Army Television Research and Development

By WILLIAM A. HUBER
and RICHARD B. LE VINO

Military TV application requires equipment with technical and operational characteristics that differ from those found in industry. To produce such equipment the U.S. Army Signal Research and Development Laboratory conducts a comprehensive research and development program that embraces all phases of the art. A technical survey of this activity is given, indicating those technological limitations that now exist and are seriously impeding the military applications of television as well as the developed and proposed methods of solution.

The U.S. Army Signal Research and Development Laboratory, Fort Monmouth, N.J., has cognizance of all television research and development activities in the Army and conducts a comprehensive television research and development program. Work carried on by scientists at USASRDL and various commercial engineering facilities, laboratories and universities throughout the country contributes to this program. Research is directed toward those technological limitations that now exist and seriously impede practical application of television to pertinent military requirements.

One example is that of reconnaissance applications in which the TV camera, transmitter, and associated equipment must be as small, lightweight, and efficient as possible for operation in the restricted space of a small aircraft or drone. This equipment must be designed for unattended operation and must include automatic data encoders and remote control facilities which can be operated from a receiving location.

Any complexity in a military TV system of this type must be incorporated in the receiving equipment where power and space requirements are generally not so stringent, in contrast to commercial broadcasting systems where it is usually preferable to engineer complexities into the transmitting equipment because of the relatively few transmitters as compared to the large number of receivers, and the availability of trained personnel for operation and maintenance.

Among technological advances made in military television as a result of Signal Corps research and development activities is the development of a military image-orthicon camera. Military TV reconnaissance application demands an image-orthicon type of camera because of resolution and light sensitivity requirements. Physically, the available image-orthicon cameras were too large and heavy and their power requirements were too high for reconnaissance application. It was, therefore, necessary to develop a military image-orthicon camera.

Presented on October 7, 1957, at the Society's Convention at Philadelphia by William A. Huber (who read the paper), U.S. Army Signal Research and Development Laboratory, Ft. Monmouth, N.J., and Richard B. Le Vino, formerly with the USASRDL, now at Smith-Corona, Inc., Product Planning Dept., 701 Washington St., Syracuse, N.Y.
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Military TV Camera

An exposed view of the military television camera is shown in Fig. 1. Camera construction features a fold-out type of chassis which permits free access for servicing. The typical camera functional units such as sync generator, deflection circuits, video amplifier, and power supply are sectionalized on individual subchassis.

To facilitate initial manual adjustment and subsequent remote adjustment of the electrical functions of the camera, appropriate potentiometers are mounted in a separate control box. Remote adjustment of these functional controls is achieved by motors mounted at the rear of each potentiometer. The motors are energized through a separate radio control channel. The camera sync system is capable of operating as either a master or slave depending on the number of cameras used and their arrangement in the system. The output of the camera is designed for direct application to the transmitter and is capable of producing a video picture with a limiting resolution of 600 lines. A few of these cameras have been produced by The Austin Co. of New York.

Picture Synchronization

While conducting airborne-to-ground TV tests on an experimental reconnaissance system, it was noted that much pictorial information was lost, even within the normal operating range of the system, because of instability in the displayed picture. It was found that picture instability was due mainly to large fluctuations in the received sync signal, resulting from variations in the exposed radiation pattern from the transmitter. This was caused chiefly by alterations in the aircraft flight course. In commercial practice sync techniques

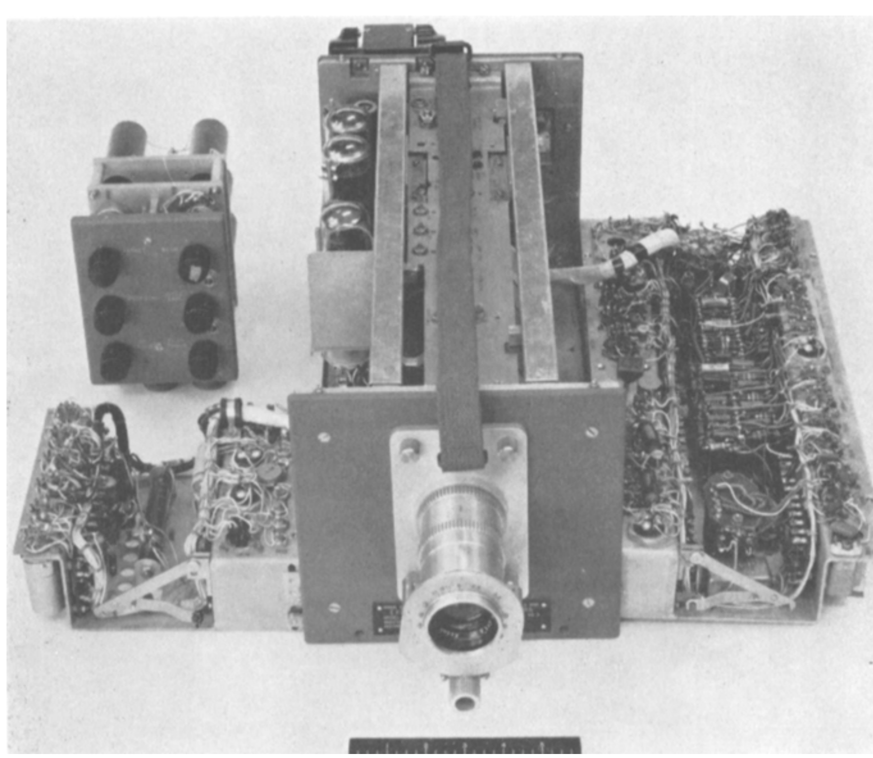

Fig. 1. Military image-orthicon camera.

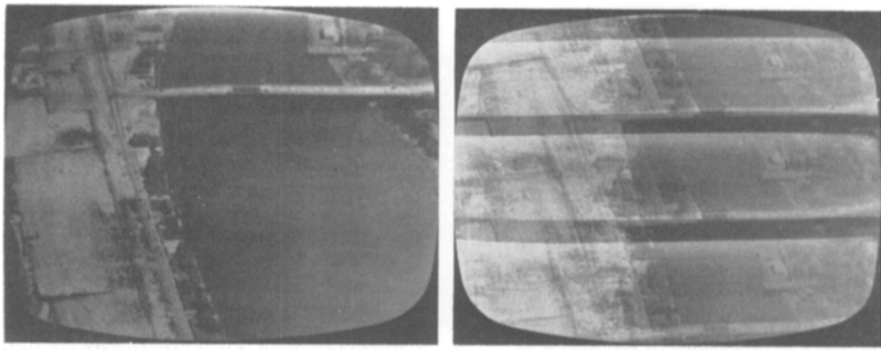

Fig. 2. Comparison data showing superior performance of lfs system (on the left) during poor signal conditions.

have been developed for fixed point-to-point operation.

These techniques generally rely on the stabilizing effects of a local oscillator having the short-term free-running stability of a one-frame period. In military applications where the transmitting, and possibly the receiving, locations are mobile, TV sync requirements demand a short-term free-running oscillator stability of many frame periods. This type of oscillator performance was obtained by the use of a local frequency stabilizer unit developed at USASRDL. This unit, generally referred to as an lfs unit, obtained its short-term free-running stability by means of a crystal oscillator which was electronically and mechanically controlled. Figure 2 illustrates the superior operation of the lfs system.

Stabilized Camera Mounting

Additional requirements for aerial reconnaissance are related to camera mounting, positioning, and stability with respect to aircraft motion. A research and development program was undertaken in cooperation with the Radio Corp. of America, Camden, N. J., for the study and subsequent development of such a camera mounting. As a result of this endeavor the stabilizer assembly shown in Fig. 3 was developed. This stabilized mount supports the TV camera in a clear plastic dome beneath the aircraft and provides positioning within a hemisphere by means of rotation about the train and elevation axis.

The motion can be controlled from within the aircraft, when used for attended operation, or from the ground receiving station when operated unattended. Stability against change of course, pitch or roll is effected along the respective axis. The degree of stability achieved during flight tests was $\pm 0.5°$ when the aircraft maneuvered at amplitudes of $\pm 15°$. The torque and control necessary to accomplish the required stability are obtained from a servo system integrated with the aiming system of the aircraft. The stability sensing for the camera mount is obtained from gyros.

Video Strobe Photographic Recorder

In order to take full advantage of the limited resolution capabilities of the television system it is customary to operate with a lens having as narrow an angle of view as is consistent with other operational requirements. In aerial reconnaissance applications this means that the displayed information is moving at a rate just below that which would produce distortion due to the scanning rate and lag characteristics of the TV system. This type of operational procedure, while useful, is not adequate for all observational requirements because of frequent need for a more extended view of a given area. If extended area viewing is desired it can be obtained by manual adjustment of the camera position through the remote-control system.

There are times when the importance of the information being televised is sufficient to warrant extended study beyond the time provided by manual camera panning. For these conditions a permanent record of the televised information is desirable.

To fulfill this military requirement, a video strobe photographic recorder was developed under a contract with RCA, Camden, N.J. This recorder is located at the receiving station and is operated by pushbutton control. Both single- and multiple-frame operation are provided by means of a function switch. Figure 4

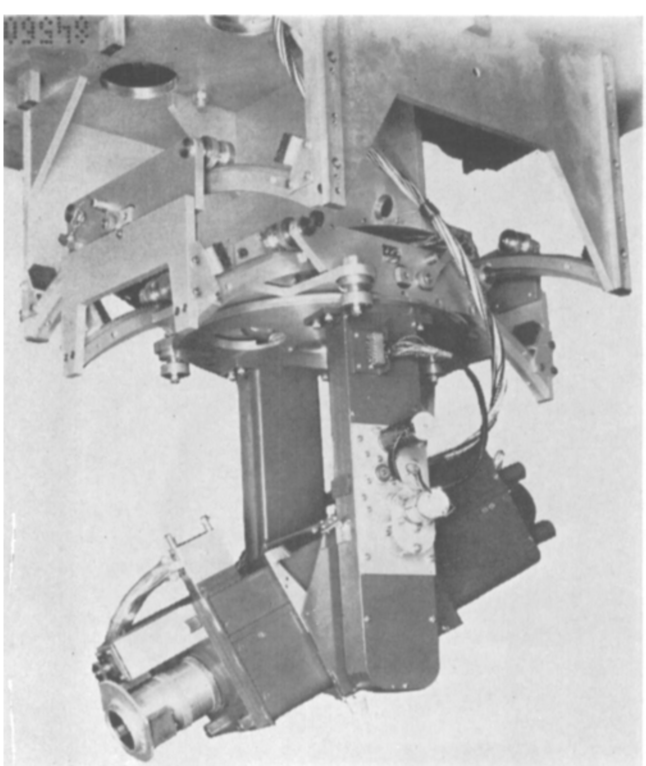

Fig. 3. Camera stabilizer assembly.

Fig. 4. Video strobe photographic recorder.

shows the pertinent components of the video-strobe photographic recorder. The TV picture is displayed on a 17-in. monitor and photographed with a modified Bell & Howell 35mm camera. This camera has a spring motor for film transport which has been provided with an automatic electric motor wind. The electrical circuits of the video strobe recorder are especially designed to provide maximum picture stability for photographing. Electrical gamma stretch controls are provided to assure optimum picture tone gradations. Either a positive or negative picture can be displayed. The multiple-picture recording rate can be adjusted between the limits of 1 to 6 pictures per second. Through the use of this multiple recording feature, and the forward motion of the aircraft, it is possible to obtain stereo effects from sequential photographs when appropriately viewed.

TV AM-FM Propagation Tests

In military television much engineering experience had been gained through the use of AM modulated transmitters and it was thought desirable to obtain comparative experience with FM modulated transmitters. Admiral Corp. of Chicago contracted for the development of corresponding AM and FM transmitters operating in the 780- to 900-mc region. This program made it possible to compare the operational performance of both systems under field conditions.

The transmitters were designed to utilize identical output-type tubes and to be approximately equal in size, weight and power input requirements. An AM modulated transmitter was developed which produced a black-level carrier power of 25 w while the companion FM modulated transmitter produced a carrier of 20 w. Engineering field tests were performed by USASRDL personnel to determine the relative merits of the two systems in actual field operation. These tests were conducted in the Ft. Monmouth, N.J., area and included operation of both transmitters simultaneously from an airborne Army H-19 Helicopter. Identical antennas were mounted on the underside of the helicopter for each transmitter, and identical video information was fed simultaneously to each modulator from a single TV camera.

The receiving station was housed in an Army Type M-109 vehicle and included an AM and FM receiver which had identical antennas, video amplifiers and display units. Various measuring and recording equipments were also available. The receiving station was powered by an Army Type PE-95 auxiliary power unit. Operational data were obtained by locating the receiving station at Monmouth County Airport, Belmar, N.J., and telecasting identical information over both transmitters as the helicopter proceeded from take-off to various

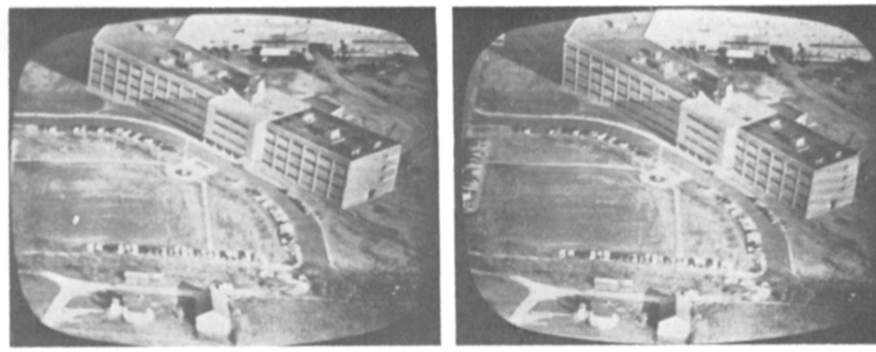

Fig. 5. Comparison data showing equal performance of FM system, on the left, and AM system on the right, for r-f range of 8 miles at an altitude of 1000 ft.

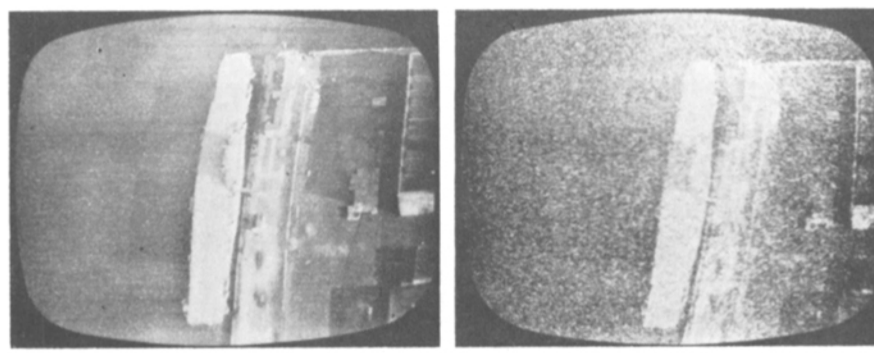

Fig. 6. Comparison data showing superior performance of FM system, on the left, and AM system on the right, for r-f range of 35 miles at an altitude of 3000 ft.

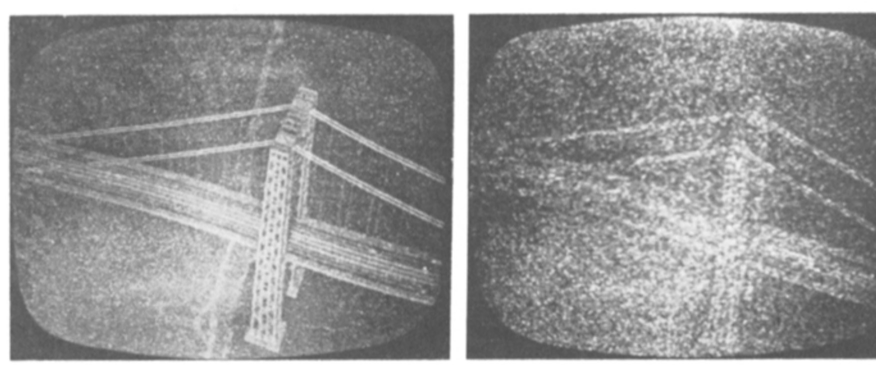

Fig. 7. Comparison data showing performance of FM system on the left, and AM system on the right, for r-f range of 50 miles at an altitude of 4000 ft.

ranges at specified altitudes. The AM and FM displays were mounted side by side and simultaneously photographed to obtain a record of the performance of each system. Figure 5 shows the front of the U.S. Army Signal Research and Development Laboratory at Ft. Monmouth. The photograph on the left was transmitted by FM carrier and that on the right by AM carrier. The r-f transmission distance for these data was 8 miles. The two systems seem to be about equal in performance.

This type of equivalent performance was consistently obtained throughout the tests for transmission ranges up to 10 miles. It should be noted that this series of pictures was transmitted with r-f carriers powered at 25 w or less and the complete system, including camera, transmitter and associated components, weighed about 125 lb. Figure 6 is an aerial view of an aircraft carrier docked in the New York area. Under these conditions of 35 miles range and 3000 ft altitude, the superiority of the FM transmission is evident. Figure 7 is a view of the George Washington Bridge from an altitude of 4000 ft and an r-f transmission range of 50 miles. While the FM picture shows the effects of attenuation by the presence of noise, it is still to be preferred over the AM picture. At a slightly extended range the FM signal dropped out completely while the AM signal was barely discernible. Only at this extended range was the AM signal superior but this was of little practical value because of the high noise content.

Military TV Systems

While many technical limitations have been overcome for the application of television techniques to the solution of

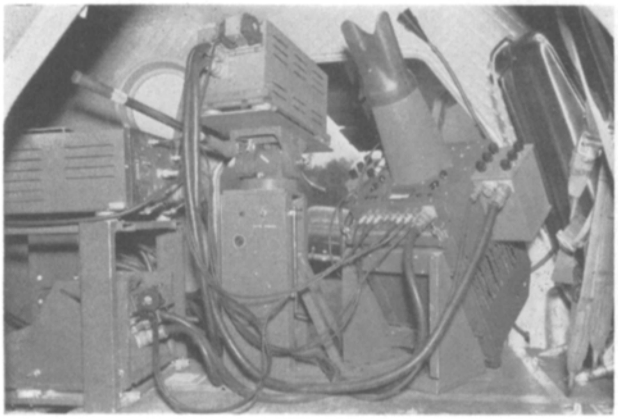

Fig. 8. Airborne installation of Army integrated "air-ground" TV system.

Fig. 9. Picture resulting from low-channel video transmission.

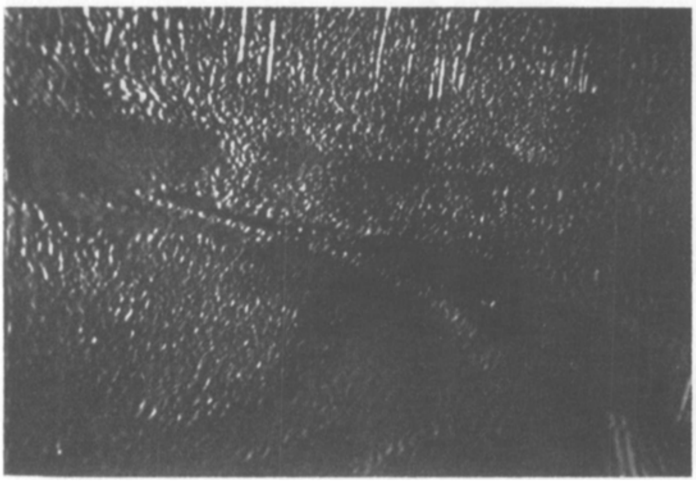

Fig. 10. Picture resulting from high-channel video transmission.

Fig. 11. Composite picture resulting from combined high- and low-channel video.

certain military problems, the improvements cited so far are related to equipment components and before their military value can be determined it is necessary to integrate the improved components into tactical operational systems. There follows a brief description of a few of these systems which are all experimental in nature and range in complexity from the portable Tele-Scout to the composite airborne and ground system which contains a multiplicity of vehicles for housing and transporting the equipment.

The transmitter of the Tele-Scout is strapped to the back leaving both hands free for operation of the camera. The equipment weighs 50 lb, and will operate for about two hours on one battery charge. The maximum range of the equipment is from one to two miles depending on the terrain.

The ground equipment of a more complex system called AG-2 consists of three complete integrated TV systems each capable of independent operation and mobility. Each of these ground systems has its own microwave relay link which provides extended ground coverage. The airborne portion of the integrated system developed at USASRDL is installed in an Army Type L-20 Aircraft. Figure 8 is an interior view of the aircraft with TV equipment installed. Equipment similar to that found in the AG-2 system but selected for pertinent operational requirements of the 101st Airborne Division has been integrated into a functional system that is now undergoing tests by that organization. All the above systems, with the exception of the airborne portions, were developed under contract with RCA.

To determine the feasibility of using TV as a visual aid for remotely controlled driving of a ground vehicle and the subsequent transmission of surveillance information from the vehicle back to the base station, an appropriate system was developed by contract by Allen B. Du Mont Laboratories. This equipment was experimental and designed specifically for field engineering investigation, the results of which established the practicability of using television as a visual sensor for remote ground vehicular driving. The practicability of using television for remote unattended surveillance was qualified to the extent that success of application depended on required angle of view, object size, object to background contrast and point of observation. The seriousness of r-f attenuation effects at UHF frequencies for signal propagation between ground-to-ground locations was evident throughout all these tests.

While all the above-mentioned systems are tactical in nature, the Signal Corps research and development programs have also extended into fields of TV instrumentation and psychological warfare.

Research

The scope of this program is basically that of equipment development and it has been timed for application to the present and immediate future military requirements. In order to fulfill military TV requirements beyond the immediate future it is necessary that the present Signal Corps activities also embrace a research program designed to satisfy these obligations. In recognition of this responsibility the Signal Corps is sponsoring a military TV research program at Denver Research Institute. This program is, in general, directed toward the development of techniques for improving radio-frequency spectrum utilization in military TV applications.

The program includes such activities

as: video signal quantizing, digital encoding and decoding, modulation techniques with emphasis on pulse code and quadrature carrier methods, transmission by radio-frequency spectrum dispersion, information theory, polarized r-f carrier applications, and video storage techniques. The motivating factor of this research and engineering investigation program is that military TV, in common with other services using electromagnetic radiation, is limited by the problem of finding adequate spectrum space at practical r-f carrier frequencies. The wide frequency band requirement of these services generally eliminates the possibility of using the already crowded VHF band. In some types of communication, such as low power ground-to-ground television, this is a distinct disadvantage due to the unfavorable propagation characteristics of the UHF frequencies under these terrain conditions.

A method has been suggested by the senior author for minimizing this difficulty by the employment of r-f spectrum dispersion. This method effects a frequency division of the wideband video information into separate channels with reduced frequency limits, and the subsequent transmission of this divided intelligence on multiple r-f carriers. By use of this technique there is the possibility of allotting the r-f carrier that is modulated with the low-frequency picture components, to a position of lower r-f frequency than would have been originally possible. Advantage is thereby taken of the superior propagation characteristics of lower r-f frequencies as carriers for the more important picture information; the less important picture information is transmitted at higher carrier frequencies.

Denver Research Institute has conducted several short-range tests by transmitting video analog information by spectrum dispersion. This was accomplished by developing a video band separation filter with a low channel bandpass of 15 cycles to 1 mc and a complementary high channel bandpass from 1 to 4 mc. This filter is inserted at the output of the camera to achieve the high and low video frequency band separation. Figure 9 shows a picture resulting from low channel video. The complementary picture resulting from the high channel video is shown in Fig. 10. Pre-emphasis of the high-frequency components can be readily applied to this signal. The information shown in Figs. 9 and 10 was transmitted over separate links and combined to form the composite picture shown in Fig. 11. While the above pictorial information was transmitted in analog form the technique can be readily adapted to digital signals.

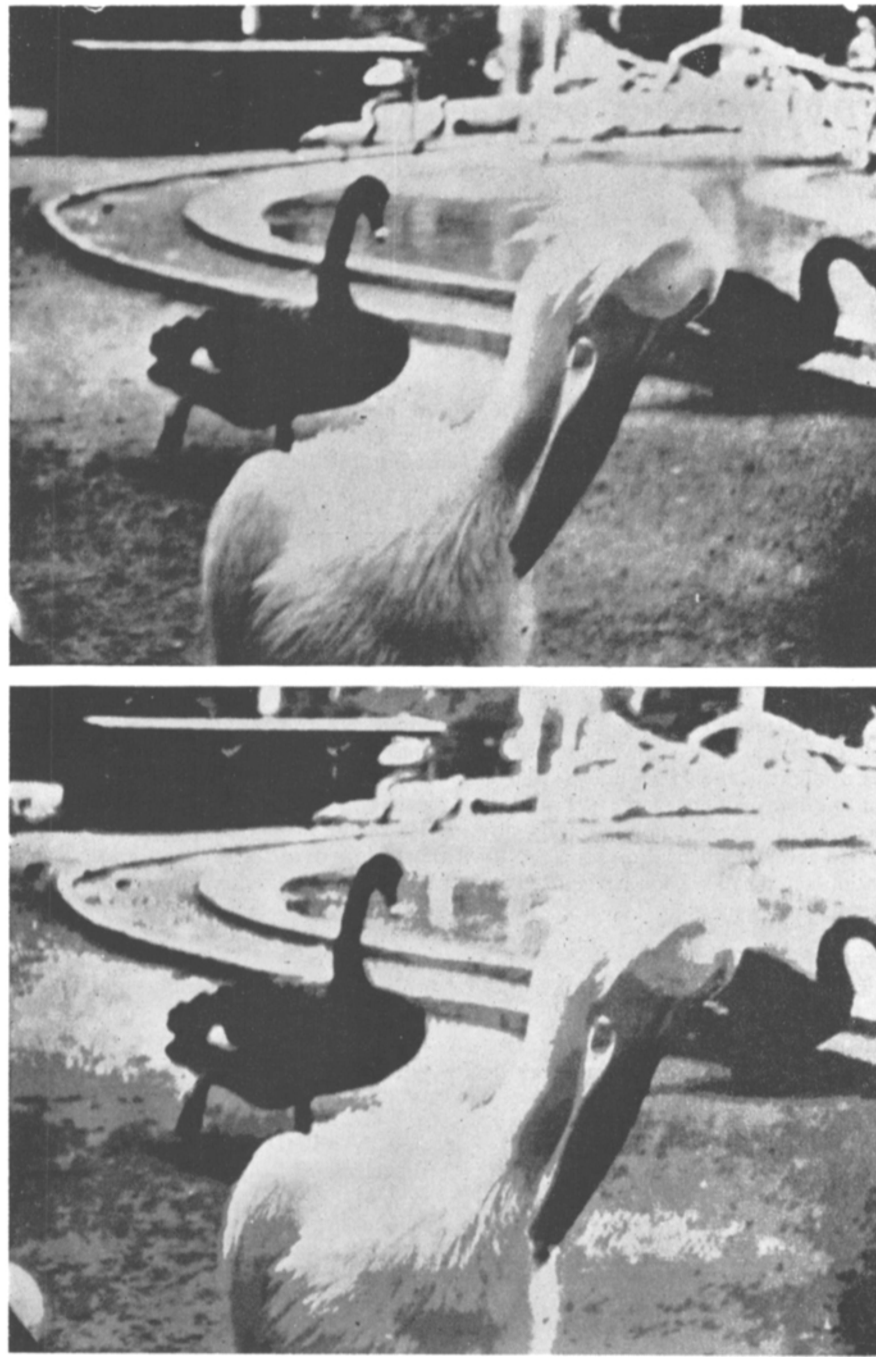

Fig 12. Comparative results of analog and 8-level quantized pictures transmitted with a 3-binary digital system.

Signal Corps-sponsored work at the Denver Research Institute in digital TV has resulted in the development of a television electronic binary encoder known as TEBE, the function of which is to process the original continuous video signal into that of a discrete binary digital form. Television signals processed by TEBE have been transmitted by pulse code modulation using three binary digits. It was found that pictures transmitted by three binary digits are adequate for many military applications. Figure 12 illustrates comparative results of analog and 8-level quantized pictures transmitted with a binary digital system.

Conclusion

This brief discussion has been concerned with reporting on present research and technological advances made in military television. We are confident that television will play an important role in future military activities. How soon this will come about and to what degree depends on to what extent future research and development are successful in overcoming present limitations on TV camera resolution and sensitivity and in achieving more efficient methods of transmission, reduction in equipment complexity, and increased system operational reliability.