SECTION IV

MILITARY TELEVISION EQUIPMENT

To what extent television in its prewar stage of development could aid a nation at war, posed an intriguing question. The problems to be met were different. Could the electronic Iconoscope and Kinescope compete with the photographic camera in displaying clear and unmistakable pictures of battle scenes, enemy aircraft, or bombing targets, under extreme variations in lighting, and in the presence of severe electrical interference? Would the range of the transmitter be satisfactory, particularly in small, speedy aircraft, where the transmitter power and antenna area would be limited? How small could a television transmitter and receiver be made and still be practical?

The answers to these and inumerable other questions came out of the experimental, developmental and production work done by RCA and its subsidiaries in negotiating approximately 10 million dollars worth of contracts for the Army, Navy, and the Office of Scientific Research and Development. With this work came proof that television-equipped aircraft could be a formidable weapon.

An Idea in 1934: In recounting the history of airborne television development, we must go back to 1934 -- more than five years before the start of World War II -- when television's potentiality as a weapon was visualized by RCA's television pioneer, Dr. Zworykin. It was at a time when the Japanese, according to newspaper reports, had organized a Suicide Corps to control surface and aerial torpedoes. Dr. Zworykin, in a report commenting on this fact and disclosing his new proposal, declared that "one possible means of obtaining practically the same result is to provide a radio-controlled torpedo with an electric eye." He then added: "This torpedo will be in the form of a steep-angle glider, without an engine, and equipped with radio controls and Iconoscope camera. One or several such torpedoes can be carried on an airplane to the proximity of where it is to be used, and released. After it has been released the torpedo can be guided to its target with shortwave radio control, the operator being able to see the target through the 'eye' of the torpedo as it approaches." The proposal is illustrated in Figure 48.

The RCA television pioneer included in his memorandum details as to radio-control equipment involved in the flying torpedo, and went so far as to estimate that this entire equipment, the television transmitter and all, could be built to weigh only 140 pounds. He also told how the system might be applied in more elaborate form to an explosive-carrying plane which, like the flying torpedo, could be radio-controlled and guided to enemy targets by television. Such aircraft, he pointed out, had the advantage of easy launching from land points or from vessels at sea. His estimate of the total weight of a satisfactory radio and television system for this use was 160 pounds, including an automatic pilot.

Television equipment in 1934 was not light enough to be used in an airplane. But in 1935 RCA, on its own initiative, began the construction of an airborne reconnaissance television equipment which was successfully demonstrated in 1937--the first television apparatus for aircraft use (Figure 49).

Research work on the project progressed toward lighter and smaller equipment and before our entry into the war, RCA had succeeded in building an airborne television camera and transmitter weighing only 35 pounds.

To recall a most significant step in airborne television development, RCA in 1939 installed newly designed television field equipment in a Boeing 247 and successfully transmitted pictures of New York City from several thousand feet above and around Manhattan to a battery of receivers installed in Radio City. This demonstration was witnessed by Army and Navy officials. It was then that RCA began its development program on compact, lightweight airborne equipment. Work was started by engineering groups headed by M. A. Trainer and W. J. Poch of RCA Victor, and R. D. Kell of RCA Laboratories.

Reduced weight was paramount, so Trainer and Poch, with some sacrifice in picture quality, redesigned their portable Iconoscope equipment, and in 1940 produced a 100-megacycle, 15-watt airborne camera-transmitter (Figures 50 and 51). Flight tests with this set proved that compact, lightweight television equipment could be developed and used in aircraft. Multipath reception -- always troublesome in television transmission -- as well as fluctuating power-line voltages and humidity and temperature changes in the aircraft were certainly problems to be dealt with, but the somewhat lower than broadcast quality of the received picture seemed adequate.

This RCA equipment -- later named "BLOCK" for security reasons -- interested military authorities. During April, 1941, the compact BLOCK set was flight-tested in a B-18 Army airplane at Wright Field. Three months later it was installed in a Model TG Navy plane at the Philadelphia Navy Yard. As a result of these tests, development and production contracts were established between RCA Victor and the Army, Navy, and the National Defense Research Committee.

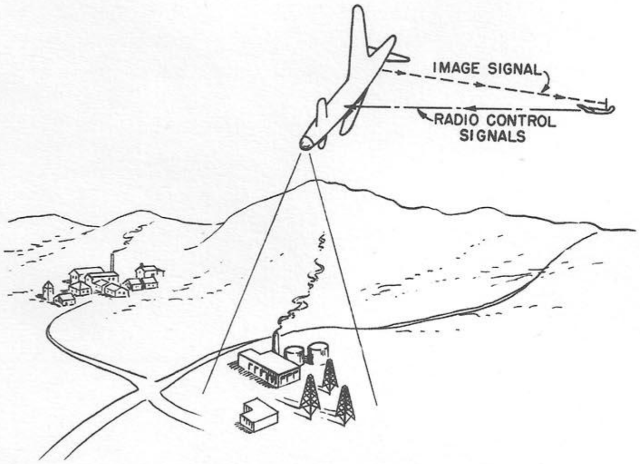


Figure 48. Aided by an image of the target picked up by a television camera in the flying torpedo, the pilot of the "mother" plane deftly steers the deadly craft into the target.

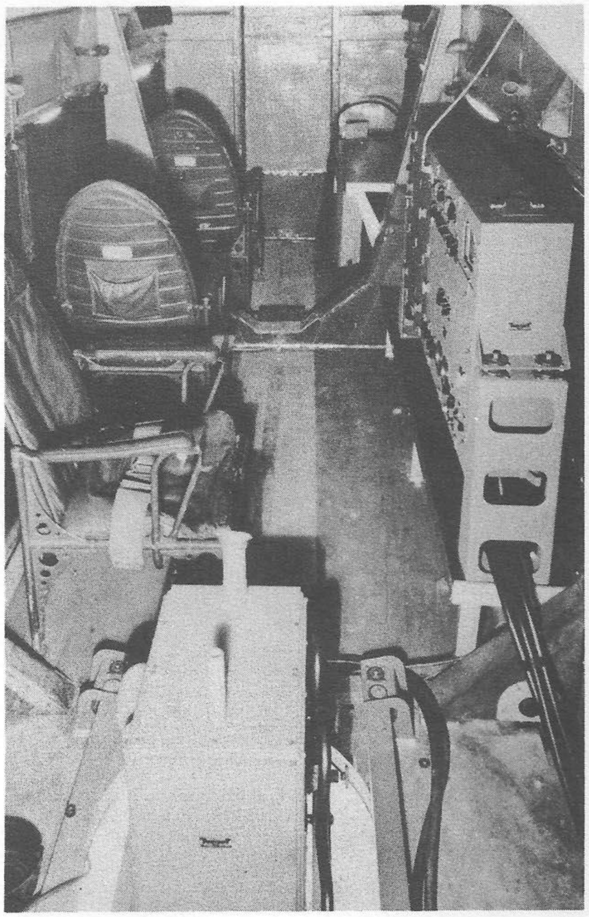


Figure 49. The first television system designed specifically for aircraft use by RCA engineers, installed in a Ford Trimotor plane. The camera is in the foreground.

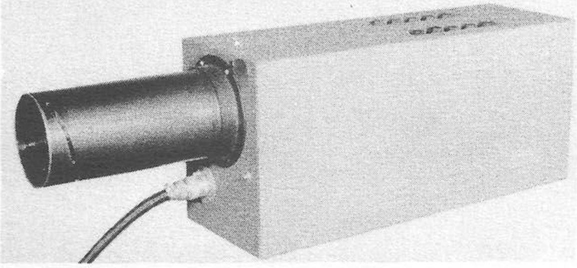


Figure 50. An early television transmitter which sprang from RCA's development of lightweight airborne television equipment. This single unit contains the Iconoscope and its deflection circuits, a six-stage video amplifier and a 12-watt 100-megacycle transmitter.

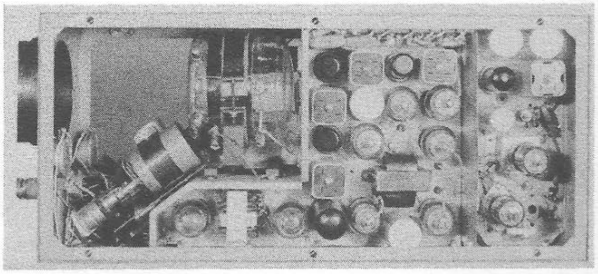


Figure 51. An interior view of the camera-transmitter. The r-f compartment at the right contains an oscillator, buffer and power amplifier. The power-amplifier is on the opposite side of the chassis.

Use of the Iconoscope in BLOCK Equipment: Prior to the Nippon attack on Pearl Harbor, RCA had completed the design of a lightweight airborne television transmitter, monitor, and receiver particularly suited for use in guiding pilotless planes and glide bombs directly to their targets. The transmitter, weighing only 35 pounds, was small and could be used in miniature flying models like the one illustrated in Figure 52. The monitor, which served for pre-flight adjustment of the transmitter, was often carried aloft in the control plane with the receiver and used as an auxiliary means for viewing the picture. The combined weight of these two units was only 57 pounds.

Between 1941 and 1942, over 500 of these early BLOCK I equipments were manufactured in the RCA Camden plant and delivered to the Army, Navy, and NDRC. The Navy was concentrating on the use of the TDR, powered drone as a carrier plane and experimenting with a glider -- "GLOMB", which in later tests proved very satisfactory (Figure 53). The Army Air Forces chief interest was in the GB-4 glide bomb, and in the use of "war-weary" bombers which could be expended in carrying up to 14 tons of explosives into the target.

Requirements for small size and light weight resulted in the use of compromise television standards in the BLOCK I sets; although, for highest picture quality, commercial or broadcast practice was adhered to as closely as possible. After consideration had been given to picture quality vs power demand and circuit complexity, tentative standards were adopted for the first military equipments. Actually, these standards provided the general basis for the design of all the subsequent BLOCK equipment:

(1) 350 lines, sequentially scanned
(2) 40 frames per second
(3) 4.5 megacycle video bandwidth, double-sideband transmission
(4) Horizontal and vertical synchronizing pulses different than RMA standards
(5) No d-c transmission
(6) Vertical polarization of the radiated signal

BLOCK I transmitting equipment, shown in Figures 54 to 59, consisted of three units: The Camera-Transmitter unit, housing the r-f transmitter, modulator, picture amplifier, Iconoscope and deflection circuits; a Dynamotor Power Supply; and the transmitting antenna. The operating frequencies ranged from 78 to 114 megacycles.

Figure 59 is a block diagram of the transmitter. For the r-f section, a 6V6 tube master oscillator, operating on the carrier frequency was capacity-coupledto a 6V6 tube buffer, which was in turn linked to an RCA 829 tube output power amplifier. The 20-watt output stage was grid-modulated by the picture signal in the direction of increasing carrier for "black," and was plate modulated by the synchronizing pulses which were "blacker-than-black." At first, the output stage was grid-modulated entirely, but plate modulation for the synchronizing pulses was later adopted because it helped to maintain receiver synchronism.

In the camera-transmitter unit, the synchronizing generator and shaping equipment customarily used in television broadcasting was replaced by three dual-triode vacuum tubes and associated circuits. This simplification was accomplished with an attendant lower number of scanning lines, lack of interlacing, and higher blanking intervals. Reasonably good picture quality resulted. The usual Iconoscope deflection system was replaced with just five vacuum tubes and their circuits. Beside deflection, these tubes performed keystone, shading and high-voltage functions. The picture amplifier was somewhat simplified by combining it and the Iconoscope in the same unit.

The monitor consisted of an RCA 1811-P1 seven-inch Kinescope, a picture amplifier and the necessary deflection circuits for the Kinescope.

Extensive simplifications such as were effected in the design of the camera-transmitter unit could not be applied, in general, to the receiving equipment, because a receiver with the utmost sensitivity was needed to complement the low-power output of the transmitter. By clever disposition of components, however, a complete receiver including the power supply and Kinescope was built into one case. It can be seen from the block diagram that the design of the receiver was in accordance with standard practice. It was unnecessary to eliminate the synchronizing pulses from the picture- and blanking-signals since these pulses drove the grid of the Kinescope into the infra-black region of its grid characteristic, and thus were not harmful to the picture.

The antenna used with the BLOCK equipment consisted of a vertical rod slightly less than a quarter-wave long, one end of which was mounted at the center of a ground system consisting of two horizontal, quarter-wave rods. A matching stub connected between the base of the antenna and the juncture of the ground rods provided a terminating impedance of 72 ohms for the coaxial feed line. On metal aircraft, a "plate" type antenna was used, wherein a circular disc supplanted the ground rods. The transmitting antenna had, in addition, a quarter-wave parasitic reflector mounted behind the radiator.

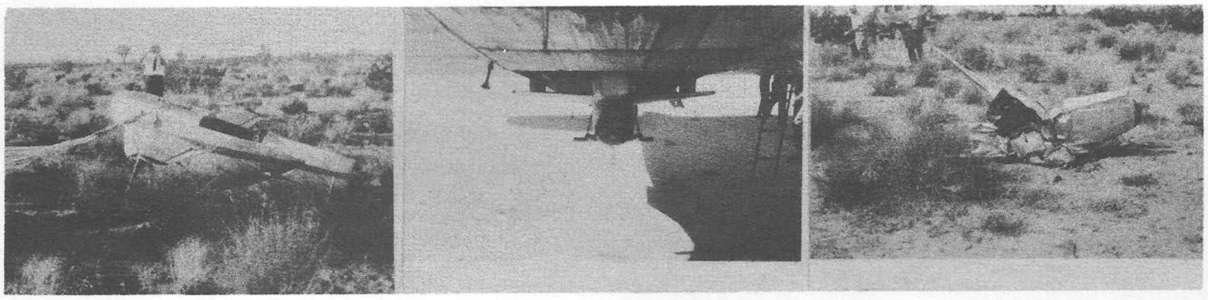


Figure 52. In November, 1914, the first three television-guided missiles on record—built by RCA under an NDRC contract—were tested at Muroc Lack, California. This early missile was designed entirely by RCA engineers; the fuselage was built under their direction by a well known aircraft company. The pictures above show the missile itself (left) with cords to the landing parachute which permitted repeated flights; the bomb attached to the plane (center); and one of the bombs after an accidental crash (right).

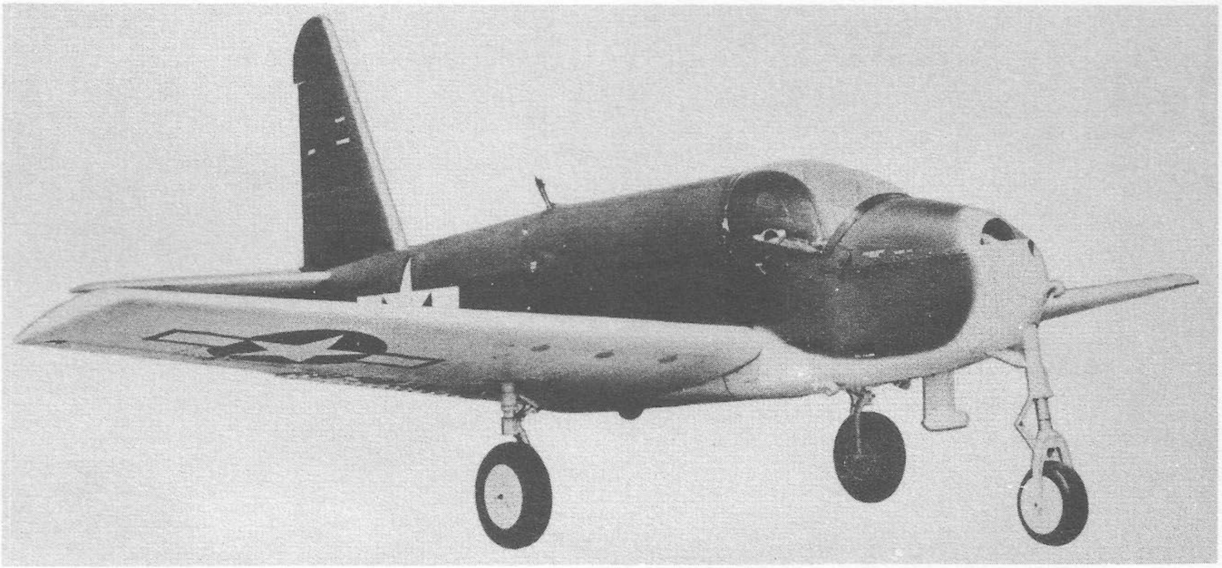


Figure 53. This is the Navy Model LBE-1 "Glomb," a television-equipped, radio-controlled glider, which was loaded with explosives, towed by plane to the vicinity of the target, and then released.

Field Tests with BLOCK I Equipment: Numerous flight tests with BLOCK I television were conducted by the Army Air Forces. Tests at Eglin Field, Florida, and at Wright Field, Ohio, with the transmitter installed in a small PQ-8 target plane, and the receiving equipment in a B-23 bomber, demonstrated that airborne television was practical. During the latter part of 1942, a complete PQ-8 radio-controlled target plane was flown at simulated targets with the aid of the television picture transmitted back to the control plane. This was one of the first airplanes to be flown "nullo" with a television camera to assist in steering a collision course.

Other tests were made at Muroc Lake, California, using a General Motors BUG as a guided missile. A BLOCK I Camera-transmitter, SCR-549-T2, was installed in the BUG, and a BLOCK I Receiver, SCR-550-T2, was installed in the B-23 control plane. In this particular installation, the television camera-transmitter unit, housed in a streamlined nacelle, was suspended beneath the fuselage of the BUG, while the antenna was mounted on top of the BUG. The radio-control and flight equipment were mounted inside the fuselage. Due to the location of the camera, a large part of the viewed scene was intersected by the propeller, resulting in the generation of low-frequency transients. This interference was reduced by lowering the value of the coupling condenser between the fourth and fifth picture stages, thus attenuating the amplifier gain at low frequencies.

After all the necessary ground checks had been completed, the BUG was launched. A satisfactory picture was obtained during the entire flight. Finally, the BUG was dived into a target by radio control, using the television picture as a means of guidance.

Other successful tests were made at Muroc Lake, using different types of aircraft. In one test, BLOCK I equipment was installed in Army YPQ-12A target airplanes to be used as power-driven bombs. The YPQ-12A was of the single-engine type, making it necessary to mount the television camera so that its line of vision would be outside the propeller arc. A nacelle for holding the camera-transmitter was mounted under the right wing of the plane, just outside the propeller disc. A lead weight mounted on the left wing counteracted the unbalancing effect of the camera.

In spite of the shock-mounting and acoustic treatment given the camera, noises from the exhaust, propeller and wind were so great that the low-frequency response of the picture amplifier had to be altered as had been done in previous tests with the BUG. Also, the operation of a television transmitter and radio-control receiver in close proximity in the missile made special protection of the radio-control receiver imperative.

Freedom from interference was obtained by the addition of a wave trap in the antenna circuit of the radio-control receiver.

During the preliminary tests, approximately ten hours of flight were made in which a YPQ-12A was under radio control, the television picture being the sole source of information for the pilot of the B-23 control plane. For the final run, a 500-pound bomb was placed in the safety-pilot cockpit of the YPQ-12A target plane and a hatch was used to cover the compartment. The television picture was adequate, and complete control over the bomb-laden ship was maintained throughout its flight. Ultimately, the ship was maneuvered to a position directly behind a radio-controlled PQ-8, and then exploded by radio control. The television picture in the control plane was good, and it was possible to explode the bomb approximately 75 feet behind the target plane.

NBC made several tests with BLOCK I equipment for both the Navy and the National Defense Research Committee. As a matter of fact, under the terms of a contract awarded RCA by NDRC for the development of airborne television equipment, field service was rendered entirely by NBC technical personnel. Assistance was given during a demonstration of BLOCK I equipment at Anacostia in October, 1942, to determine the usefulness of the equipment for reconnaissance work. Other flight tests were made at Wings Field, Ambler, Pennsylvania, and at the Naval Aircraft Factory, Philadelphia.

Altogether, these tests showed that satisfactory picture transmission from aircraft demanded exact operating characteristics of the television equipment. After the pilotless, transmitting plane had taken off, it was impossible to readjust any of the camera-transmitter controls. Frequently, poor picture quality and loss of synchronization resulted from variations in power supply voltage, changes in light-intensity at the camera, and in signal strength at the receiver. Acoustic vibration of the transmitter components was in many cases responsible for loss of picture definition. These imperfections formed the basis for further development of airborne television equipment.

Under the Army and Navy contracts, work was done on all the BLOCK components -- cameras, transmitters, receivers, power supplies and antennas. More efficient optical systems were provided; pickup tubes with greater sensitivity were designed and built, and several circuits were developed to make the receivers immune to "jamming."

Television-Equipped High-Angle Bombs: A great deal of development work was required to adapt television to the high-angle bomb (Figures 60 to 63). If the course of these weapons could be effectively controlled from altitudes of several thousand

Figure 54. BLOCK I was supplied to both armed forces. This photo shows the Navy Model ATE Transmitting equipment.

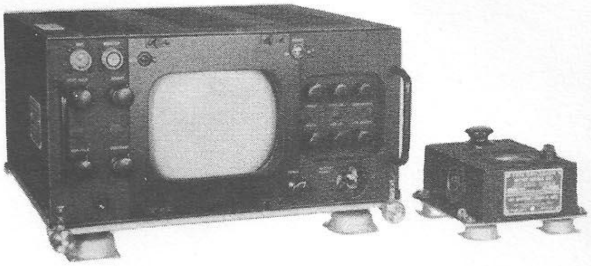


Figure 55. BLOCK I receiving equipment. Navy Model ARE, comprised the Type CRV-46 ABP Receiver, and Type CRV-23ACR Line Voltage Control Unit.

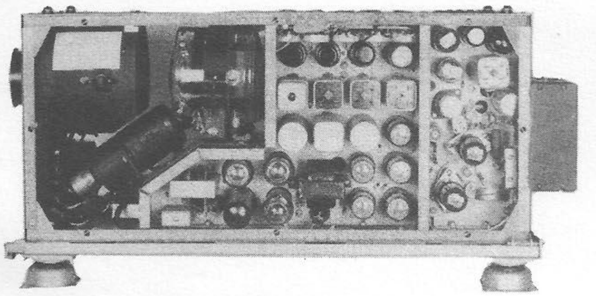


Figure 56. The Camera-Transmitter with the Side Shield Removed. The r-f section is at the right.

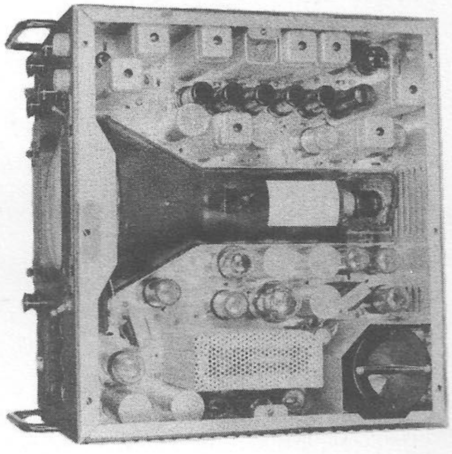


Figure 57. Interior view of the 27-tube superheterodyne receiver, employing an RCA 7-inch Kinescope.

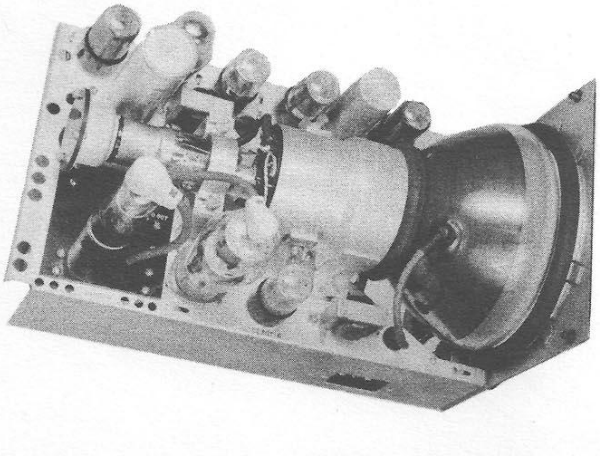


Figure 58. The BLOCK I Monitor. As in the receiver, 4000 d-c volts for the Kinescope was obtained from the horizontal output transformer.

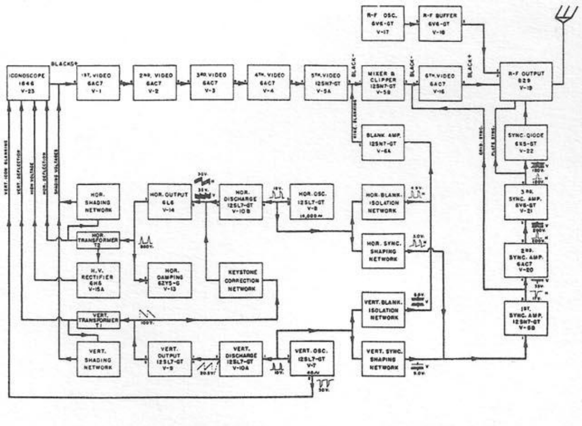


Figure 59. BLOCK I Camera-Transmitter (Block Diagram).

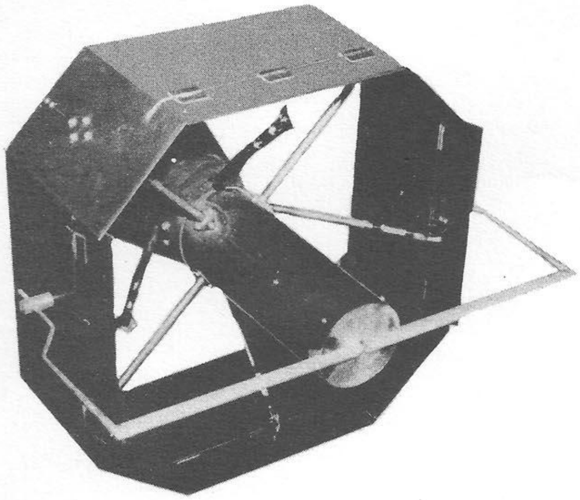


Figure 60. Special BLOCK I Transmitting Antenna Mounted to the Tail of a High-Angle Bomb.

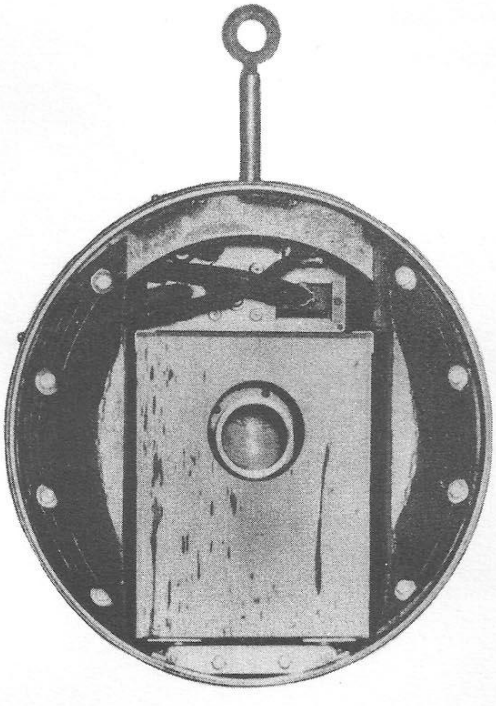


Figure 61. Mounted in the fuselage of the high-angle bomb, the BLOCK I Camera-Transmitter unit and its components were shielded from acoustic vibration by a felt-lined plywood box.

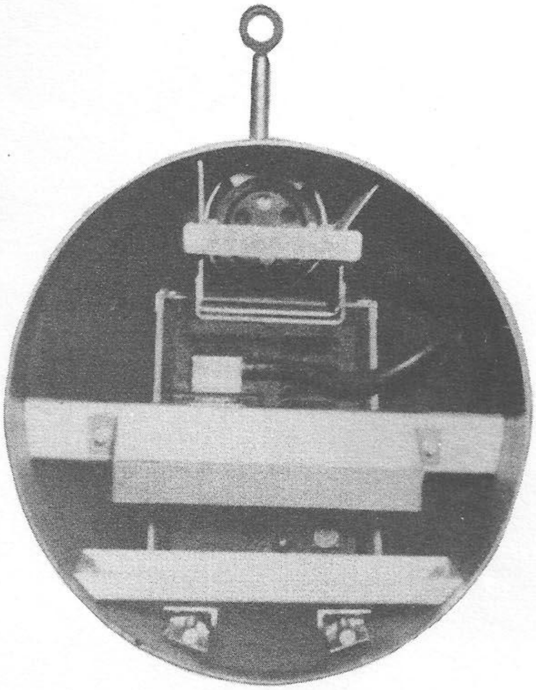


Figure 62. A Rear View of the Bomb's Fuselage with the Camera-Transmitter Unit Installed.

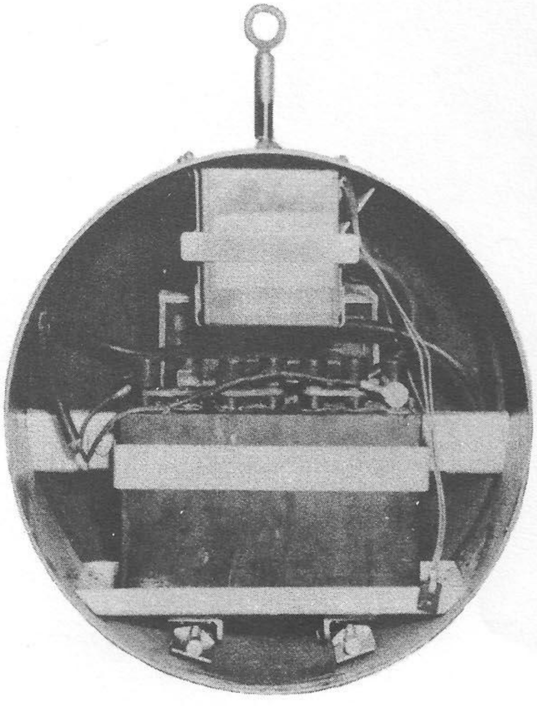


Figure 63. Batteries for the BLOCK I equipment and the radio-control equipment were mounted behind the camera.

feet, the percentage of direct hits could be made high. The conditions to be met, however, were somewhat different from those encountered with the glide bomb. The average high-angle missile was smaller and greater speed was developed by it in flight.

Several high-angle bombs equipped with BLOCK I Camera-Transmitters were dropped at Tonopah Airfield, Nevada. While the results of these tests were encouraging, it was found that a number of difficulties must be overcome if television-equipped missiles were to be accurate weapons. Multipath transmission too often caused serious interference to reception, preventing positive identification of the target as the missile sped to earth. Also, the camera was not always in the proper position to indicate the instantaneous path of the bomb, a mechanical crosshair provided for this purpose, did not prove accurate enough. Noise and vibration generated high-frequency microphonics which greatly marred the picture, unless extreme care was taken in acoustically shielding the equipment. Furthermore, it was discovered that some of the radio frequency energy from the BLOCK I transmitter was being coupled into the camera. There were also more fundamental problems: Tactical considerations required additional r-f channels to permit simultaneous operation of several missiles. Also, the size of the antenna prohibited the use of the equipment in high-speed missiles, the requirements for its rigidity and strength increasing as the speed of the missile, which often reached several hundred miles per hour.

These difficulties were, however, partially compensated by the success of several experimental changes made during the course of the tests: An automatic synchronizing system, developed in RCA laboratories and employed in two of the receivers, was found to be greatly superior to the standard triggering system, in maintaining receiver synchronism. A low-impedance, fast-acting a-v-c system was another step forward in preventing loss of synchronism, particularly through severe radar and other pulse interference; also the acoustic boxes placed on the camera-transmitters in the later test and the sound-deadening felt with which the bombs were lined, were highly effective in reducing microphonic interference.

Nevertheless, it was not until pickup tubes of greater sensitivity and smaller size were developed that television actually became practical for use in the high-angle bomb. The equipment finally designed for this application is described under "MIMO" in a later section.

<u>Special Test Equipment:</u> After BLOCK I had been in use for a short time, it became apparent that some form of special test equipment was needed to expedite flight tests. Ordinary

slide projectors and other laboratory test equipment was found to be inadequate for adjusting the camera-transmitters.

Pre-flight adjustment of the camera-transmitter involved a number of operations. The r-f system had to be checked for proper alignment to insure adequate power output. Proper modulation of the transmitter was to be assured, and this required that the correct input levels of sync and video be delivered by the modulator. Also, the controls of the Iconoscope, such as bias, size, contrast, centering, and shading, as well as the gain control of the picture amplifier, had to be properly adjusted before flight. Thus, the TS-95/AX Alignment Test Bench (Figure 64) and an associatedTS-93/AX Projector (Figure 66) were developed to provide a set of known parameters for testing the equipment. Figure 65 illustrates an I-231-T1 Alignment Test Set, a different packaging of the same components used in the TS-95/AX, which was developed for the Signal Corps; the TS-95/AX was developed for the Navy.

On the Test Bench were guide blocks to position the test projector and the camera-transmitter to be tested. When the units were properly positioned, a test pattern could be projected on the mosaic of the BLOCK equipment under test. At the same time, many of the characteristics of the equipment could be determined; the transmitter's power output and modulation percentage, the system's resolving ability and contrast, the required level of input illumination, and the correct settings for the operating controls.

For checking transmitter power output, the test set provided an r-f load, and measurements were made possible by an associated diode rectifier and microammeter. There were terminals to which an oscilloscope could be connected for observing the r-f envelope. A base line for checking percentage modulation was provided by a vibrator-keyer which periodically shorted the input of the oscilloscope to be used in the test. Using this device, percentage modulation was adjusted so that the "white" picture element caused the carrier to go to zero amplitude.

A tubular fluorescent lamp was used as the light source in the projector, to insure uniform illumination. The lamp current could be measured and adjusted, if necessary. Directly behind the lamp was a cylindrical reflector and condensing lens, giving uniform distribution of light over the test slide. The illumination of the projected image could be varied from one to 20 foot-candles by means of a calibrated iris diaphragm. Details of the light source are shown in Figure 67.

The projector lens, which was the type used in later BLOCK III cameras, was so located with respect to the test slide as to secure infinity focus. Since the emerging light rays were

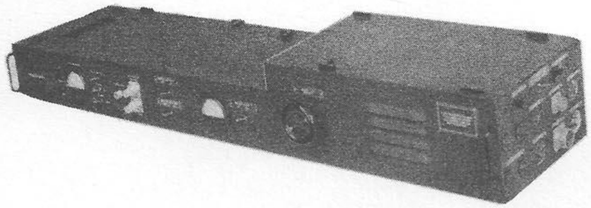


Figure 64. Test Bench. Navy Model TS-95/AX. This unit when used with the Navy Model TS-93/AX Projector provided about all the facilities needed for testing the BLOCK Camera-Transmitter.

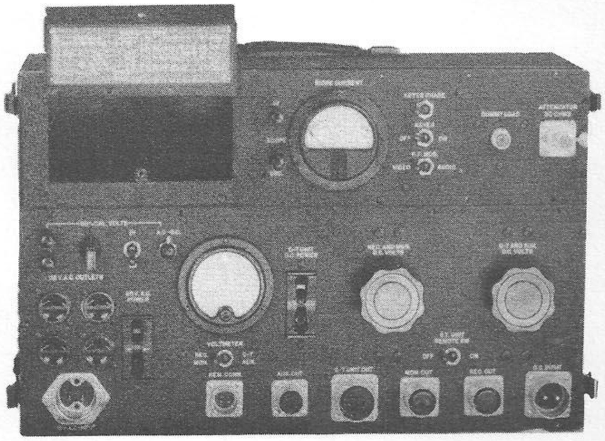


Figure 65. Test Set Type I-231 was developed for the Army. It contained the same components and offered the same salient features as the Navy Test Bench. The unit was used with the Army I-232 Projector.

Figure 66. Army Model I-232 and Navy Model TS-93/AX Projector.

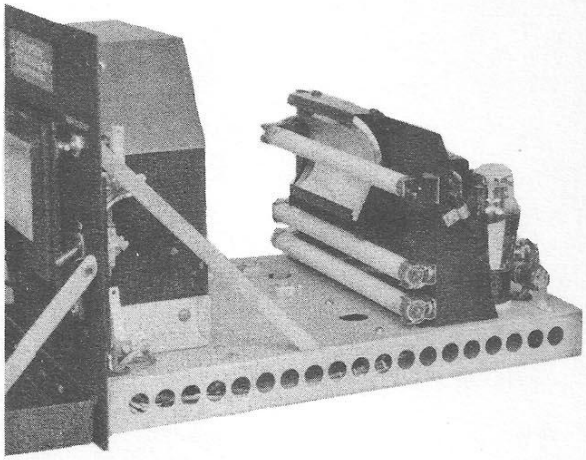


Figure 67. This interior view of the Projector shows details of the six-watt fluorescent light source and the cylindrical reflector. The lamps at the bottom are spares.

parallel, the distance between the camera and the projection lens was not critical. Also, there was no magnification in the optical system and the size of the picture on the mosaic and that on the slide were identical.

A variety of patterns on a set of test slides provided images to test the resolving and contrast capabilities of the BLOCK equipment.

The frequency and power output of the self-excited BLOCK transmitter required checking prior to flights to insure good reception in the control plane. Therefore, a portable field strength indicator (Figures 68 and 69) was designed. The instrument, weighing only two pounds including a self-contained battery power source, consisted of an RCA 957 triode connected as a diode rectifier, and an 0-200 microampere d-c indicating meter. In making transmitter adjustments, the field strength meter was placed about fifteen feet from the transmitting antenna. With the Range dial of the test instrument set to the desired frequency, which was between 250 and 350 megacycles for the later BLOCK equipment, the transmitter was tuned for maximum indication on the microammeter.

Dummy Loads: A new type, non-radiating load for use with the BLOCK transmitter was developed by Dr. H. N. Kozanowski of RCA Victor Division. The dummy load illustrated in Figures 71 and 72, is an incandescent lamp with two filament wires of finely coiled tungsten stretched straight and parallel to each other inside a shield-cage of six parallel wires. The cage simulates the outer conductor of a concentric line, while the two filaments, electrically in parallel, form the inner conductor. The cage and filaments are shorted together by a metallic disc at one end of the lamp. The wires of the cage and the filament wires are brought out through seals in the glass, and welded to two concentric collars which slide over the end of a 55-ohm, concentric transmission line.

This load was used for several months and was found to be superior to standard incandescent lamps for determining power output. At frequencies up to 400 megacycles, the very nearly uniform current distribution in the filament made photometric calibrations taken at low frequencies reasonably reliable. These lamps, which radiated very little energy, were made in two sizes having maximum power ratings of 10 and 40 watts.

There was one difficulty in the use of these lamps. A large inductive component in the impedance was introduced by the coiled filaments, making it difficult to change from the lamp load to an antenna load without readjusting the transmitter. The 40-watt lamp, for example, is one-quarter wavelength at 375 megacycles. Impedance transformers were therefore developed to match the lamps to the 50-ohm line at the various carrier frequencies. However, the use of straight carbon filaments in the lamps to replace the coiled tungsten was expected to reduce the inductance to a minimum and eliminate the need for matching transformers.

Modulation Monitor: The Modulation Monitor (Figure 70) consisted of an r-f tuning indicator which when used with the BLOCK video monitor or an oscilloscope served as a picture signal monitor and a percentage modulation indicator. The unit included a short rigid section of 50-ohm concentric transmission line fitted with a female connector, and a short piece of 50-ohm copolene line and male connector. This composite 50-ohm line was connected in series with the antenna transmission line at the transmitter. The demodulated output from an RCA 9004 diode, tapped on the inner conductor of the rigid line, was amplified by an RCA 6AC7 tube feeding a 75-ohm flexible line to the monitor or oscilloscope. A five-milliampere meter indicated the diode current. Even at BLOCK III frequencies, very little reactance was introduced by inserting the unit in the antenna line; at BLOCK I frequencies, no adjustment of the transmitter was necessary.

Motion Picture Cameras: With the flight-testing of television equipment, particularly in expendable missiles, came the need for permanent, visual records of the results. Missile flights in some cases were very short. For that reason it was important that adequate information be assimilated quickly.

A project was carried out for the development of portable equipment for taking pictures of the receiver screen. Cameras of different manufacture were tested until one was found which offered the greatest flexibility in operation. The television receiver and the film camera had to be mounted on a common base plate to minimize the effect of different vibration periods of the two units. Heavy-duty B batteries supplied 110 volts to run the camera motor. These batteries would run out 10,000 feet of film before replacement batteries were required. The total weight of the equipment was 88 pounds.

300-MEGACYCLE BLOCK III EQUIPMENT: Out of the BLOCK I tests and further development work came the more efficient, more compact BLOCK III television equipment. So acceptable were these units that over four thousand BLOCK III equipments were supplied by RCA Victor Division under Army and Navy contracts. The small, lightweight cameras, which were now constructed as individual units, were placed at gunmounts on larger naval aircraft, and thus were used as Television Gun Sights. This reduced the overall weight of the aircraft, because the cockpit and crew quarters could be made smaller with the camera located outside. On large ocean-going vessels such as aircraft carriers, cruisers and battleships, cameras were placed

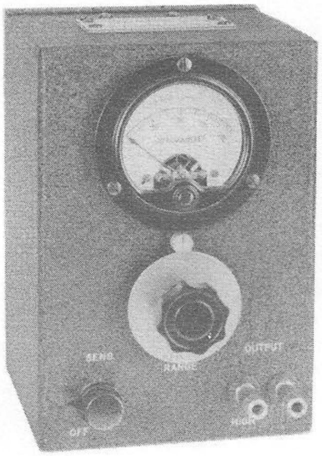


Figure 68. Powered by a 1.5-volt cell, this portable frequency meter and field strength indicator, Army Type I-237-T1, provided for checking transmitter output.

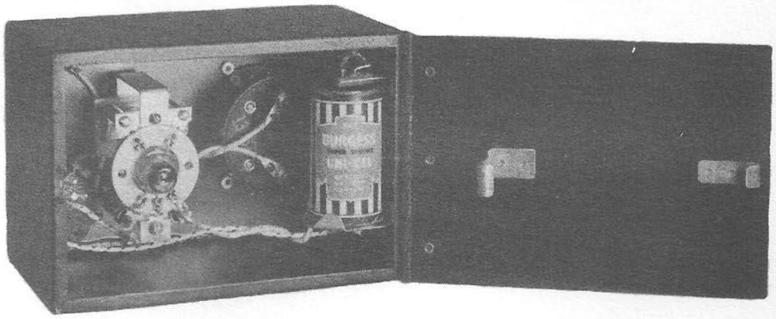


Figure 69. Interior View of the Field Strength Indicator, Showing the "Power Supply" and the RCA 957 Acorn Tube.

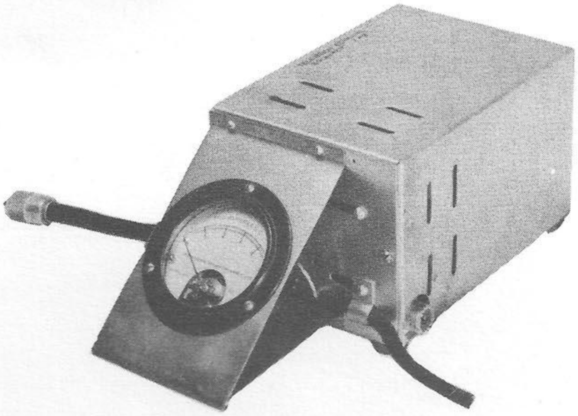


Figure 70. The Modulation Monitor.

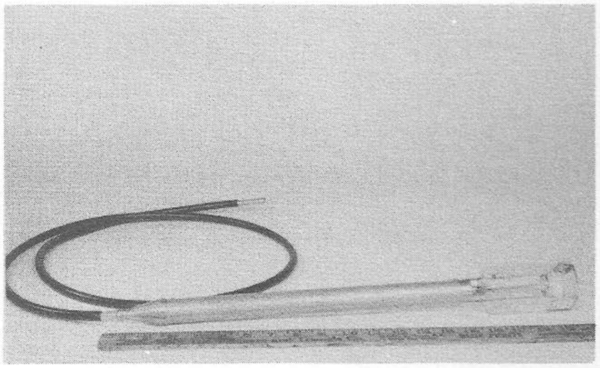


Figure 71. Dummy Load Developed for V-H-F Transmitters.

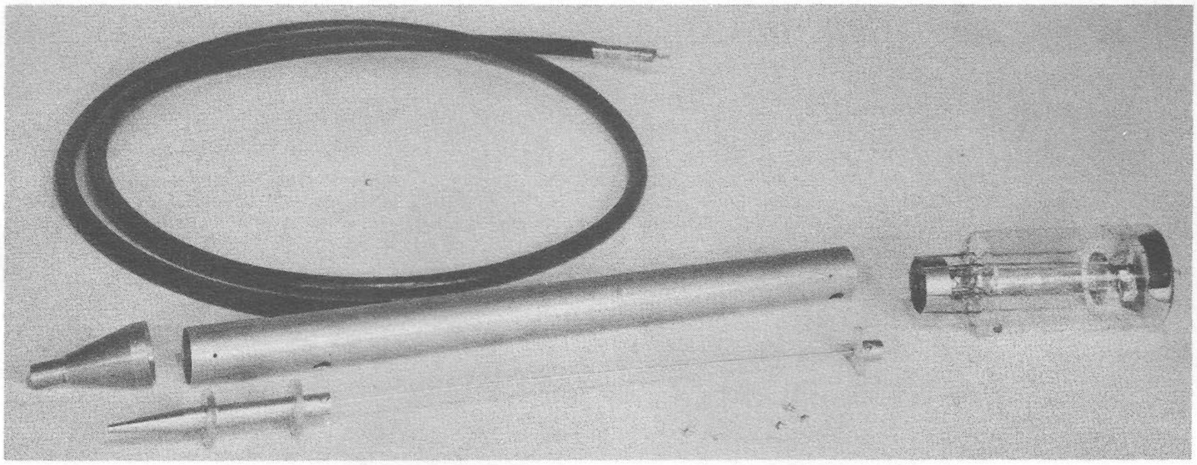


Figure 72. Dummy Load Disassembled to Show Construction.

in the plotting rooms to reproduce at a remote location aboard ship the information recorded on the plotting board. Industrially, too, the equipment found application. Seven cameras and receivers were supplied to a well known chemical company to monitor potentially unstable chemical reactions which might prove too violent and dangerous for personal viewing. In fact, BLOCK III was used in the development and manufacture of the atomic bomb.

The Gun Sight, Plotting Room, and Industrial television equipments were all similar in design and all utilized coaxial cable to link the pickup equipment with the remote viewing equipment. In general, each consisted of an Iconoscope camera, picture amplifier, deflection-control circuits and a power supply located at the pickup end, and a monitor and power supply at the receiving end. The equipment is illustrated in Figures 73 to 78.

There were two versions of the higher-frequency BLOCK III equipment: BLOCK III-A and BLOCK III-B. The BLOCK III-B was tunable over ten channels in the frequency range from 264 to 372 megacycles, while the BLOCK III-A covered only five channels, from 264 to 312 megacycles. Significant improvements in the BLOCK III-B receivers culminated in a BLOCK III-BB receiver. BLOCK III transmitters, on the other hand, were developed through four models: BLOCK III-A, III-AB, III-B, and III-BB. This was partly because undesired frequency-modulation appeared in early models, and partly because simplification of transmitter controls later became a requirement. The earliest BLOCK III television sets are illustrated by Figures 79 to 94.

The camera circuits of the earliest 300-megacycle BLOCK III television sets were similar to those of the 100-megacycle equipment. As previously mentioned, the camera and the transmitter were constructed into two separate units. The camera, or Conversion Unit as it was sometimes called, contained the RCA 1846 Iconoscope, optical lens, picture amplifiers, synchronizing and blanking circuits and the deflection circuits. There were two electrical outputs; a picture and blanking output delivering 0.5 volts peak-to-peak, and a synchronizing output delivering 3.5 volts peak-to-peak. These two signals were not mixed because, as in the BLOCK I equipment, the transmitter was grid-modulated by the picture signal and plate-modulated by the synchronizing signal.

The BLOCK III transmitter employed a master oscillator and power amplifier, each stage using two RCA 8025 tubes in grounded-grid, push-pull circuits. Amplifiers in the transmitter unit increased the picture and synchronizing inputs to the required levels to modulate the power amplifier. A dynamotor supplied plate and bias voltage for the camera and transmitter, and a-c filament voltage for the four 8025 tubes.

Bias (back) lighting, used in the later BLOCK I design, was also incorporated in the BLOCK III Conversion Unit. A small lamp placed at the back of the Iconoscope adjacent to the mosaic, provided constant low-intensity illumination of the walls of the pickup tube, permitting greater variations in scene brightness and contrast, with no change in black spot signal.

An RCA 6L6 tube was added to the Conversion Unit to supply heater voltage for the Iconoscope. Operating approximately as a class A amplifier, and fed by the horizontal discharge tube, the 6L6 tube supplied sufficient heater current through a step-down transformer. This novel arrangement, the circuit for which is shown in Figure 93, reduced the high-voltage cabling for the conversion unit to a minimum.

Inasmuch as higher frequencies were used, the converter section of the BLOCK III receiver was completely new in design. Two gang-tuned lines for the mixer and oscillator, driven by gears, provided good tracking. Later, the r-f section was further improved when the tuner was redesigned to cover ten channels. The new r-f section utilized lines tuned by a capacitor, eliminating all sliding and rotating contacts, and providing mechanical simplicity and ease in ganging the circuits. By employing an r-f stage ahead of the detector, the signal-image ratio increased from 3.5 to 100, and the more efficient construction of the tuner, together with the use of new tubes, gave a 14-db improvement in signal-to-noise ratio.

These tunable head ends were constructed for 14 BLOCK I receivers, which were used in Navy Project RING, and in the latter series of tests conducted in the High-Angle Missile Project.

Field Tests of BLOCK III: The first Army models of BLOCK III, Models SCR-549-T3 Transmitting equipment and Models SCR-550-T3 Receiving equipment were delivered during June 1943. At about this time a few GB-4 glide bombs became available, and the first installation of the transmitting equipment in the bombs was completed in July.

The GB-4 glide bomb consisted of a standard 2000-pound bomb to which an airframe had been fitted. The flight-servo, radio-control and television transmitting equipment were housed in the body of the airframe, while the camera was mounted inside a streamlined nacelle beneath the bomb. Two seven-cell storage batteries connected in series provided 28 volts for the SCR-549-T3 equipment. The television transmitting antenna was mounted on top of the bomb toward the rear, with the reflector in the forward position.

Preliminary flights made at Eglin Field, Florida, without releasing the GB-4 from the control plane indicated satisfactory operation. (It was customary to test the costly television set in this manner before it was demolished in its plunge). An Air Corps trailer, completely equipped to receive and photograph the television pictures, served as auxiliary equipment. Several GB-4's were dropped to determine the practicability of hitting a small pyramidal target constructed for the tests. The results were not too encouraging. The power output of the transmitter in one of the bombs suddenly decreased to zero after release, while with other bombs, numerous disturbances appeared on the receiver screen during flight. Some of these effects were also seen on the receiver at the ground station. Interference such as fine-to-heavy horizontal lines, vertical black bars and loss of synchronization occurred more frequently in the control plane.

It was fortunate, however, that motion-picture cameras had been set up to take pictures of the television screen, both in the air and on the ground, making possible a thorough analysis of the disturbances. It was found that the fine horizontal lines in the picture were produced by acoustic pickup in the camera, and their frequency was approximately 3000 to 4000 cycles per second. This high-pitched noise was apparently generated by the wind rushing past the glide bomb, and a solution was found by placing the camera in a soundproof box. Heavy horizontal lines in the picture were produced by acoustic pickup in the transmitter. The low-frequency noise in this case was approximately 120 to 200 cycles per second, and was generated by the plywood body of the airframe, acting as an effective sound chamber or resonator. It was eliminated by coating the airframe on the inside with automobile-body silencing compound and a thick layer of felt.

Changes in picture shading were caused by the influence of the earth's magnetic field on the Iconoscope, especially when the video gain control was turned to a high level. This was overcome by the installation of a magnetic shield around the entire Iconoscope in addition to the shield around the electron gun.

Iconoscope saturation under high light levels caused blooming of the top half of the picture and consequent loss of video information. Various experiments were conducted with combinations of lens stops and light filters. A yellow filter seemed to be the most effective counter measure, especially under conditions of low contrast caused by haze.

The most significant disturbance was the appearance of the vertical bars having a moire-like appearance and bearing no direct relation to the picture itself. This effect was much more pronounced in plane-to-plane transmissions, in some cases being completely absent in plane-to-ground transmission. It was thought that the interference must be due to some reflective phenomenon; its true cause, frequency modulation of the master oscillator of the transmitter, was not established until after some time had been spent in field tests. Still more field work was done in an effort to determine how much frequency modulation could be tolerated without causing undue disturbance to reception. The results were not conclusive, but it was shown that any frequency deviation from the carrier of less than the line frequency, in this case 14 kilocycles, would have no objectional effects. Early BLOCK III transmitters had as much as 200-kc deviation. In the later BLOCK III-BB transmitter, equipped with a buffer amplifier, the 25-watt carrier could be modulated at maximum on the highest frequency band with attendant frequency modulation of less than ten kilocycles.

Finally a television transmitter incorporating all these and other improvements was dropped in a glide bomb at Eglin Field, in November, 1943, and a flawless television picture was received in the control plane during the entire flight.

An Electronic Crosshair: One of the greatest problems in guiding missiles with the aid of television was target identification. In general, if the target could be identified, hits or near misses would be scored; but often the operator, although thoroughly familiar with the terrain, would get "lost." The television camera, unlike the human pilot, could not "look around." Consequently, if for some reason the target was obscured or just outside the picture, it was difficult to locate. An ideal solution might have been a lens in which the viewing angle could be changed by remote control. The equipment necessary to accomplish this was found to be too complicated, and more emphasis was put on dropping the bomb accurately with a bomb sight. Later, however, an electronic crosshair was developed by RCA engineers, though the war ended before the device could be put into use.

In the system developed, an electrically produced crosshair appearing in the received picture indicated the bomb's line of flight. This signal was produced at the camera by a cathode-

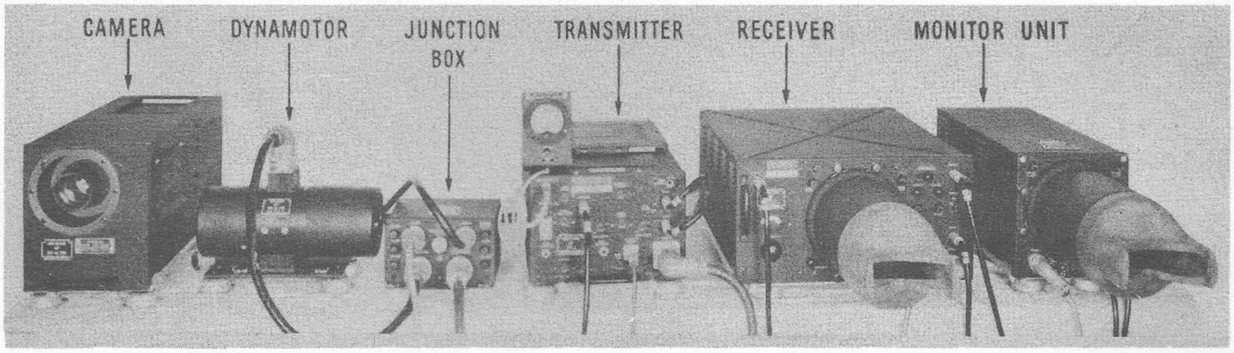


Figure 79. The first BLOCK III Transmitting and Receiving equipment—Navy Model ATJ and ARJ Aircraft Television Equipment, and Army Radio Sets Types SCR-549-T3 and SCR-550-T3.

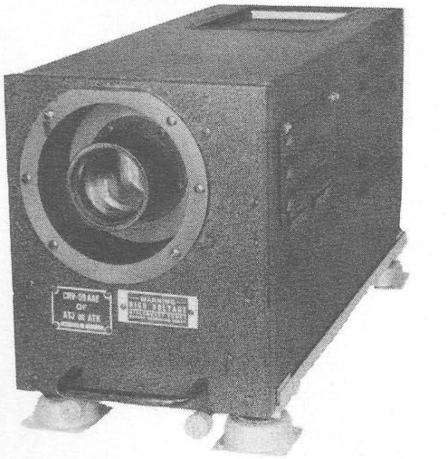


Figure 80. The BLOCK III Camera contained five video amplifier stages and the deflection and blanking circuits.

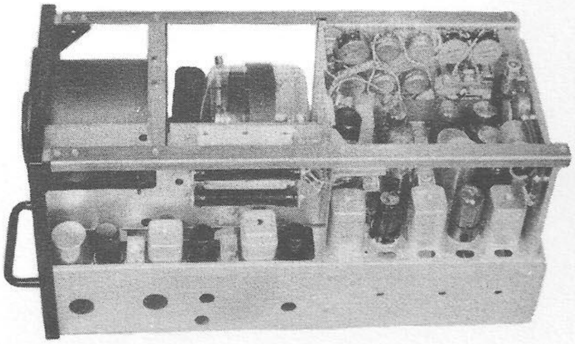


Figure 81. Interior View of Camera.

Figure 82. The r-f section of the first BLOCK III Transmitter used a push-pull master oscillator and power amplifier, but no buffer stage.

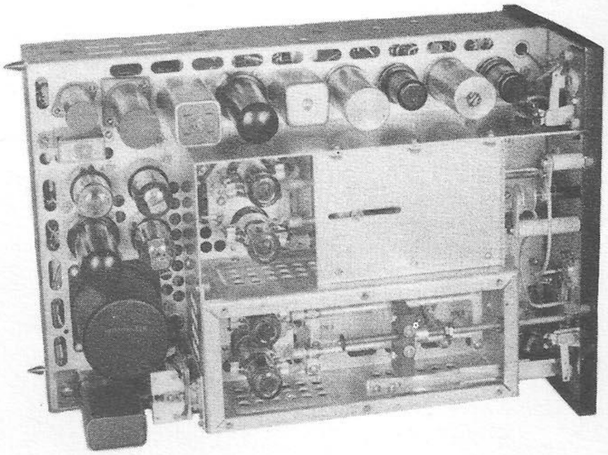


Figure 83. An Interior View of the Transmitter.

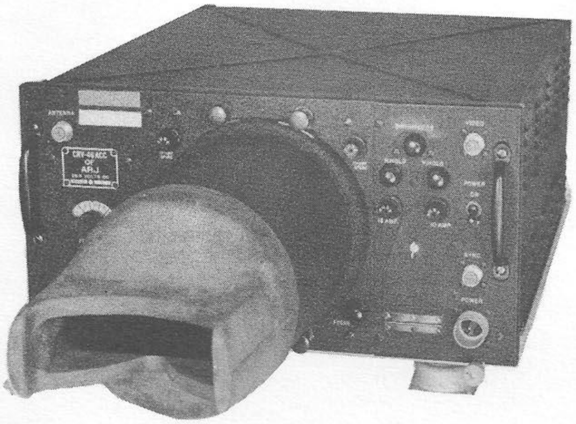


Figure 84. The BLOCK III Receiver. The RCA 6J6 first detector, coupled directly to the antenna, was followed by a six-stage 23-megacycle i-f amplifier.

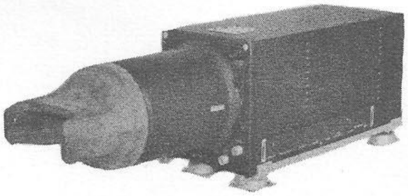


Figure 86. The BLOCK III Monitor.

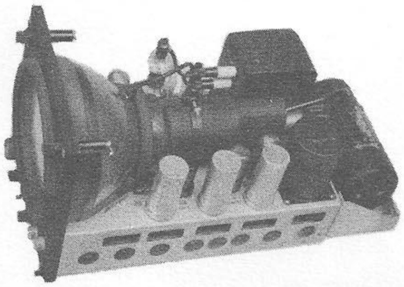


Figure 87. Interior View of the BLOCK III Monitor.

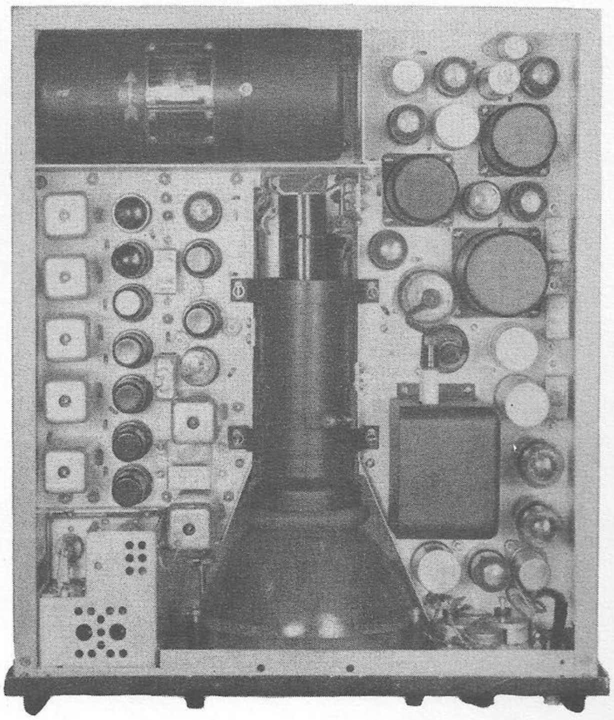


Figure 85. The Receiver Removed from its Case. Note the Dynamotor Power Supply.

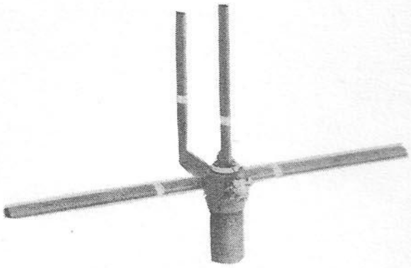
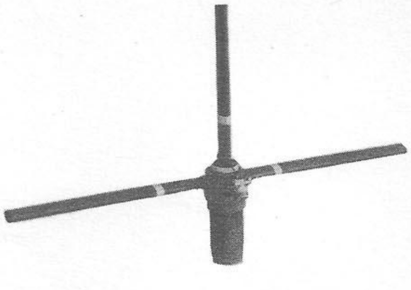


Figure 88. BLOCK III Transmitting and Receiving Antennas. The transmitting antenna (top) used a parasitic reflector.



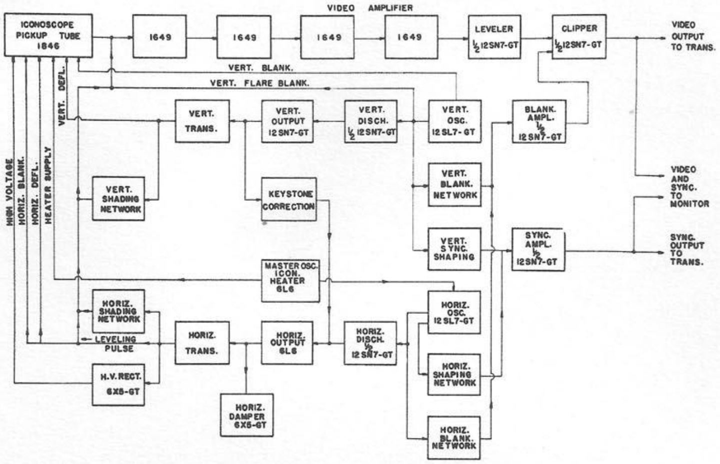


Figure 89. BLOCK III Camera Unit (block diagram).

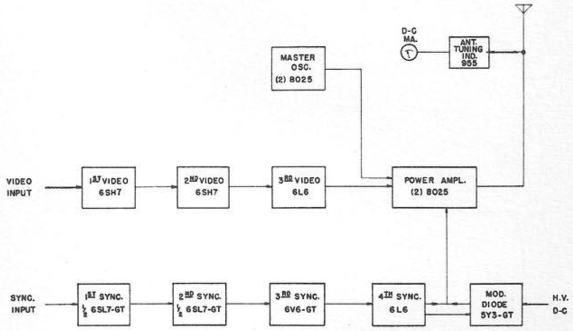


Figure 90. A Block Diagram of the BLOCK III Transmitter.

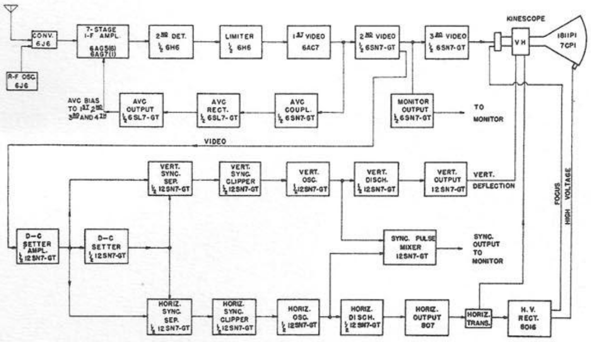


Figure 91. BLOCK III Receiver (block diagram).

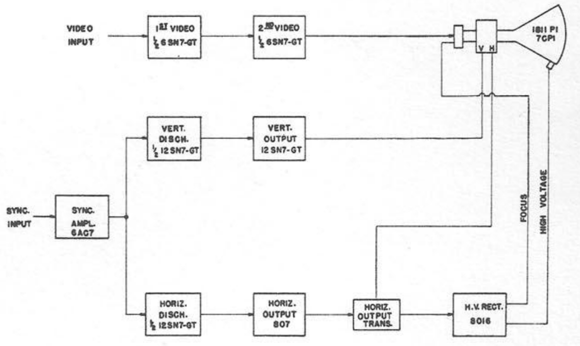


Figure 92. The BLOCK III Monitor (block diagram).

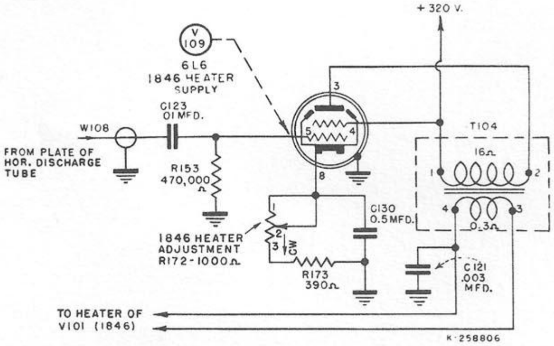


Figure 93. Schematic Diagram of the Iconoscope Heater Supply.

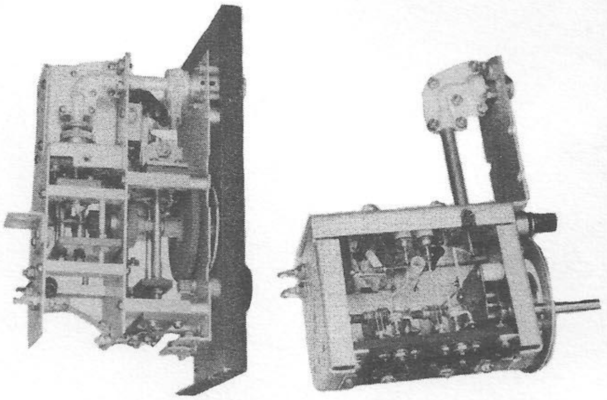


Figure 94. BLOCK III Receiver R-F Tuners. Early Tuner (Left); Later Model (Right).

coupled multivibrator driven from the vertical deflection circuit. The square wave so produced was differentiated and the resulting signal was added to the picture signal. By changing the value of the cathode resistor in the multivibrator, the crosshair could be moved from the top to the bottom of the picture. Using this principle, a variable resistor having the proper change in resistance per degree of rotation, was mounted inside the body of the glide bomb in such a position that it could be mechanically coupled to the lever system operating the elevator. Thus, after the initial alignment of the electronic crosshair with the position of the fin, the crosshair would indicate the line of flight of the bomb. The only requirement for flying a collision course in elevation was to apply control so as to make the crosshair and the image of the target coincide.

Special BLOCK Equipment: Under an NDRC development contract, NBC, subcontracting for the RCA Victor Division, developed a narrow-band system of television to be adapted to "Telemetering", the transmission of aircraft instrument indications from a pilotless, experimental or radio-controlled plane to the control plane or to the ground.

Electronic television as applied to telemetering had a number of advantages over other telemetering systems. The image of practically any standard indicating instrument could be transmitted without the necessity for altering the meter mechanism, and the television pickup imposed no external loading on the meter mechanism which might impair its accuracy.

Lightweight BLOCK equipment already developed had been tested experimentally for telemetering with good results. But the equipment required a radio-frequency bandwidth of nine megacycles. For many cases the occupation of such a wide r-f channel was prohibitive due to lack of channel space. Furthermore, other specialized telemetering systems had been developed utilizing a comparatively narrow r-f channel.

In the design of the telemetering equipment, the narrow bandwidth requirement was met by the use of a ten-frame repetition rate and 300-line definition, which reduced the bandwidth to 750 kc. A two-inch orthicon tube was used in the camera, and a long-persistence Kinescope was used in the receiver to reduce flicker resulting from the low frame rate. The number of tubes, weight of the equipment and power drain were about the same as for the wide-band television systems. The RCA Type C-7475 Kinescope used in the receiver has a screen persistence many times longer than the usual kinescope screens. The screen material of this tube has a blue fluorescence of very short duration which excites a yellow phosphorescence lasting for an appreciable period. Because the blue fluorescence produced by the electron beam was much brighter than the ensuing yellow, an optical filter was mounted in front of the screen to effectively eliminate the blue component of emitted light.

The 15-watt transmitter utilized an RCA 829 tube as a power amplifier, grid-modulated by combined video and synchronizing signals. To insure better synchronization of the receiver, the synchronizing pulses were fed also to the plate and screen of the 829 tube, increasing the peak carrier output for the duration of the pulses. Several successful demonstrations of the equipment were given for the Army, Navy, and NDRC representatives during 1943.

Compact BLOCK: For another special television service, fifteen Compact BLOCK equipments were designed and supplied to the Navy for the Wolf Project. In this project, airplane wing stresses and other technical characteristics were studied by diving pilotless, television-equipped airplanes to earth at great speed. During flight, the Compact BLOCK equipment transmitted television pictures of instrument readings within the experimental aircraft to either a ground installation or to another plane. The Compact transmitting equipment (Figures 95, 96, and 97) consisted of four units: The camera, using an RCA Iconoscope; a camera control unit; the transmitter, tunable to 190, 202 or 214 megacycles; and a dynamotor power supply. The Compact receivers were BLOCK III-A receivers, converted to embody some of the improvements described in the next section.

General BLOCK Improvements: From the earliest flight tests it was learned that picture degradation, after the missile was launched, was caused principally by the following conditions: Power-line voltage variations in the aircraft, the presence of microphonics, radar or ignition interference and unstable synchronization, insufficient signal at the receiver, and variation in light intensity on the pickup tube. With the development of BLOCK III equipment and the consequent use of higher frequencies, multipath reception and doppler effect were given a prominent place in the list of difficulties to be overcome.

Altogether, these problems were satisfactorily solved by the design of new circuits for the cameras, transmitters, and receivers, and by marked antenna developments. The creation of much more sensitive pickup tubes with greater stability contributed in large measure to the solution of these problems, while further steps were taken to reduce the size of the equipment and to simplify its operation.

Very often, production was under way while improvements were being investigated. Some were incorporated in later production, others were not used, either because of added circuit complexity,

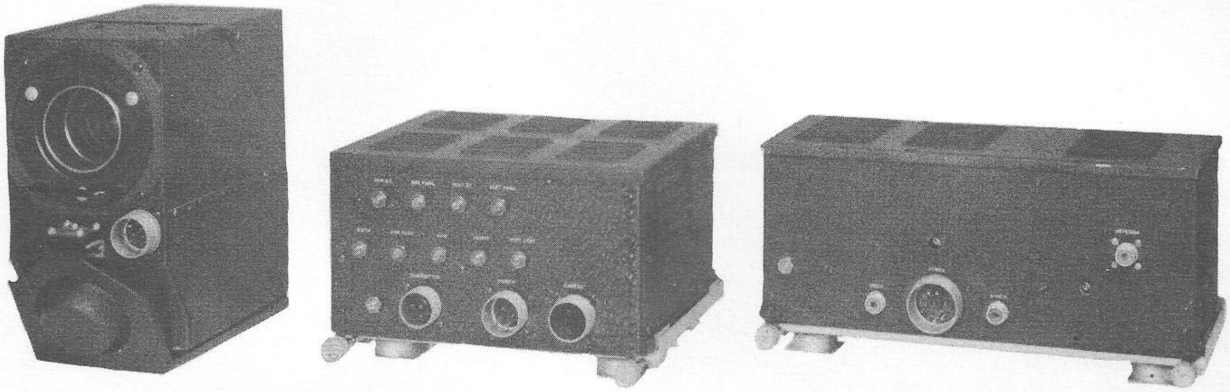


Figure 95. The Compact BLOCK Equipment. Left to right are the Camera, Camera Control Unit, and the Transmitter.

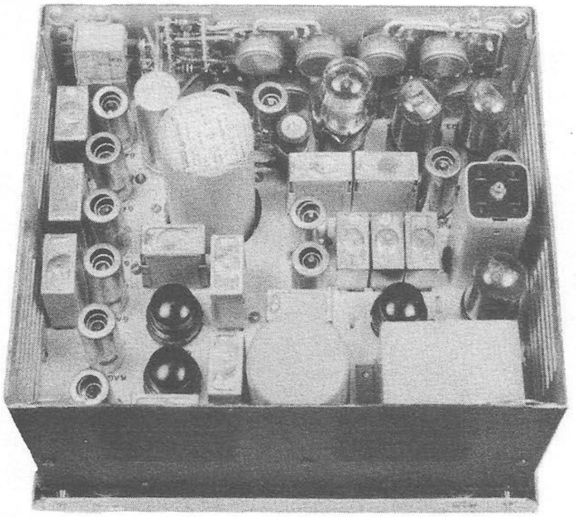


Figure 96. Interior View of the Compact Camera Control Unit.

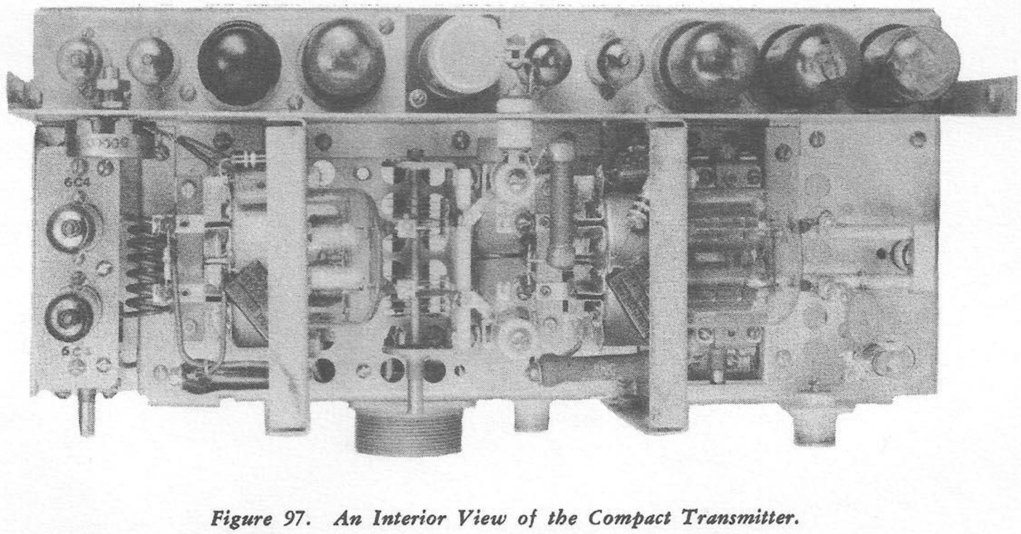


Figure 97. An Interior View of the Compact Transmitter.

or because the required parts were not available. The most significant developments, however, will be described in the following paragraphs according to the particular problem leading to their development.

Variations in the primary d-c voltage supplied by the aircraft made proper adjustment of the television equipment quite difficult, since the voltage with the plane engine idling or stopped was usually much lower than in flight. In later stages of the development, dynamotors were obtained which had a constant output voltage over a considerable range of primary voltage change. However, special B+ voltage-regulator circuits were developed, and for installations where small size was less important, these circuits were also used. They provided a low-impedance source of B+ voltage for the various circuits of the equipment, eliminating, to a great extent, the need for high-capacity electrolytic capacitors to prevent crosstalk.

The problem of microphonics became less important with the proper shock-mounting of the camera and transmitter. Still further improvement in operation resulted from better tube construction, and by application of the "clamp" circuit, previously used in RCA's Orthicon equipment. This circuit clamps the bias of the output picture stage at the beginning of each line. As a result, low-frequency microphonics, introduced in preceding picture stages, are eliminated. Further, the circuit permits designing the picture amplifier so that it is flat only down to line frequency. Space limitations prevented the use of the clamp circuit in the BLOCK camera; however, a leveling circuit providing many of its features was used instead. The chief difference between the leveling and clamp circuits is that the leveling circuit employs the amplifier output tube instead of a separate diode, and depends for its operation on the time constant of a resistance-capacitance network located in the grid circuit.

Radar signals proved to be one of the most disturbing types of interference. The radar frequency was sometimes very close to that of the television receiver, and the power used, particularly in the larger radar installations, produced an interfering signal that could easily over-ride the 20-watt signal from the television transmitter. In the first BLOCK receivers, a high-impedance, resistance-capacitance filter circuit was used in the a-v-c section. While this provided the greatest immunity from noise and other random disturbances, in the presence of large amounts of signal such as accompanied radar interference, sufficient grid current flowed to bias i-f stages to cutoff. The time constant of the filters was long compared to the duration of a line, so that considerable degradation of the picture resulted.

It was observed that while the amplitude of the radar signal was large, the energy content was small. This characteristic was used to improve the operation of the a-v-c circuit. Under normal conditions, the a-v-c voltage is determined by the amplitude of the synchronizing pulses appearing at the output of the receiver second detector. Since the energy content of the synchronizing pulse is usually much greater than that of the radar pulses, it was possible to change the constants of the a-v-c circuit so that it operated to an extent on signal energy rather than on peak amplitude. This circuit, known as the low-impedance a-v-c circuit, permitted satisfactory operation of the receiver under radar-interference conditions at least 100 times as severe as formerly possible. A still further improvement was made possible by introducing pulses from the horizontal output circuit into the a-v-c circuit in such a way that signals could reach the a-v-c detector only during a short interval which was slightly greater than that required by the horizontal synchronizing pulse. This keyed a-v-c circuit prevented interference from affecting the operation of the automatic volume control during the interval the picture was transmitted.

Figures 98 and 99 show the pertinent part of the BLOCK receiver a-v-c circuit before and after low impedance automatic volume control was incorporated. The time constants in the grid-return circuits were reduced to approximately three microseconds. The d-c resistance of the a-v-c circuit was reduced approximately 40 times, so that the voltage developed across the resistance of the circuit, due to the sum of all the grid currents, would be small. The circuit was then by-passed with a one-microfarad capacitor to provide filtering for video frequencies.

In early BLOCK receivers, the second half of the 6H6 second-detector tube was used as a clipper to limit the magnitude of noise or interference peaks. When interfering pulses of large amplitude were received, the clipper was biased by the rectified current through it so that the cathode became more positive, thus closing the gate and preventing the desired as well as the undesired signals from passing through. This disadvantage was overcome in the modification by the use of a-c coupling between the second detector and the clipper, and by using low values of resistance in the clipper circuits (Figure 100). Thus, the direct current developed through the clipper, by the interfering pulses, could not change the bias of the clipper enough to impair its operation.

During tests conducted in Florida, radar interference did not prove objectionable with the modified receiver. The usefulness of the circuit was further proved when a receiver incorporating the modification was demonstrated to the NDRC Committee at the RCA Manufacturing plant in Camden on February 13, 1943.

For this test, the input leads to both the modified receiver and a standard receiver were connected in parallel. A four-microsecond, one-volt pulse at the carrier frequency was applied at a repetition rate of 2000 cycles together with a video-modulated carrier wave to both receivers. The voltage of the television signal had to be increased at least 40 times to give approximately the same interference ratio on the standard receiver as on the modified receiver. The pictures on both receivers would tear out at the edges over small portions of the picture. However, the results were considered satisfactory for the purpose. The new receiver held in synchronism while the video signal was reduced to approximately 500 microvolts.

To prevent the interfering signal in the receiver from attaining an amplitude greater than the desired signal, adequate clipping or limiting was provided. The multiple clipping circuit requires the addition of the 6H6 tube second-limiter clipper to supply voltage to the synchronizing separator. This clipper is adjusted to clip at the peaks of the synchronizing pulses, or preferably below these peaks on strong signals.

As previously stated, in the standard receiver a clipper limits the noise peaks to approximately the amplitude of the synchronizing pulses. This limiter, however, cannot be set at the peaks of the synchronizing pulses, or motorboating in the a-v-c system will occur. The second clipper is provided, therefore, to limit the peaks of noise to the amplitude of the synchronizing pulses. Since the a-v-c does not hold the signal absolutely constant, the clipper is adjusted to limit the synchronizing pulses as well as the noise pulses on strong signals. On weak signals, it limits the amplitude of the noise pulses to that of the synchronizing pulses. Voltage appearing at the synchronizing separator will then contain no noise pulses of greater amplitude than the desired synchronizing pulses.

Tearing out at the edges of the picture is reduced considerably by the multiple clipping circuit (Figure 101). The repetition rate of interfering pulses can approach the frequency of the synchronizing pulses to within less than one per cent before the interference ratio is markedly decreased.

A demonstration was made at Princeton before the NDRC Committee. The circuit was arranged so that the clipper could be switched in and out of the circuit. The interference was increased to a point where the receiver, equipped with low impedance automatic volume control circuits, would not synchronize. When the second clipper was switched in, the receiver synchronized properly and the picture was acceptable.

Another effect of noise and interference was to disturb the synchronization of the picture at the receiver, resulting in many cases in a loss of much more intelligence than caused by the actual presence of interference in the picture.

A fundamental difficulty with the first BLOCK equipment was scanning oscillator instability. Both the vertical and horizontal scanning oscillators were cathode-coupled multivibrators whose frequencies were a function of a large number of variables including the supply voltage, ambient temperature and all the resistors and capacitors in the feedback circuit. These oscillators were used because they produced wave shapes which served directly for blanking and synchronizing. Many other types of relaxation oscillators were tried in an effort to find one with better frequency stability, but none exhibited stability comparable to that of the sine wave oscillator. The sine wave oscillator, therefore, was finally used, and relatively simple circuits were developed to produce the necessary blanking and synchronizing pulses from the sine wave of the oscillator. The oscillator was of the inductance-capacity type with an adjustable powdered iron-core for tuning the circuit to the proper frequency.

The addition of automatic-frequency-control circuits to receivers incorporating low-impedance a-v-c circuits improved the picture quality of the receiver. The a-f-c circuits provided a means for integrating the received synchronizing pulses over a long period of time, thus providing immunity from noise. When receiving weak signals with this circuit, the edges of the picture did not tear out as readily, and the detail of the picture was improved.

It is obvious that if an independently stabilized deflection circuit in the receiver is to provide satisfactory synchronization over any period of time, the frequency of the transmitted synchronizing pulses must be constant. In the original camera equipment, the line scanning frequency varied during vertical scanning due to cross-modulation between the circuits. This was not serious with the synchronizing system then in use at the receiver. However, when the a-f-c system was employed, the edges of the picture were displaced an intolerable amount. The solution was to stabilize the horizontal and vertical oscillators in the camera, in the same manner.

In stabilizing the horizontal oscillator either of two methods could be employed. A tuned circuit could be made a part of the pulse oscillator, or the pulse oscillator could be synchronized by the signal obtained from a separate oscillator. The first method introduced a slight ripple on the horizontal axis, although, this could be reduced so that it was not objectionable. The second method required an additional tube. Both resistance-capacitance and inductance capacitance oscillators were tried. The oscillator utilizing the inductance was preferred as it was more stable. An adjustable, powdered

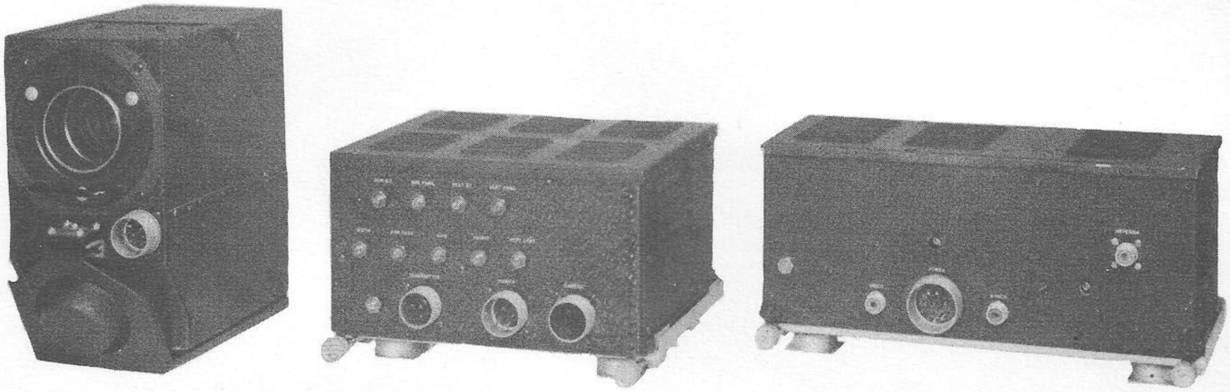


Figure 95. The Compact BLOCK Equipment. Left to right are the Camera, Camera Control Unit, and the Transmitter.

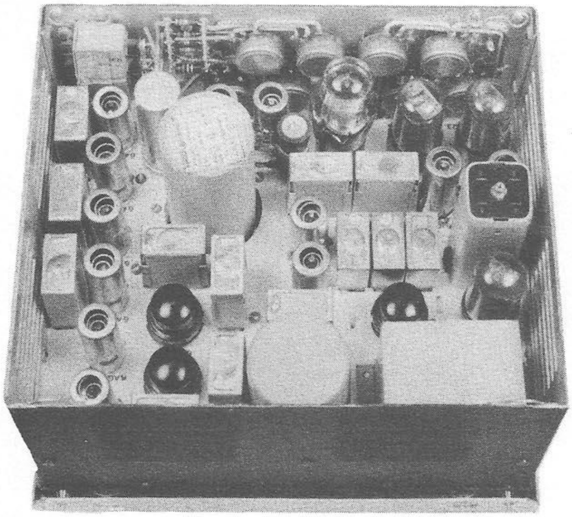


Figure 96. Interior View of the Compact Camera Control Unit.

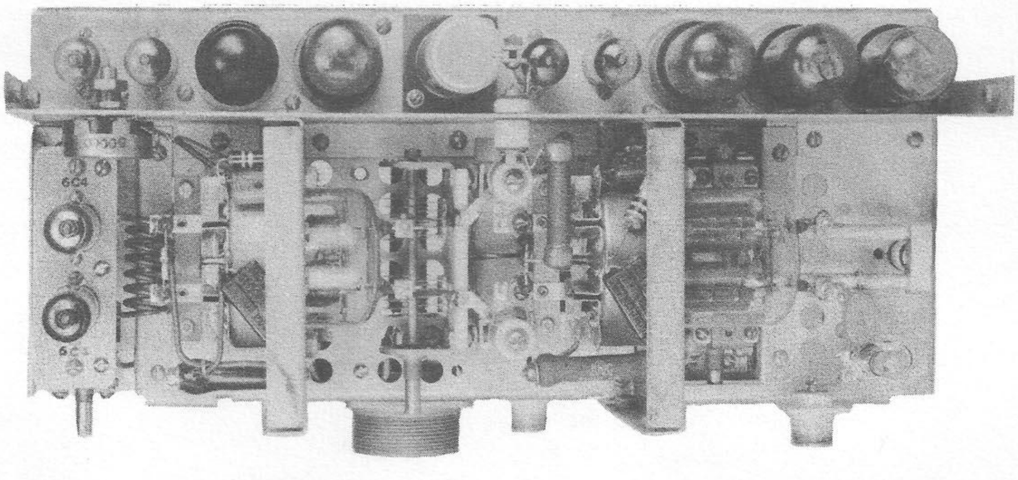


Figure 97. An Interior View of the Compact Transmitter.

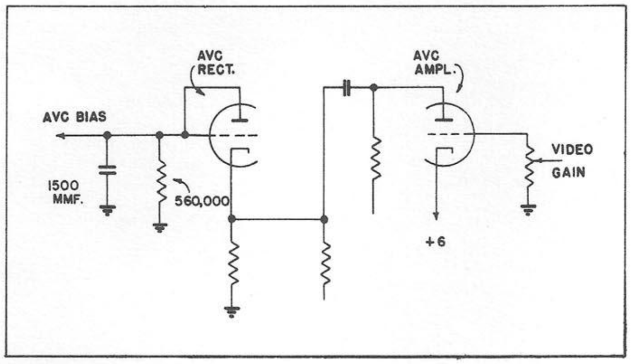


Figure 98. Original High-Impedance A-V-C Circuit of the BLOCK III-A Receiver.

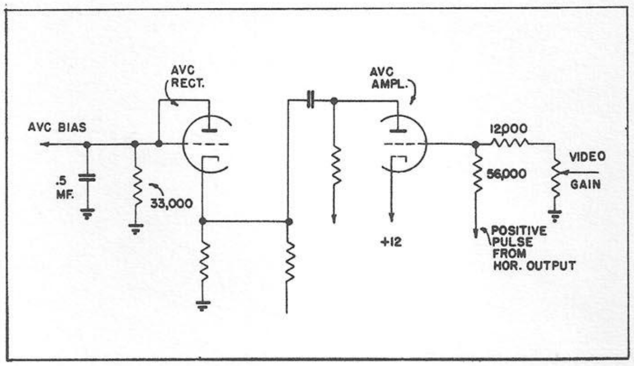


Figure 99. The Revised Low-Impedance Circuit. Keyed a-v-c action was obtained by applying positive pulses to the biased a-v-c amplifier.

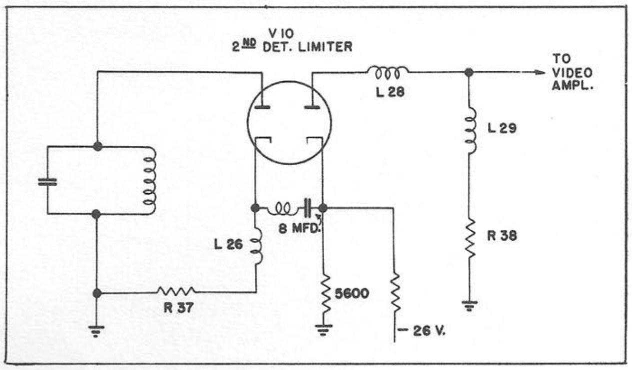


Figure 100. A Circuit for Improving the Operation of the Clipper.

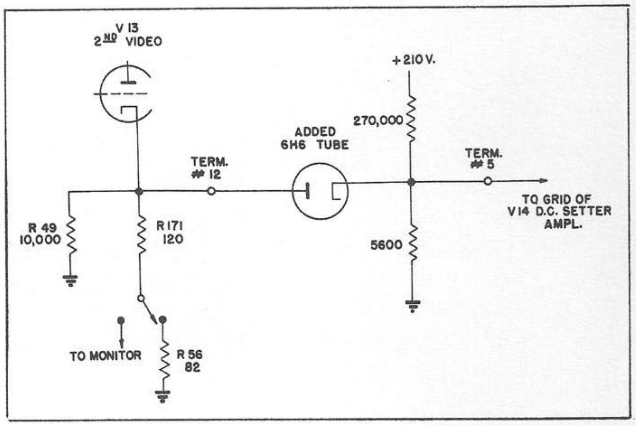


Figure 101. Multiple Clipping.

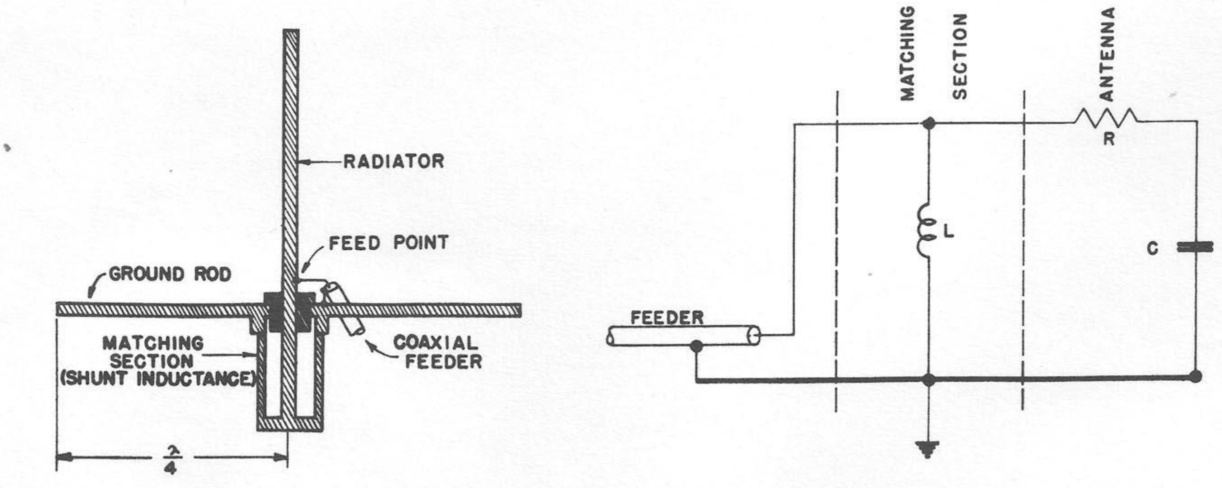


Figure 102. Schematic of the BLOCK Antenna and its Equivalent Circuit. Two quarter-wave rods at the base of the radiator produced an artificial ground plane.

iron core served for tuning the circuit to the required frequency.

The vertical pulse oscillator was stabilized by an r-c oscillator, since the size of the coil and capacitor required for an inductance-capacitance oscillator was prohibitive.

Beside the additional tubes required, the a-f-c circuit had at least one disadvantage, in that, when a-f-c circuits were used to control the vertical deflection, it was very difficult to eliminate an unsteadiness or vertical bounce in the picture due to power supply variations.

The circuit was demonstrated to the NDRC Committee at the same time the low-impedance a-v-c system was demonstrated. The receiver held in synchronism with signals as low as two hundred microvolts together with the one-volt interfering pulse described. This represented a ratio of interference-to-signal of five-thousand-to-one.

A number of flight tests were made to determine the relative value of the l-i-a-v-c and a-f-c circuits. A camera-transmitter was located on the roof of Building Six at Camden, New Jersey, with a directional antenna aimed at Atlantic City. Flights were made in an AT-11 plane which was equipped with two receivers, one of which was a standard BLOCK I receiver, and the other a receiver equipped with the improved circuit. The route taken was a round trip from Wings Field over Camden to Atlantic City. Near Camden, the effects of reflection due to the bridge and other tall structures could be observed, and toward the coast the effects of radar and other types of interference were present.

In summarizing the results of these tests to determine what modifications were desirable in future production, account was taken in each case of the complexity of the new circuit and the additional parts required. Since the equipment was designed for use in aircraft, small size and light weight were primary requirements. Obviously, circuit simplicity was desirable as a time-saver in production as well as in servicing the equipment.

The order of preference in the circuits discussed was as follows: The l-i-a-v-c circuits, (2) the l-i-a-v-c circuits with multiple clipping, and (3) the l-i-a-v-c circuits with automatic frequency control.

It was estimated that probably 75 per cent of the advantages obtained by the more complicated circuits were obtained with the l-i-a-v-c circuits. These circuits did not require extensive rewiring of the standard receiver.

By adding a-f-c to the l-i-a-v-c circuits, the receiver's susceptibility to interference was decreased by perhaps another 25 per cent. The picture quality was also improved. However, for military purposes, it was believed that the complication in circuits, additional tubes, etc., more than offset the increase in picture quality and improvement in operation through interference.

The performance with multiple clipping plus l-i-a-v-c circuits almost equalled the performance with a-f-c circuits, except at very low signal levels.

With a carrier output of about 15 watts, the BLOCK I aircraft television transmitter provided a reliable operating range of approximately ten miles. Reception at greater distance was possible, but the signal was usually lost with a change in the position of the plane. An increase in the range was desirable, and since any appreciable increase in the transmitter would necessitate a larger and heavier transmitter, it was decided to first improve the signal-to-noise ratio of the receiver.

Thus, a new type r-f tuner was developed for the receiver. This tuner gave an improvement in signal-to-noise ratio of at least two-to-one over previous circuits, and increased the effective range of the transmitter to at least 25 miles. A push-pull r-f stage employing RCA-6J4's was included which considerably improved the r-f selectivity and prevented excessive oscillator radiation. Flight tests made with receivers in which the new tuner had been installed, showed considerable improvement in selectivity as well as sensitivity. It was possible by slight tuning to eliminate or greatly reduce interference. This was, of course, impossible with the earlier fixed-tuned receivers.

Mechanical failure was the chief difficulty encountered in the use of early BLOCK I antennas. As a result of severe vibration, the ground rods crystallized at the clamp and then broke off. Steel instead of aluminum was used in later antennas. The structure was so small that increased weight with the use of steel met no objection.

A series of transmitting antennas for the ten channels used in BLOCK III equipment was designed (Figure 102). These antennas, identical except for overall dimensions, utilized parasitic reflectors. The radiator, reflector, and ground rods were all of either copper- or silver-plated steel tubing, having an eliptical cross-section to reduce wind resistance. The matching section was made of round, steel tubing, the inner and outer conductors being fastened together at the base with screws. All other metal parts were brazed together, making a sturdy, solid unit.

In checking production models of the BLOCK III transmitting antennas, it was found that the impedance-change taking place when an antenna designed for the nominal center frequency in one channel was operated on the center frequency of the channel above, was in most cases less than ten per cent. However, the impedance deviation to the next lower channel was greater, and the antenna would not operate satisfactorily. This seemed to offer a possibility for reducing the number of transmitting antennas required for several adjacent channels.

A study of the broad-banding effect obtained by increasing the diameter of the radiating element, however, led to the development of an antenna which covered the entire frequency range of BLOCK III. The radiator, approximately eight inches long, was made of airfoil steel tubing, the eliptical cross-section measuring 4 inches by 1 3/4 inches (Figure 103). The bandwidth characteristics are shown in Figure 104. Measurements of horizontal directivity showed substantially constant radiation in all directions. The polar plot of the vertical pattern is shown in Figure 105.

Requests were made by NDRC for two special BLOCK antennas, one for 100-megacycle operation and the other for 300 megacycles. The antenna which was to be used for transmitting from an experimental fighter, was to project straight out the rear of the ship's tail, using the tail structure as a ground system. An accurate mock-up of the tip of the fuselage was made from plywood covered with copper, and a special antenna was designed. The cadmium-plated, steel radiator projected from a short-circuited quarter-wave section of concentric line which served as a rugged mechanical support. The radiation resistance measured about 140 ohms, hence a 100-ohm series matching section was required to couple the antenna to the 72-ohm transmission line. The matching section is the small tube mounted along the side of the large quarter-wave section as shown in Figure 107. The rugged construction used was intended to withstand stresses and vibration anticipated at a flying speed of 700 miles per hour in a power dive.

The antenna when flight tested gave good and unexpected results. Though it was designed to radiate a vertically polarized signal while the plane was diving, it apparently produced a vertically polarized wave even when the plane was in level flight and the antenna horizontal.

A vertical receiving antenna was always used, and plane-to-ground reception was found to be consistent over distances of 65 miles, regardless of the aspect of the plane. It was thought that the close proximity of the plane's rudder and stabilizer orientated the polarization of the radiated signal.

In wide contrast to the illumination on the ground, scenes observed from an airplane during daylight hours are very often characterized by an extremely high light-level and low contrast, caused by either moisture or smoke in the atmosphere. This further complicates the problem of adjusting the camera equipment on the ground for satisfactory performance in the air.

The test bench equipment, developed for adjusting the camera-transmitter unit, greatly improved the performance. Another development was an a-v-c circuit which automatically changed the gain of the video amplifier as a function of the Iconoscope output, eliminating the manual gain control and increasing the reliability of operation under varying conditions of incident illumination. The design of such a circuit was difficult because of the spurious signal delivered by the Iconoscope. The circuit was used in the Compact BLOCK equipment and in some of the Orthicon cameras.

A much more compact video amplifier was made possible by the use of RCA 6AG5 miniature pentodes to replace 6AC7 and 6SH7 video amplifier tubes previously used (Figure 108). Frequency compensation was then obtained by means of small capacitors bypassing the cathode resistor, thus eliminating all the peaking coils. The lower gain per stage due to low frequency degeneration required the use of more stages, but this was more than compensated for by the saving in space. In fact, it permitted the addition of an r-f buffer in the BLOCK III transmitter without increasing the size of the transmitter (Figures 109 and 110).

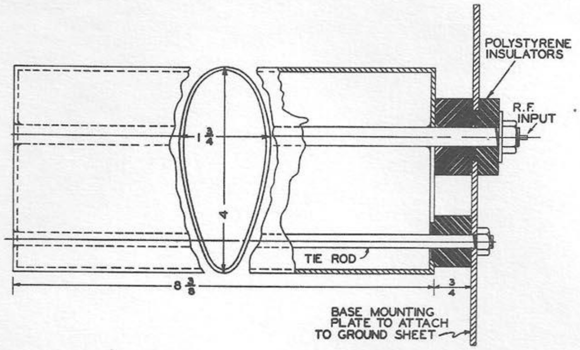


Figure 103. Cross-Sectional Drawing of the Special Broad-Band Antenna.

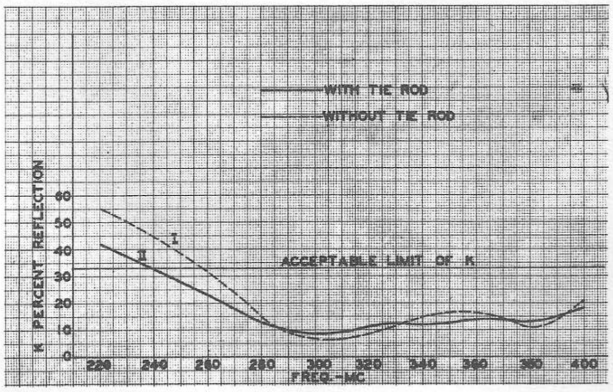


Figure 104. Bandwidth Characteristics of the Antenna.

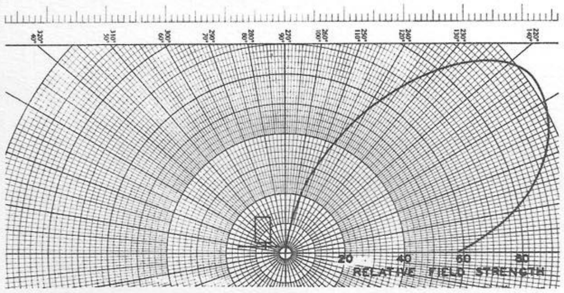


Figure 105. Vertical Directivity Pattern of Wide-Band Antenna.

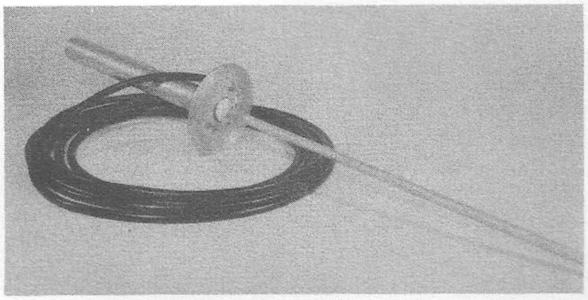


Figure 106. A "Skin"-Type Antenna, Used on Metal Aircraft.

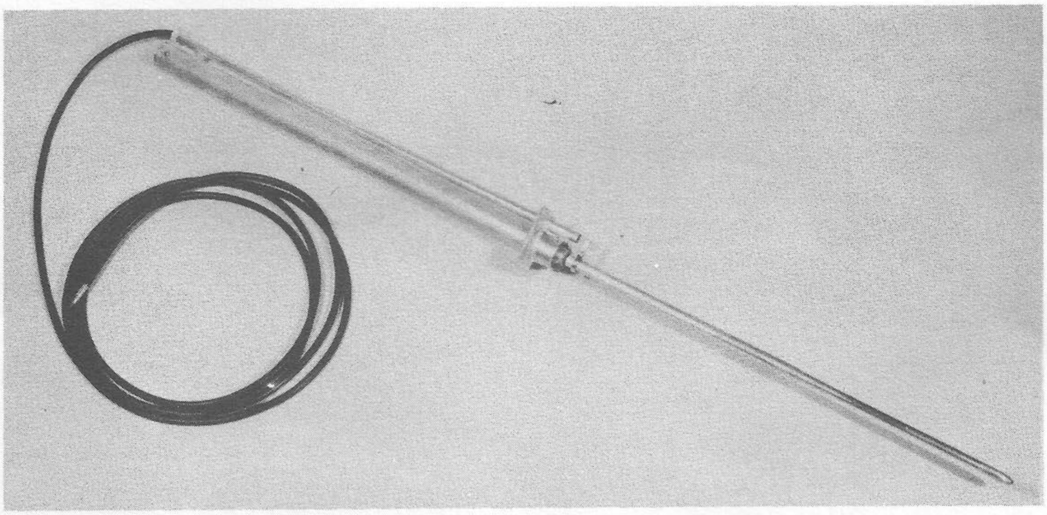


Figure 107. The Special Transmitting Antenna Made for Use in Fighter Planes.

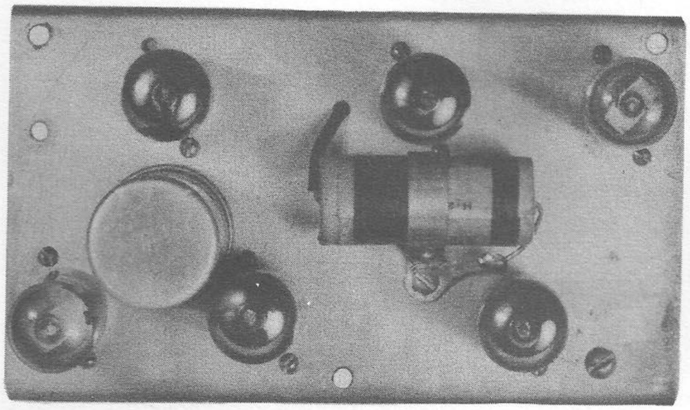


Figure 108. A Compact Video Amplifier made possible by the Use of RCA Miniature 6AG5 Tubes.

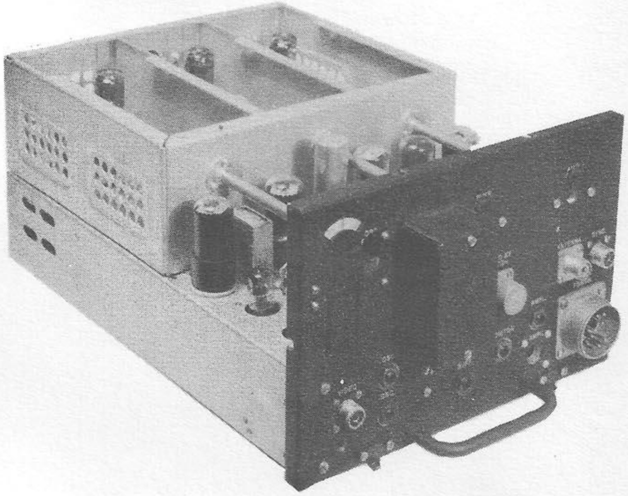


Figure 109. The BLOCK III-BB Transmitter. Use of miniature tubes and the elimination of peaking coils and electrolytic cathode by-pass capacitors saved enough space for the addition of an r-f buffer.

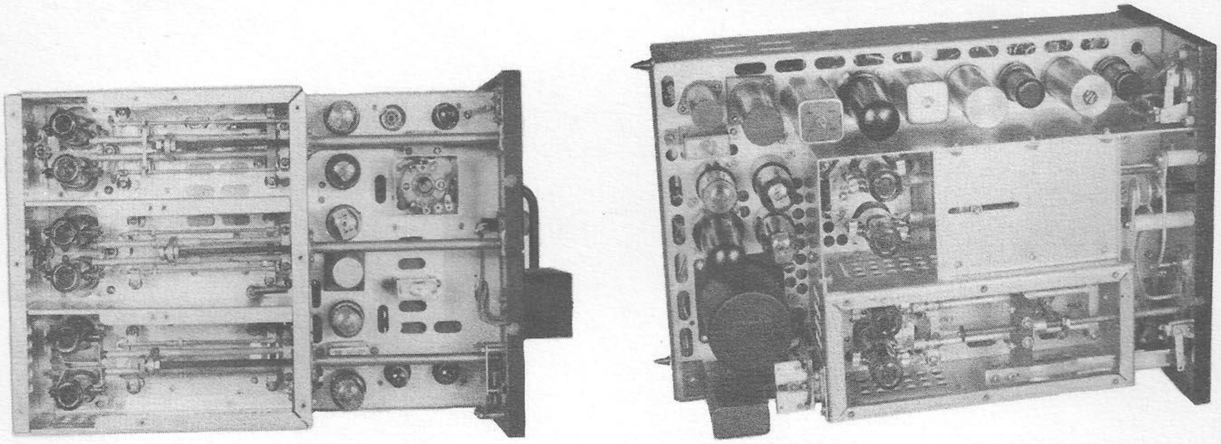


Figure 110. An Interior View of the BLOCK III-BB Transmitter (Left). For Comparison, the BLOCK III-A Transmitter is also shown.