $\Pi 13-11$) at such moments when the ground potential is applied to the differentiating stage with the aid of commutator B1-7. The commutator ring used for this purpose has a conductive section of 300°, therefore the lock-on range pulse mark is represented by a ring with an unbrightened section of 60°.



Appearance of Indicator Screen in Target Tracking Mode with Button INDICAT. ON Depressed



Appearance of Indicator Screen in Target Tracking Mode

FIG. 14

1 - lock-on range mark; 2 - locked-on target mark; 3 - antenna head position mark

The lock-on range mark pulses are then supplied to the signal and mark mixer (И13-19).

Identification Mark Shaping Circuit

The identification marks located behind the target marks and differing from them by a greater duration (about 2 μ s) are used for determining the national identity of the target. For this purpose, radar ИРС-3 is coupled with set СР30-2.

Control of the identification circuit is effected with the aid of switch INTERROGATION (ОНРОС) В6-3 located in the 2ИК-6 control panel. When switch В6-3 is set to position ON (ВКЛЮЧ.), +27 V is applied to relay Р13-2 located in unit 2ИК-13.

The relay operates, and the СР30-2 set starting pulses, leading the transmitted pulses by 0.6 μ s, are fed from the synchronizing pulse generator (1/2 of И13-10) through the cathode follower (1/2 of И13-18) and the contacts of relay Р13-2 for starting the identification set. The identification signals with a duration of 2.5 \pm 0.5 μ s are supplied through the contacts of relay Р13-2 to the identification mark shaping circuit in which they are amplified by the two-stage amplifier (1/2 of И13-24 and 1/2 of И13-23) supplied to the coincidence stage (И13-22). Applied to the same circuit are the target pulses (in the function of key pulses) which are delayed by 3.5 μ s in the receiving channel (in delay line И13-6 of unit 2ИК-3).

The identification pulses are delayed by 5.25 \pm 0.75 μ s with respect to the radio frequency target pulse at the input of the receiver. In order that the target pulses may coincide in time with the middle of the identification pulses, the target pulses supplied to the coincidence stage are delayed additionally by 2.5 to 4.7 μ s in delay lines И13-1 and И13-2, depending upon the position of the slider of variable delay line И13-2.

The use of the variable delay line is dictated by the necessity to compensate possible deviations of the rated parameters of the delay lines in units 2ИК-3 and 2ИК-13 and possible deviations of the identification pulse delay with respect to the target pulses (5.25 \pm 0.75 μ s). The moment the target pulses coincide with the identification pulses a negative pulse is picked off the coincidence stage. It is differentiated and integrated by the network of И13-10, С13-72, Р13-169, Р13-171, and is applied to the output stage (И13-23) to be amplified and then supplied in the positive polarity to the mixer (И13-19).

Since the target pulses are applied to the mixer without delay, the identification marks are observed on the indicator screen behind the target marks.

When the targets are located at great distances, the amplitude of the target pulses may be insufficient for operation of the coincidence circuit. In this case, switch В6-3 is to be set to position LONGER RANGE (ПОДЛИН. ДАЛБ.), and instead of the target pulses the chassis potential is applied to the coincidence stage. The identification signals therewith pass through the coincidence stage without being selected by the target pulses.

Circuit for Generating Hostile Target Pulses and Voltage of +230 V in Locking On Hostile Targets

When the radar operates in the mode of automatic positioning of the antenna, only hostile target pulses should be sent to the automatic antenna-positioning channel, which excludes the possibility of directing the antenna to friendly aircraft.

Therefore, the target signals are supplied to the automatic antenna-positioning unit through the hostile target signal generating circuit, the operation of which is described below.

The target signals from the output of receiver 2AK-3 (assembly 2G8) come through delay line Hs 13-1 and the phase inverter (1/2 of H13-21) to the input of the friendly target suppression stage (H13-20). Applied to the other input of this stage are the identification pulses from the identification pulse amplifier (1/2 of H13-23). If there are friendly target pulses in the channel, they are suppressed by the identification pulses. The hostile target pulses are supplied through the cathode follower (1/2 of H13-21) to automatic antenna-positioning unit 2AK-29 where they are applied to coincidence circuits H29-4 and H29-20.

When the target is locked on, the hostile target pulses start arriving at the input of the +230-V generating circuit (H13-25) continuously rather than in packets. In the grid circuit of the detector (1/2 of H13-25), the pulses are rectified to set up a control voltage which is applied to the electronic relay (1/2 of H13-25, P13-4). The relay operates and its contacts connect the circuit which supplies +230 V to the automatic fire control device of unit 2AK-29 (H29-24) through the winding of relay P5-17.

Antenna-Positioning Mark Circuit

The antenna-positioning mark is observed on the indicator screen in the form of a luminous dot and serves for directing the antenna head to the target in the mode of manual antenna positioning.

Used as antenna-positioning mark pickoffs are the potentiometers of the TH-1A control panel, which are linked with the azimuth and tilt axes of the handle.

Since there is selsyn coupling between TH-1A and the antenna head, the coordinates generated by the potentiometric pickoffs will represent the coordinates of deflection of the antenna head from its position in scanning.

In the mode of manual antenna positioning, the voltage of +27 V is applied to the windings of relays P5-14 and P5-15. The relays operate. The contacts of relay P5-15 feed the voltage of the aircraft mains to the TH-1A potentiometric pickoffs while relay P5-14 switches vertical and horizontal deflection coils L4-4 from the stator windings of antenna rotary transformer BT1-3 to the azimuth and tilt potentiometric pickoffs of TH-1A. Direct currents start to pass through the deflection coils, their value and direction depending on the value and direction of the deflection of the TH-1A control panel and handles in azimuth and tilt. The indicator screen therewith stops displaying the radial-circular sweep which is changed for an antenna-positioning mark in the shape of a luminous dot. This mark is to be brought from the centre of the screen in the direction of the target, i.e., to the zone in which the target is situated. The scale of the indicator is divided by three dashed circular lines into the three zones: Zone I, Zone II, and Zone III.

In case the target is locked on in range, the circuit supplying the +27-V voltage in the manual antenna-positioning mode is disconnected from relays P5-14 and P5-15. The relays get de-energized and the indicator screen stops displaying the antenna-positioning mark and starts displaying the radial-circular sweep.

Shaping of Antenna Head Position Mark

The antenna head position mark is observed on the indicator screen in the form of a luminous dot and serves for indicating the antenna head position in azimuth and tilt in the mode of target tracking, i.e., for indicating the position of the locked-on target with respect to the aircraft flight axis, as well as for monitoring the shift of the zones with knob INDICATION ON (BKJL.MHJMK.) depressed (Fig. 14).

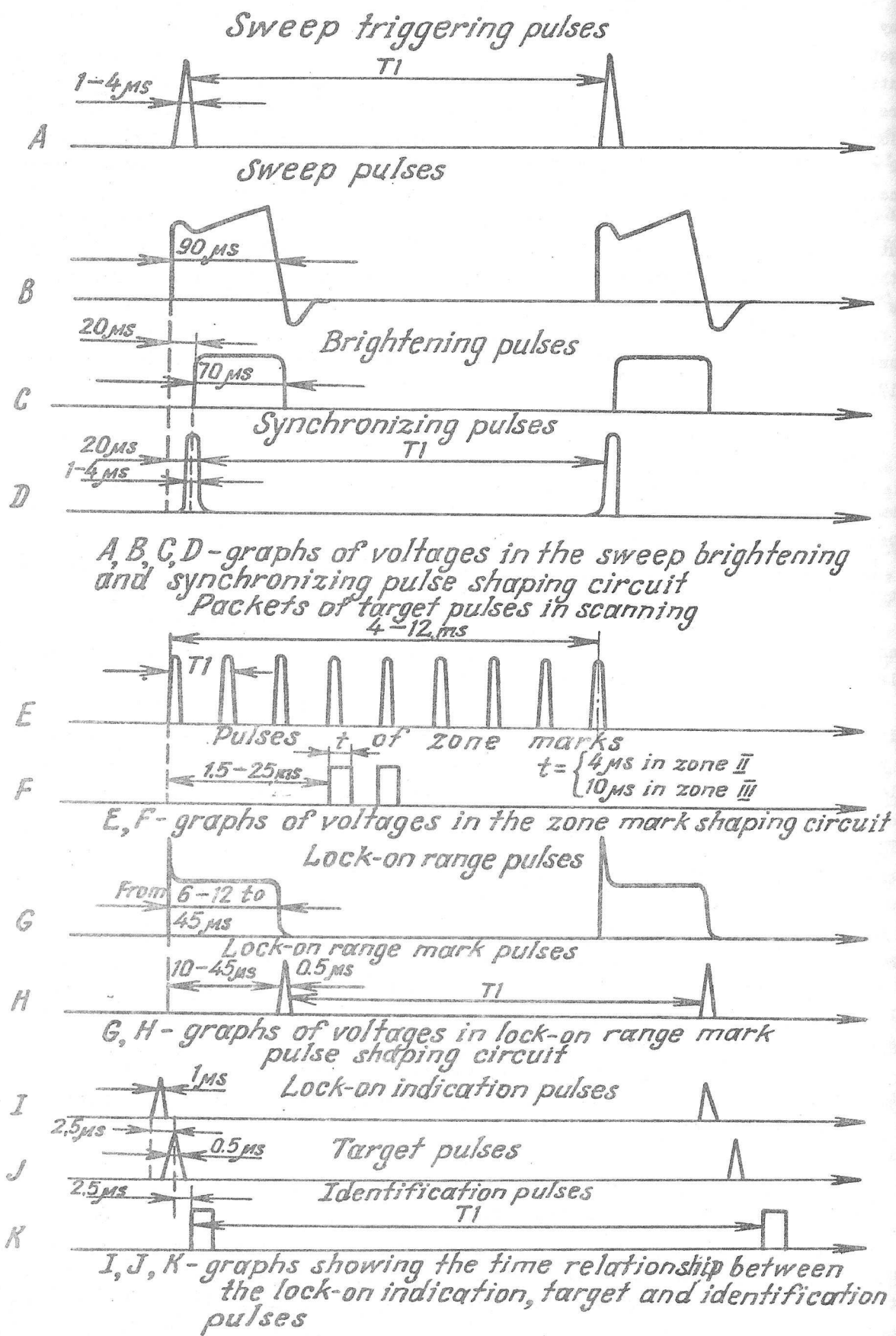


FIG. 15. DIAGRAM OF TIME RELATIONSHIP BETWEEN PULSES IN UNIT 2JK-13

For determining the numerical value of the antenna head azimuth and tilt, use is made of potentiometric pickoffs R1-13 and R1-14 which are coupled with the axles of the antenna head rotation in azimuth and tilt. When knob INDICATION ON of unit 2AK-4 is depressed, the voltage of +27 V is applied to potentiometric pickoffs R1-13 and R1-14 located on the antenna and relay P5-8.

As a result, potentiometric pickoffs R1-13 and R1-14 get connected to deflection coils L4-4 through the contacts of relay P5-8. The indicator screen starts displaying a mark in the form of a luminous dot whose azimuth and tilt coordinates correspond to the antenna head position.