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TEACHERS GUIDE for BUILDING AND OPERATING WEATHER SATELLITE GROUND STATIONS

FOR HIGH SCHOOL SCIENCE

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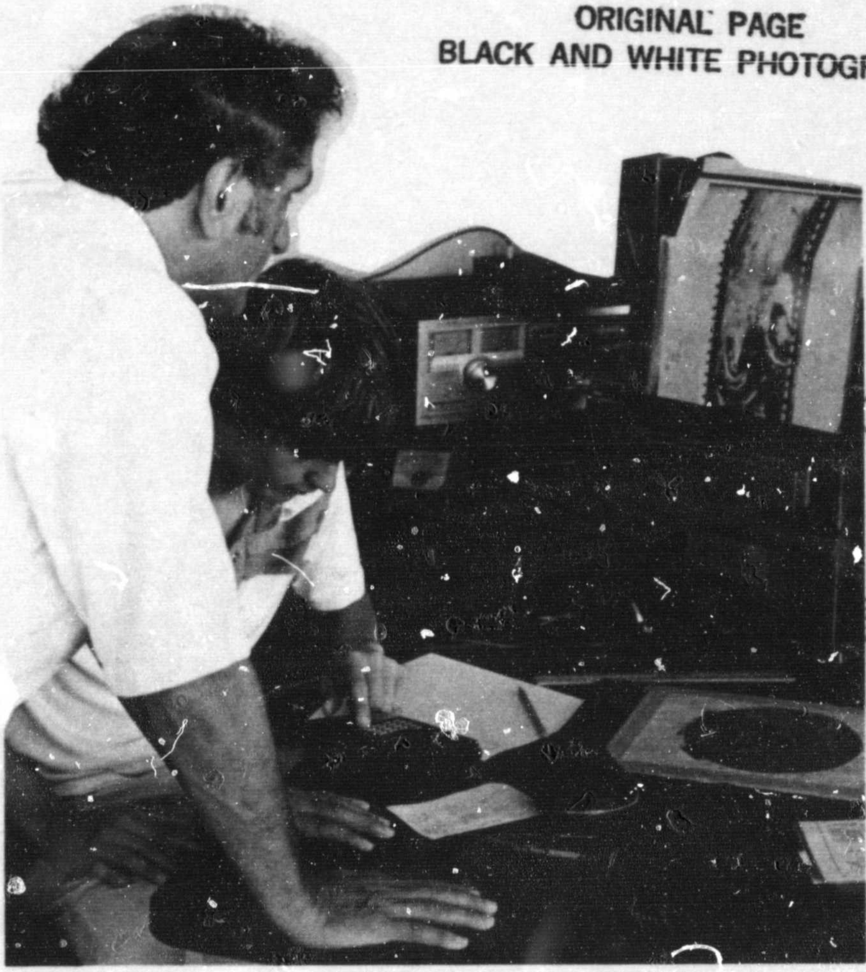

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TEACHERS GUIDE for
BUILDING AND OPERATING WEATHER SATELLITE GROUND STATIONS

FOR HIGH SCHOOL SCIENCE

by
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Chambersburg, PA 17201

Educational Programs Branch
Office of Public Affairs
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Greenbelt, MD 20771
1981

MEET THE AUTHORS

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R. Joe Summers is a graduate of Shippensburg State College, Pa., where he majored in Biology and General Science. He received a Master's Degree in Biological Science from Shippensburg and has done additional graduate work at Indiana University, Alfred University, and the Pennsylvania State University. He is presently teaching in the Science Department of the Chambersburg Area School District, Pennsylvania. Interests in electronics, space science and science education have led to the preparation of this publication involving weather satellites and their use in science education.

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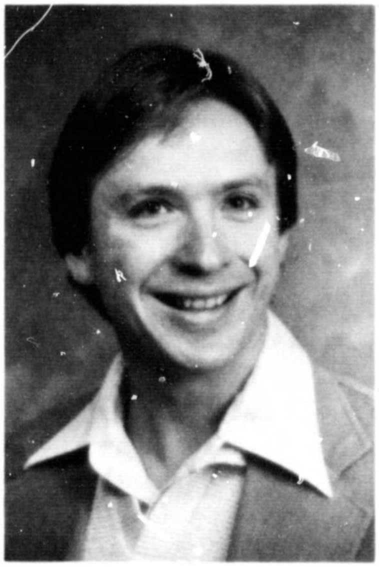

Timothy Gotwald

FOREWORD

This publication has been prepared in keeping with NASA's commitment to serve the public, and educators in particular, by providing for the widest possible dissemination of information based on its research and development activities.

The environmental/weather satellite program has its origins in the early days of the U.S. space program and is based on the cooperative efforts of the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA) and their predecessor agencies.

The information assembled here describes actual classroom experiences at the Chambersburg, PA, Area Senior High School. It represents a unique combination of aero-space research, technology and applications, providing actual experiences which will afford an insight into some of the most exciting activities of science and technology to come out of the space program. Hopefully, for many of the students, these activities may also provide a sampling of future careers.

In the preparation of this publication the cooperative efforts of NASA's technical and educational staffs, the faculty of the Chambersburg Area Senior High School and representatives of NOAA are acknowledged.

Since this publication is designed to serve as an instructor's manual for the construction of electronic equipment, brand names are cited in an attempt to help identify and locate items from readily available sources. However, this information is not to be construed as an advertisement or an endorsement of such items or their manufacturers.

WE WOULD LIKE TO HEAR FROM YOU!

The Educational Programs Office of the Goddard Space Flight Center would like to know of your activities and experiences in the use of this booklet.

If you would like to share your experience, or wish to contact other educators who are involved in this project, please send us a letter giving us permission to include your name, address, and telephone number on a master list of school users and builders.

The list will then be shared with your educational colleagues. By sharing your experiences and classroom activities all may further benefit and hopefully establish a unique national network of Weather Satellite Ground Station users.

Please direct your correspondence to Mr. Elva Bailey, Educational Programs Officer, Code 202, Goddard Space Flight Center, Greenbelt, Maryland 20771.

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I

Introduction

I. INTRODUCTION

Satellites, those marvellous inventions of the twenty-first century, provide us with a unique and long-sought opportunity to look at the Earth from space. These spacecraft now enable us to observe and measure the many forces of nature which converge in our planet. From the unique vantage point of space, sophisticated environmental/weather satellites bring us information about cloud formations and movements, temperature, ocean currents, air and water pollutants, droughts and flood conditions, — even volcanos and earthquakes. With the aid of ground stations, this information is then brought back to Earth where it can be plotted to arrive at more accurate weather forecasts to help us in planning our daily chores.

Many of these ground stations have direct and automated read-out facilities. Most popular among these are the Automatic Picture Transmission services (APT).

On October 13, 1978, TIROS-N, the first of a new series of United States polar-orbiting environmental satellites, was launched. NOAA-6, a twin of TIROS-N, followed on June 27, 1979. These two satellites represent the third generation of United States operational environmental satellites to offer several direct readout services. Most popular among these are the Automatic Picture Transmission (APT) services. There is also a series of Russian Meteor polar-orbiting satellites currently providing similar services.

APT images are real-time weather pictures transmitted from these satellites on a radio frequency in a video format. Amateur radio enthusiasts and electronic experimenters have for a number of years designed, built, and operated direct readout stations capable of receiving APT photographs. The equipment to receive these weather satellite pictures can be collected and/or built by individuals who do not have a high degree of technical training.

A number of colleges and universities are presently operating APT direct readout stations. However, high school science teachers have often failed to realize the potential of meteorological satellites and their products as unique instructional tools. The ability to receive daily pictures from these satellites offers exciting opportunities for secondary school teachers and students to assemble the electronic hardware and to view real-time pictures of earth from outer space.

The station and pictures can be used in the classroom to develop an approach to science teaching that could span many scientific disciplines and offer many opportunities for student research and participation in scientific processes. This can be accomplished with relatively small expenditures of funds for equipment. In most schools some of the equipment may already be available. Others can be constructed by teachers and/or students. Yet another source might be the purchase of used equipment from industry or through the government surplus channels. This publication will present the information necessary for individuals unfamiliar with these systems to construct a direct readout station for receiving real-time APT photographs on a daily basis in the classroom.

II

The Weather Satellite Automatic Picture Transmission System

II. THE WEATHER SATELLITE AUTOMATIC PICTURE TRANSMISSION SYSTEM

Satellite pictures received from early weather satellites were analyzed by U.S. Weather Bureau meteorologists, and the results, in the form of hand-drawn "neph analyses" (cloud depiction charts) were transmitted to major forecast centers throughout the United States and overseas. These charts, sent by conventional landline or radio facsimile circuits, often reached these centers too late to be of practical value in forecasting the weather. The Automatic Picture Transmission system was developed to help alleviate this problem by making it possible for forecast centers in any part of the world to receive satellite images in "real-time" — by direct readout — whenever an APT-equipped satellite passed within radio range of the receiving station.

The first APT system was pioneered on TIROS-VIII (Television Infrared Observation Satellite), launched in December 1963. Several U.S. weather offices were equipped to receive transmissions from this satellite, and plans for building relatively simple, low-cost ground receiving and display devices were widely distributed to foreign meteorological services. By 1965, radio amateurs ("hams") were designing stations for home reception and publishing design information in popular electronics magazines. Activity and interest in direct readout satellite data reception also permeated the academic community, in large part, perhaps, due to a series of articles by Professor H.R. Crane which appeared in 1968–1969 issues of *The Physics Teacher.*

Polar orbiting environmental satellites launched by the United States (TIROS-N series) and Russian (Meteor Series) are presently transmitting images of the earth and its weather systems via APT on frequency modulated (FM) frequencies between 137.3 and 137.62 MHz. The acquisition of facsimile pictures from these satellites is not restricted; therefore, anyone with the proper receiving and printing (display) equipment can receive these pictures on a daily basis.

At the receiving station, the APT signal is detected as an audible tone of 2400 Hz (the subcarrier) which is amplitude modulated (AM) to correspond to the light and dark areas seen by the detecting instrument on board the satellite. The louder portions of the tone represent the lighter areas of the picture and the lower volumes, the darker areas. Intermediate volumes produce various shades of gray.

On the new TIROS-N series satellites (TIROS-N and follow-on spacecraft) the APT pictures are produced by the Advanced Very High Resolution Radiometer (AVHRR). This instrument is a 4 channel (5 channel on later spacecraft) scanning radiometer sensitive to visible, near infrared and infrared spectra. The APT signal derived from the AVHRR consists of a multiplexed output of two selected channels of this instrument. The scan of the AVHRR is first converted to a digital format. The digital information is then converted to an analog signal which modulates a 2400 Hz subcarrier. This subcarrier is then frequency modulated on a VHF rf carrier and transmitted to ground stations.

The scan rate of the current APT is 120 lines per minute (2 lines per second). Because of the multiplexing of the two channels of the AVHRR, one-half of each scan line consists of data from one spectral channel (channel A) and the second half from another selected channel (channel B). Channel selection is determined by ground command from National Oceanic and Atmospheric Administration (NOAA). Therefore, the final product consists of two complete pictures, side by side, representing views of the same area of the earth in two different spectral bands (see Plate I).

The two Russian Meteor series satellites presently transmitting APT do not have this multiplexing and produce only one picture (see Plate II). The scan rate of 120 lines per minute is the same as the TIROS-N satellites and can be received and reproduced by the same method.

The APT from the polar-orbiting satellites is continuous, resulting in a strip of pictures (see Plate III). Radio reception of the signal, however, is limited to line-of-sight so that the ground station can only receive pictures from the satellite while it is above the ground station horizon. This is determined by the altitude of the satellite and the particular path the satellite follows during its orbit across the receiving station's reception range. The TIROS-N and Meteor series satellites presently in operation are at altitudes between 810 and 880 kms (488 and 544 miles). The maximum reception of the signal would be the duration of an overhead pass which will last for about fourteen minutes. During this time a ground station can receive a strip of pictures about 5800 km (3600 miles) long.

Reception of the signal is only the first stage of picture production. The audible signal (containing the video) must be fed into an appropriate line printing device before a photograph can be reproduced. It is also possible to tape record the signal and replay it into a printing device to produce additional photographs.

APT is only one function of polar-orbiting weather satellites. They also carry numerous other environmental sampling instruments which transmit data to earth by radio transmissions at other frequencies. Much of this data is transmitted in digital form and requires relatively expensive electronic processing to be meaningful.

The diagram in Figure 1 represents the components and connections of a completely functional direct readout station operated by students at the Chambersburg (Pennsylvania) Area Senior High School. The function of each component with suggestions on construction and/or obtaining these components will be discussed in this publication.

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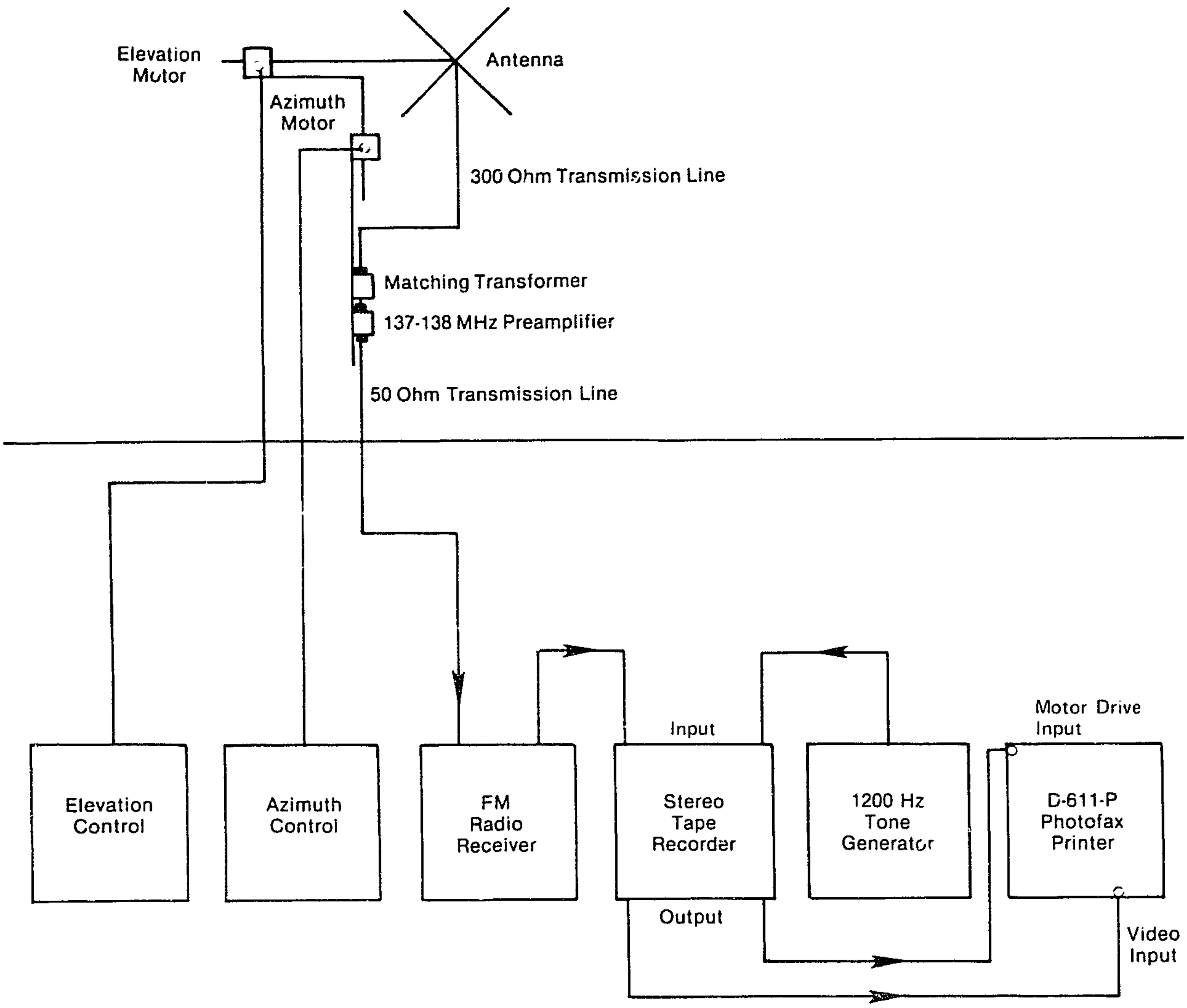

FIGURE 1
Components of APT Direct Readout Station Utilizing A- D-611-P Photofax Recorder

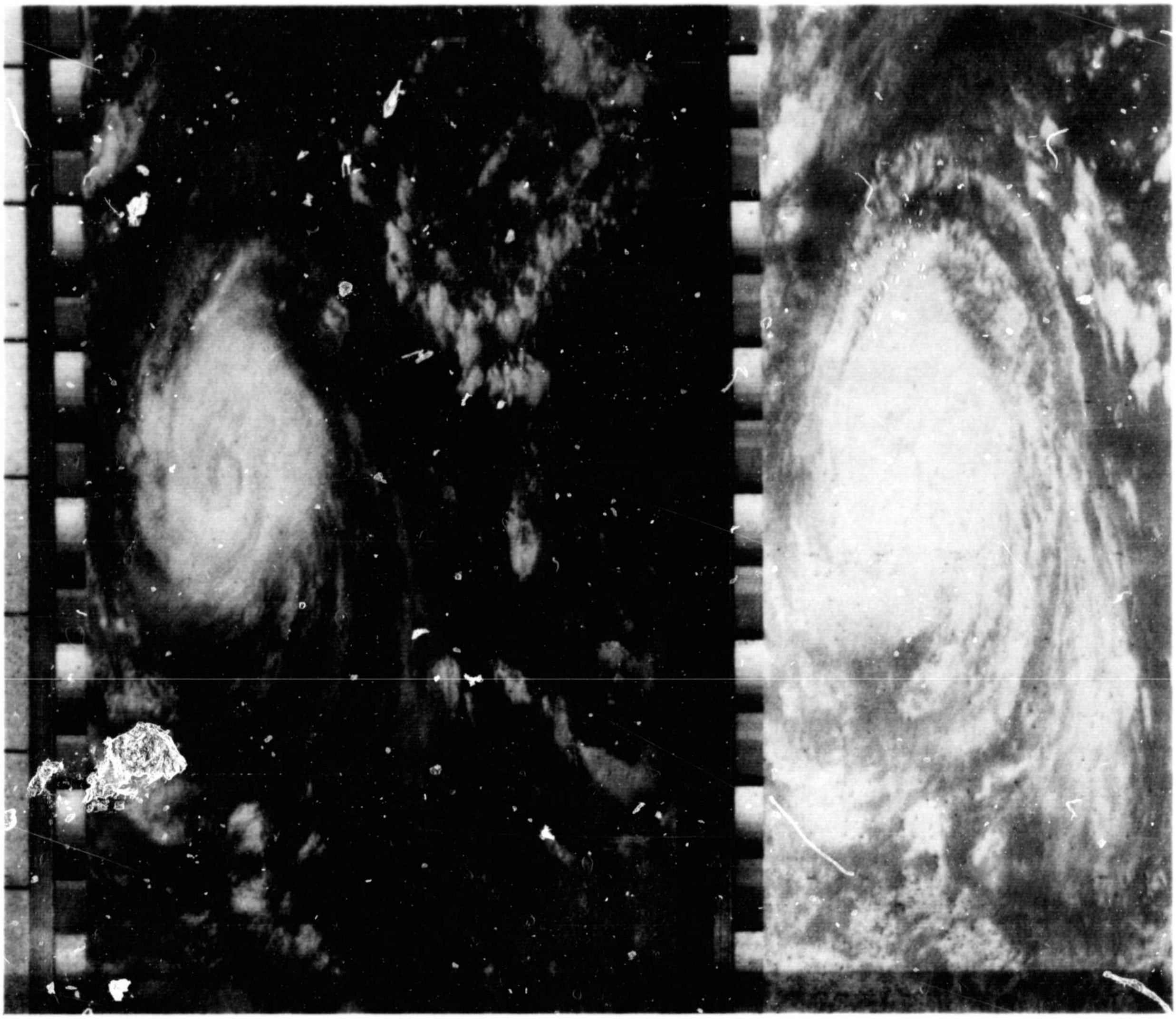

Plate I

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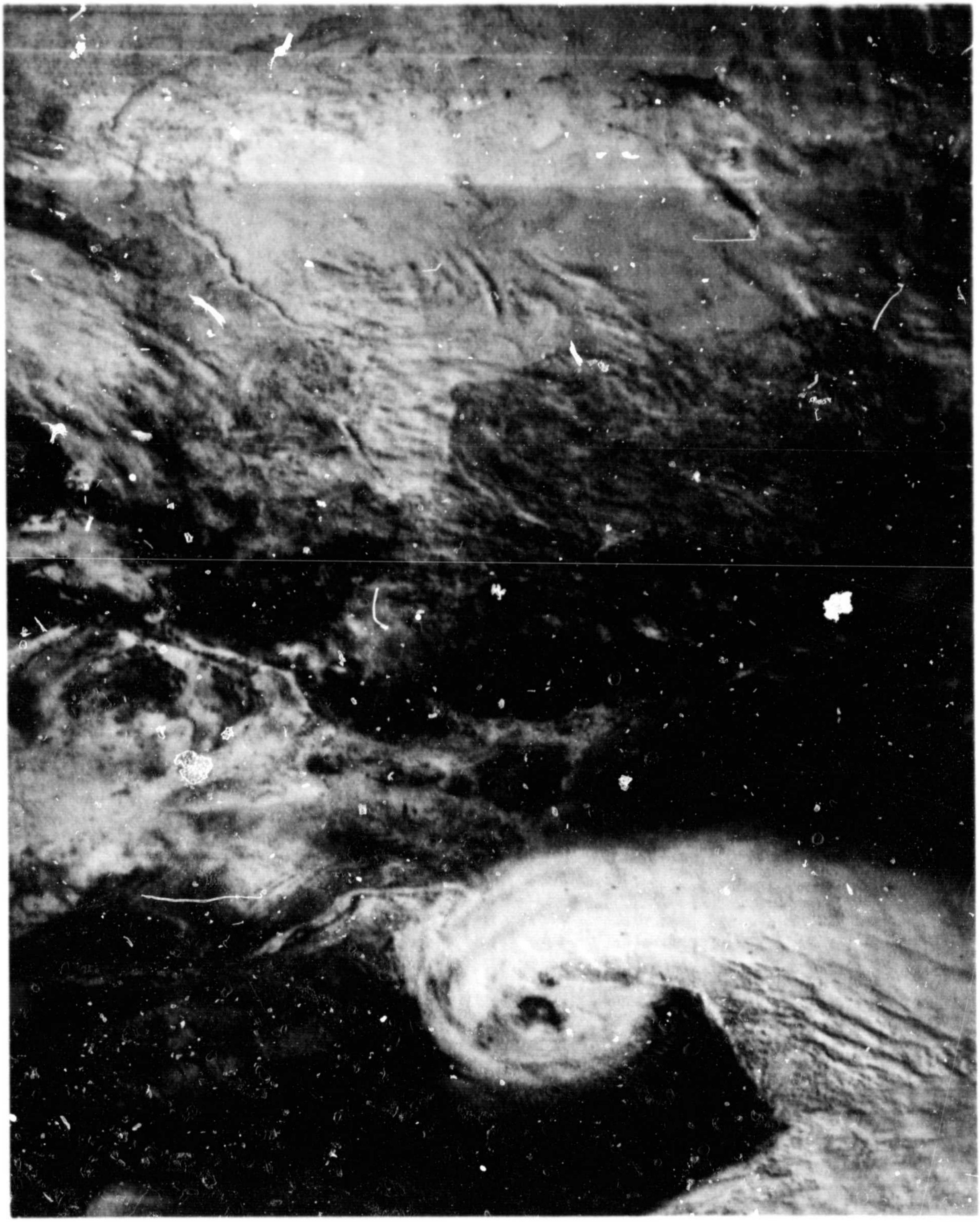

Plate II

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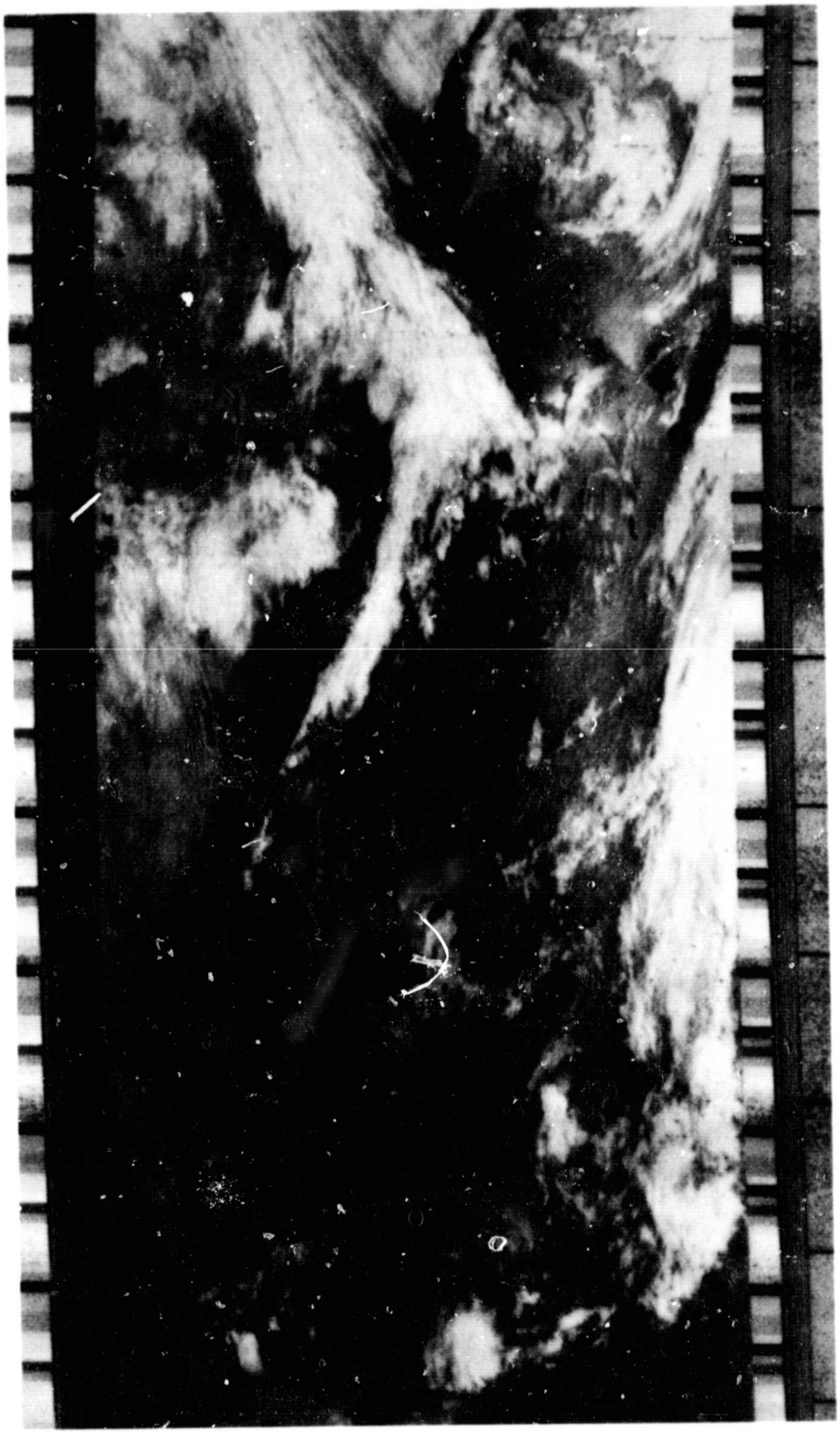


Plate III

III

General Description of a Direct Readout Station

III. GENERAL DESCRIPTION OF A DIRECT READOUT STATION

The antenna system used to receive APT imagery at the Chambersburg Area Senior High School is located on the roof of the building and is comprised of a ten-element, crossed yagi antenna mounted with two TV-type direction motors for adjusting the azimuth and elevation during satellite tracking. The transmission line from the antenna is a short section of 300 ohm, twin-lead TV wire which is connected from the antenna radiators to a 75 ohm transformer. A short section of 50 ohm coaxial cable is used to connect the transformer to a 137.5 MHz preamplifier. Both the transformer and the preamplifier are mounted on the antenna mast. Approximately 15.24 m (50 feet) of 50 ohm coaxial cable is used to transmit the rf signal from the preamplifier to a crystal controlled radio receiver capable of receiving FM radio signals in the 137-138 MHz frequency range. The azimuth and elevation motor control units are located with the other components of the station. Separate control wires are needed for each of the two motors. These wires enter the building with the 50 ohm coaxial cable connected to the radio receiver.

The APT video is detected by the FM radio and is passed from the radio output into channel one of a stereo tape recorder. At the same time, a synchronization tone, produced by a crystal-controlled 1200 Hz tone generator, is fed into channel two of the tape recorder.

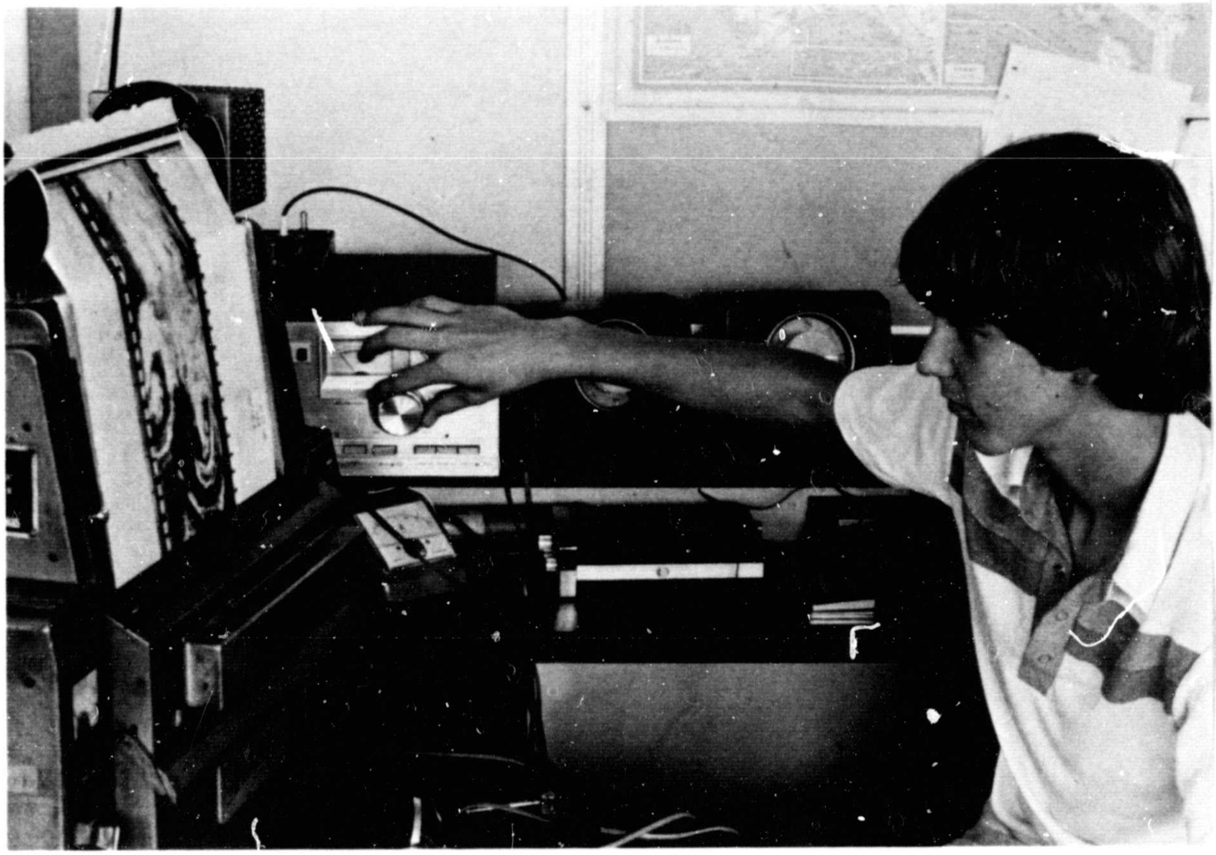
The output from channel one of the tape recorder is connected to the signal input of a D-611-P, AP Photofax facsimile recorder, which contains minor modifications. The output of channel two contains the synchronization tone necessary to operate the Photofax printer at the required 120 lines per minute to produce the picture. This is fed into the printer through a phono jack which is part of the modification on this component. All the connections between components are made with shielded cable.

When making a print during the satellite pass (real time), all the components are in operation. Later, the recorded video on channel one and the tone from channel two can be replayed into the printer for additional picture production.

NOTE: A slightly different arrangement is required when a K-550 facsimile recorder is used at this APT direct readout station. The modification and use of the K-550 is contained in section VI of this publication.

IV

The Antenna and Transmission System



IV. THE ANTENNA AND TRANSMISSION SYSTEM

A number of antennas are commercially produced that can be used for weather satellite reception. It is more practical, however, from an economic and instructional standpoint to construct this part of the APT direct readout station at the school. Antennas adequate for receiving pictures via APT do not have to be expensive or difficult to construct. Many high school industrial shops have the tools and equipment necessary for the construction requirements. Many students have the skills to do the work. With any efficient antenna, however, correct design and construction is necessary. Three design considerations are of primary importance:

1. The physical size of the antenna components is determined by the frequency of transmissions it is intended to receive. In most VHF antenna designs, the driven elements or radiating elements are designed at 1/4 or 1/2 wavelengths.
2. The antenna design should fit the type of rf signal polarization it is to receive.
3. The antenna needs to produce sufficient signal gain to produce noise-free reception whenever it is used with an appropriate radio receiver.

At the present time the two United States TIROS-N series satellites are transmitting APT at 137.5 and 137.62, and the two Russian Meteors at 137.3 MHz FM and 137.15 MHz with a transmitter power output of 5 watts. The rf signal is circularly polarized on the U.S. spacecraft and assumed to be on the Russian Meteors.

Considering the frequencies, signal strength, and polarization factors of the transmissions; a number of antenna designs can accomplish adequate reception when used in conjunction with a properly designed radio receiver. Information is available in numerous publications (i.e. ***ARRL Antenna Handbook***, Reference 3; ***The Weather Satellite Handbook***, Reference 26; ***The Radio Handbook***, Reference 18) which give details on construction of antennas for receiving radio signals from space. In these publications the helical antenna, the turnstile antenna, and the crossed yagi appear most often.

The crossed yagi is probably the antenna of choice in most "amateur constructed" APT stations. The crossed yagi described in this publication is currently in use at the Chambersburg Senior High School. (See Figure 2.) It functions well for APT reception, is relatively inexpen-

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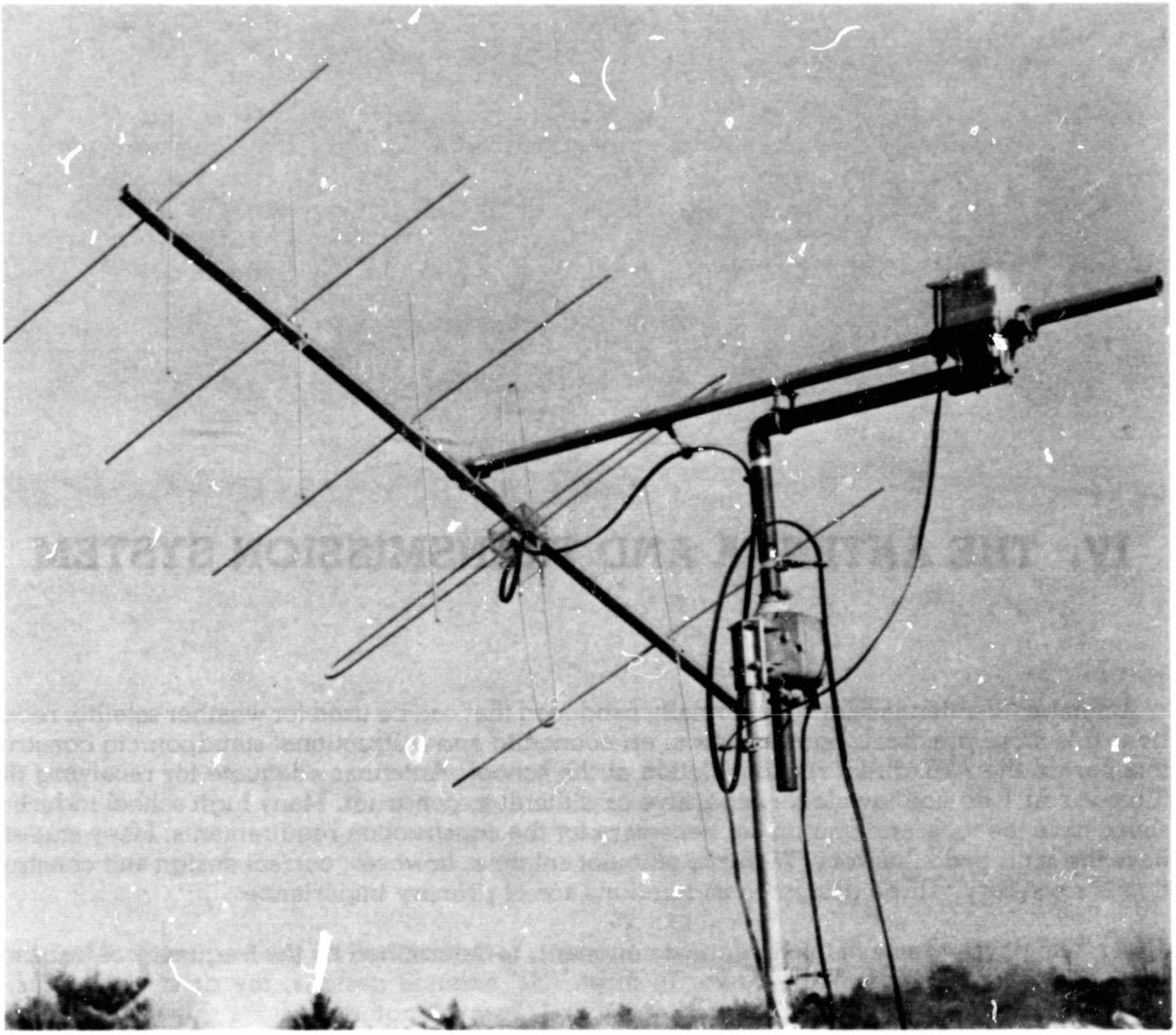

FIGURE 2
Crossed Yagi Antenna

sive, and is not difficult to construct. All materials needed should be easily obtained locally.

The crossed yagi is a directional, beam-type antenna comprised of a number of elements similar to a multi-element TV antenna. The major exception is that the elements are arranged at right angles to each other. This crossed element design eliminates fading of the circular polarized rf signal transmitted by the satellites. Because it is a directional beam design and in order to get maximum signal gain, the antenna must be pointed toward the satellite. This presents an additional problem.

Polar orbiting satellites are NOT stationary. They travel in paths that are generally either north to south (descending nodes) or south to north (ascending nodes). Following or tracking of the satellite by the antenna is therefore necessary. In the design given here, such tracking is accomplished by using two TV-type direction motors. One controls the elevation (angle above the horizon) of the antenna and the other controls the azimuth (compass direction) so that the satellite can be tracked at any elevation angle and direction as it passes within range of the receiving station. The beam width of this antenna is about ± 20 degrees which gives it sufficient width so that pinpoint accuracy is not necessary.

ANTENNA CONSTRUCTION

Figure 3a gives the spacing, arrangement, and physical dimensions of the one set of elements of the antenna pictured in Figure 2. An identical set of elements with the same dimensions and spacing are then arranged at right angles to the first set but located 5.1 cm (2 inches) behind them. This forms the crossed arrangement necessary for proper reception of circular polarized rf signals.

The main beam which supports the elements is made from a piece of 2.5 cm (1 inch) square aluminum tubing, 1.83 meters (six feet) long. The elements are cut from 9.5 mm (three-eights inch) diameter aluminum rods. These elements consist of three crossed sets of directors (D1, D2, D3). A pair of folded dipoles form the driven elements or radiators (RA) and a pair of reflectors (RE) are positioned behind the radiators. The length and spacing of all of these elements are dependent on the frequency that the antenna is designed to receive. All measurements given in Figure 3a were calculated for a frequency of 137.5 MHz by formulas published in the ***ARRL Handbook*** (Reference 3) for this type of antenna. The folded dipole radiators are similar to a design suggested in the ***Weather Satellite Handbook*** (Reference 26).

The first stage of construction requires measuring the correct spacing for the elements along the square beam. The first set of directors (D3) should be located about 12.7 cm (5 inches) from the end of the beam. The remaining element spacings should be drilled through both walls of the square beam. These holes should be as close to perpendicular as possible and centered on the flat surface. Another complete set of measurements and holes, following the same spacing as the first, should be marked and drilled. These, however, should be set 5.08 cm (two inches) behind the first and at RIGHT ANGLES to the first series. If possible, a drill press should be used. If the holes are correctly made, the aluminum rods should fit snugly.

The directors (D1, D2, D3) and reflectors (RE) offer no special problems. The aluminum rods forming these elements can be cut and pushed through the holes in the square beam so that they extend through the square equidistant on either side of the beam. There are a number of ways that these can be held in this position permanently. The simplest of these is to notch or crimp the rods on either side of the beam as close to the beam as possible using a large screwdriver and hammer. This will deform the rod enough so that it will not pass through the holes. Care should be exercised so that the rods are not bent!

The pair of radiators (RA) require a little more attention and care. The final design for one of the sets should look like the diagram in Figure 3b. This requires two rods 2.08 meters (82.1 inches) long and positioned through the holes marked "RA" in Figure 3a. These should be, one at a time, positioned so that they are centered and have equal extension on both sides of the square beam. The rods should then be crimped so that they retain their position. This rod is then bent 180 degrees at a point 50.9 cm (20.05 inches) from the center of the beam on both ends. A 3.8 cm (1.5 inch) wooden dowel can be held at this point and the rod bent around the dowel. Spacing between the two parallel portions of the dipole should be as close to 5.08 cm (two inches) as possible.

The open ends of this folded dipole are held in position by a plastic holder shown in Figure 4. This plastic insulator should be constructed from 6.4 mm (.25 inch) plastic sheet with 9.5 mm (3/8 inch) holes that will accept the open ends of the folded dipole. The ends of the dipole should be slid into the plastic holder first. Then the insulator should be drilled and mounted with metal screws on the flat portion of the beam. The second folded dipole, set at right angles to the first, is positioned in the same way. The final arrangement is shown in Figure 5.

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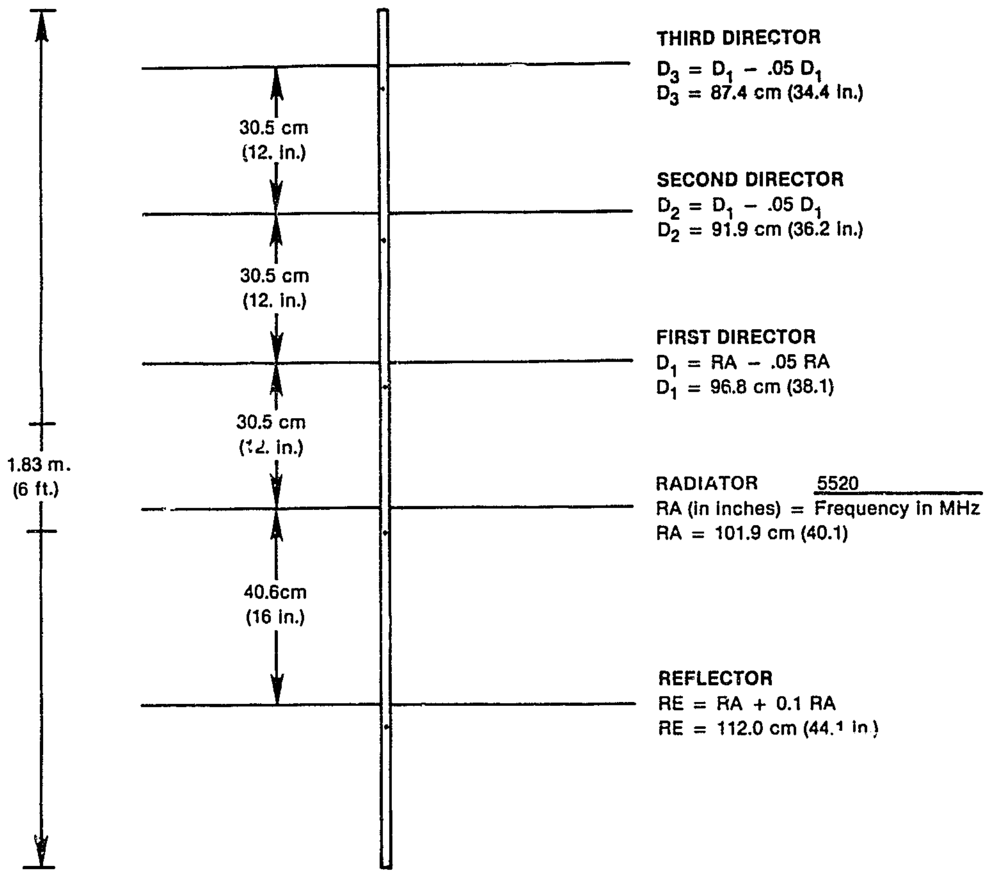

FIGURE 3a
Spacing, Arrangement and Dimensions of One Set of Elements of the Crossed Yagi Antenna

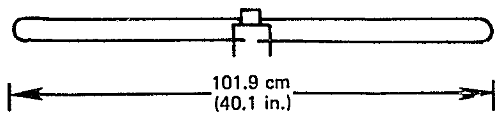

FIGURE 3b
The Design of One of the Radiators Shown in Figure 3a

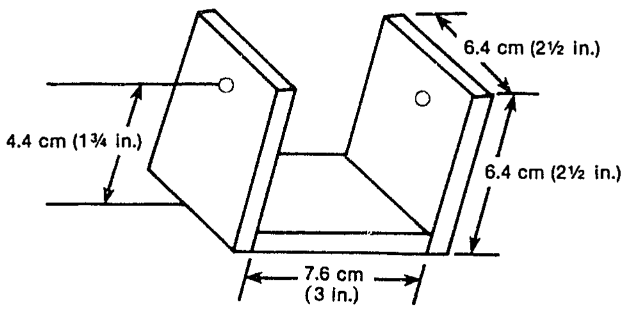

FIGURE 4
Plastic Insulator for Supporting Open Ends of Folded Dipole (Two Needed)

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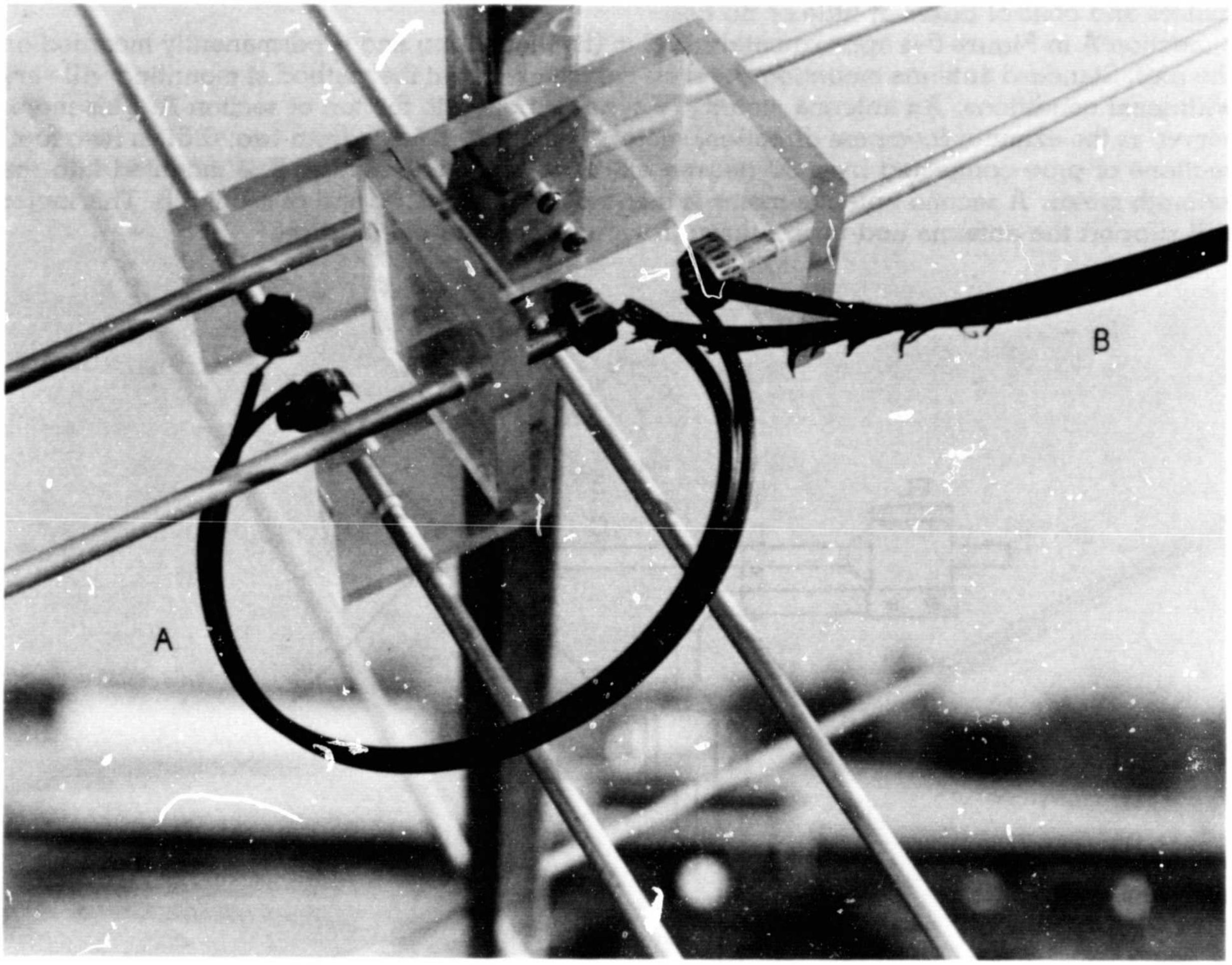

FIGURE 5
Plastic Holders Supporting Folded Dipoles

ANTENNA MOUNTING

The location of the antenna should be given careful consideration. If at all possible, it should be placed so that a clear view of the horizon is available in all directions. Consideration should also be given to a location where repairs and adjustments can easily be made. Long lead-in wires should be avoided. Generally, a flat roof of the school near the room where the electronic components are located would be best.

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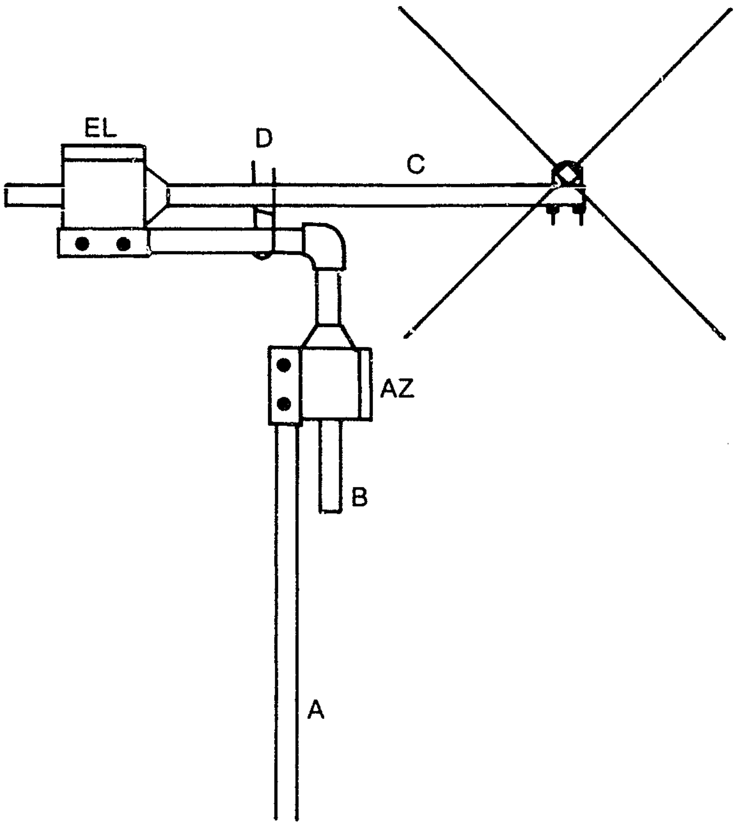
There are a number of mounting designs which allow azimuth and elevation antenna tracking of satellites. The design shown in Figure 6 is being used at this station.

Steel pipe 3.2 cm (1.25 inch) diameter was used for all mounting supports. It can be found at most plumbing supply houses or electronic stores which sell antennas. Sections of this pipe can often be found around the school at no cost. Also, a careful search may produce the antenna motors and control boxes at little or no cost.

Section A in Figure 6 is approximately 1.52 m (five feet) long and is permanently mounted on the roof. Standard antenna mounting brackets can be used, but the method of mounting will vary with local conditions. An antenna motor (TV-type) is bolted to the top of section A. This motor serves as the azimuth (compass direction) motor. Section B is made from two, 0.61 m (two foot) sections of pipe connected by a 90 degree elbow. One end of section B is mounted into the azimuth motor. A second antenna motor is then bolted to the other end of section B. This motor will support the antenna and turn it through various degrees of elevation.



A - 1.52 m (5 foot) section of mast pipe
B - Two, 0.61 m (2 foot) sections of mast pipe connected by a 90° elbow
C - 1.22 m (4 foot) section of mast or aluminum pipe
D - Support U-bolt
EL - Elevation motor
AZ - Azimuth motor

FIGURE 6
Antenna Mount Design

A third, 1.22 m (four foot) section of pipe (C), is mounted through the elevation motor. The antenna is mounted with U-bolts to the other end of section C. (See Figure 7). The antenna should be attached at its center of balance. This pipe (C) can then be slid through the antenna motor until the weight of the antenna and the weight of the elevation motor counterbalance each

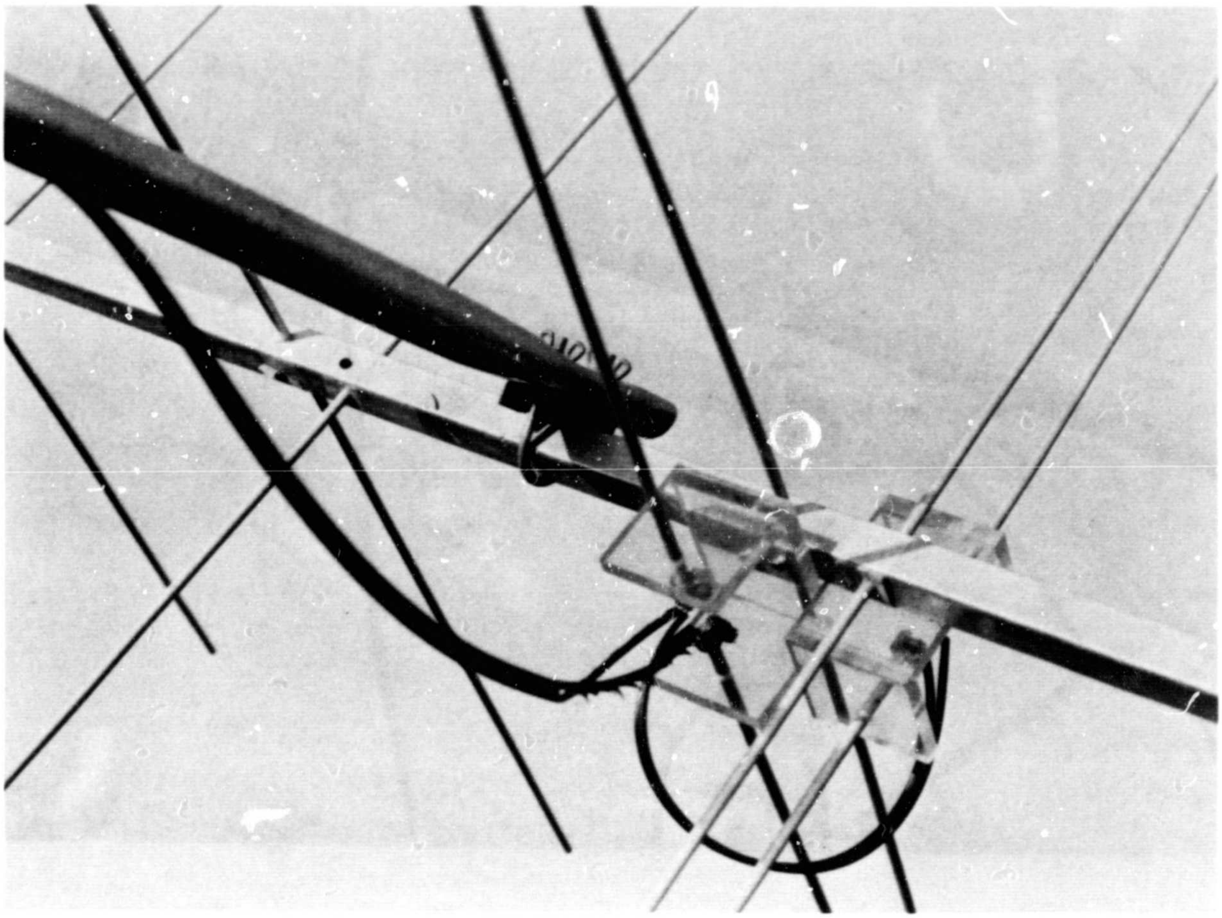


FIGURE 7
Antenna Details

other. A U-bolt with a supporting plate (D), is attached to C to support the weight of the antenna to take the stress off the bearings of the elevation motor. (See Figure 8).

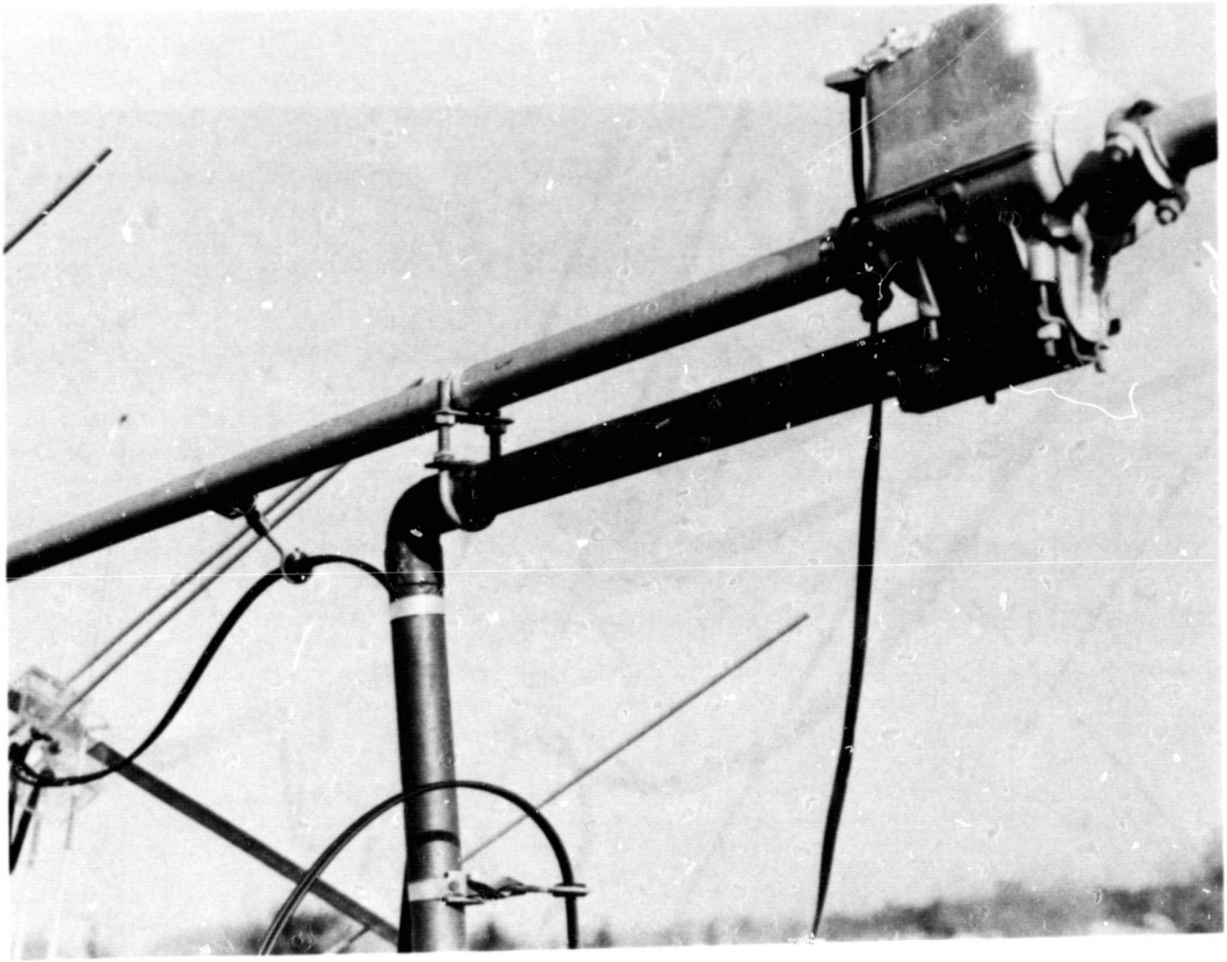


FIGURE 8
U-Bolt Support for Antenna

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CALIBRATION OF MOTORS AND CONTROL BOXES

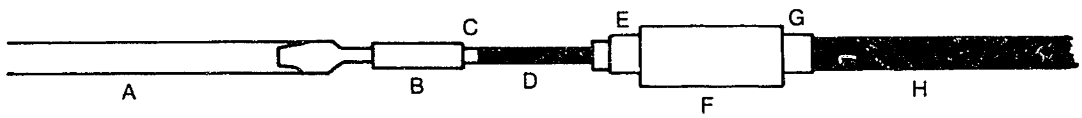
After mounting is completed, motor control wires should be run from each motor to separate control boxes. It is important to allow enough slack in the wires and wire standoffs, to permit the antenna to move freely in all directions. It is then necessary to calibrate the antenna azimuth and elevation directions so that the control indicators will give accurate representations of antenna directions.

To adjust the elevation of the antenna, rotate the control indicators of the elevation control box to the NORTH position. At the antenna, loosen the motor bolts of section C and rotate the antenna by hand until it points directly overhead and then retighten the bolts. NORTH on the control box will then represent 90 degrees of elevation. Whenever the control indicator is moved to the EAST position, the antenna should be level and pointing at the horizon. EAST will then be 0 degrees of elevation. A scale from 0 degrees to 90 degrees can be made and placed on the control box face between east and north which will give the operator the degrees to which the antenna is elevated.

The calibration of the azimuth (compass direction) is accomplished in a similar manner. First, the elevation control should be positioned to 0 degrees (EAST). Then the azimuth control box should be rotated to the NORTH position and the antenna rotated to the north position on the roof. Whenever the bolts of the azimuth motor are retightened, the compass directions of this control should be a true indication of the antenna's azimuth through 360 degrees. With this arrangement, it is possible to track any polar-orbiting satellite through all the compass directions and elevations.

THE TRANSMISSION SYSTEM

The components of the transmission system which carries the rf signal from the antenna to the radio receiver are shown in Figure 9. Proper construction of this portion of the direct readout station is important to insure that radio frequency signal losses do not exceed acceptable limits.



A - 300 ohm TV lead-in, 1.52 m (five foot) section
B - 300 ohm to 75 ohm matching transformer
C - F59 connector
D - RG58U, short section 30.5 cm (approx. 12 inches)
E - PL 259 connector
F - Vanguard Lab Preamplifier (Model 102W)
G - PL 259 connector
H - RG8U coaxial cable to radio receiver

Figure 9
Components of the Transmission System

At the antenna, the open ends of one of the radiators are connected by a 54.6 cm (21.5 inch) length of 300 ohm TV lead-in wire to the open ends of the second radiator. (See part A of Figure 5). To insure good electrical contact, 1.3 cm (one-half inch) automobile hose clamps are used to hold the stripped ends of the TV lead-in wire in contact with the aluminum rods. Other methods can be used as long as electrical contact is insured.

A second 1.52 m (five foot) section of this 300 ohm wire is attached by the hose clamps to the ends of one of the folded dipcle radiators. (See part B of Figure 5). This section is used to carry the signal from the antenna radiators and should be supported by TV stand-offs with enough slack allowed so that the antenna is free to move in all directions of azimuth and elevation.

To avoid excessive losses of signal from the antenna to the radio receiver, low loss 50 ohm RG-8U coaxial cable must be used for the transmission line leading through the building to the receiver. Also, most receivers will require a 50 ohm impedance match between the antenna and the receiver.

For a better impedance match between the 300 ohm TV line and the 50 ohm RG-8U, a 300 to 75 ohm matching transformer has been inserted between the 1.52 m (five foot) section of TV line and the RG-8U cable. This type of transformer was used because it is inexpensive and easily available in most TV appliance stores. Of course, a 300 to 50 ohm transformer would offer a better match and this type should be used if available.

Since high quality, noise-free signals from the satellite are the desired goal of a direct readout station, it is recommended that a preamplifier be incorporated into the transmission system. At the Chambersburg High School station, a preamplifier manufactured by Vanguard Labs (Model 102W) is used. This is a low noise preamplifier offering less than 2 db noise for about 17 db gain. It can be ordered, pretuned to 137.5 MHz, which is the center of the frequencies of interest. The bandwidth is sufficient to cover all the APT frequencies. Purchase of this component will add about $40.00 to the cost of the station, but it will give a noticeable improvement to the quality of the APT signal.

The preamplifier, if used, should be placed in the 50 ohm RG-8U line close to the antenna. The Vanguard preamplifier is weatherproof and can be placed in exposed locations. To insert the preamplifier, the RG-8U cable should be cut and two male PL 259 connectors placed on the open ends. These in turn will be mated to the input and output female connectors on the preamplifier.

This preamplifier has provision for powering the electrical components through the coaxial line rather than running a separate power line to the preamplifier. The Vanguard comes with instructions and components to provide + 12 volts to the center conductor of the RG-8U cable at the radio receiver.

All connector plugs in the transmission line should be installed carefully so that good electrical contacts are made. Any connectors exposed to the weather should be weather protected with some type of sealant so that water cannot enter the connectors or cable and cause electrical shorting. If this does happen, serious signal loss will occur.

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V

Radio Receivers for Automatic Picture Transmission

V. RADIO RECEIVERS FOR AUTOMATIC PICTURE TRANSMISSION

Radio receivers for direct readout stations are similar to the many FM "high band", solid state receivers with crystal controlled frequencies that are available today. In fact, many of these receivers could be modified for direct readout service. Basically, any receiver must meet certain minimum requirements for adequate video reception. These requirements are set by the nature of the APT signal transmitted from the satellite. The APT transmission parameters for the United States TIROS-N and Russian Meteor series satellites are given in Table 1.

TABLE 1
APT Transmission Parameters

	TIROS	METEOR
Frequency	137.5, 137.62 MHz	137.3, 137.15 MHz
Carrier modulation	analog AM/FM	analog AM/FM
Transmit power	5 watts	5 watts
Transmit antenna polarization	Right hand circular	circular
Carrier deviation	± 17 kHz	± 15 kHz

There are four factors of primary importance in a direct readout station receiver:

1. The frequency of the APT signal
2. The type of rf signal modulation
3. The bandwidth of the transmitted signal
4. The sensitivity of the receiver

The "satellite band" for the APT from polar orbiting satellites is between 137 and 138 MHz. This is a thin section of frequencies located between commercial aircraft allocations and the 2 meter amateur radio band. Presently, TIROS-N is transmitting at 137.62 MHz and NOAA-6 at 137.50 MHz. The Russian satellites are using a frequency of 137.3 MHz, and occasionally a Russian satellite can be received over the United States transmitting at 137.15 MHz. Future TIROS-N series satellites are planned with APT at the same frequencies. All these satellites are transmitting with Frequency Modulation (FM). Based on these transmitting frequencies, it will be necessary to obtain an FM receiver that is capable of operating through this range of radio frequencies.

The most practical approach for a direct readout station is to use a radio receiver that has crystal controlled tuning. Using this type of receiver, after the crystals of the proper frequency are placed in the radio, no further tuning should be necessary; and the radio will be on frequency for proper reception. Also, many radios of this type will accommodate a number of crystals of different frequencies with a switch for frequency selection.

Crystals of the proper type can be purchased from a number of manufacturers. Many of these advertise in popular radio magazines, and some have toll free telephone numbers for placing orders. The crystals for the APT frequencies will probably not be in stock, and there will be a few weeks before they will be available after the order is placed. The type and model of the receiver should be included with the order.

The bandwidth of the APT receiver is also an important factor in receiving good video products from the weather satellites. In receivers the bandwidth is established by a filter in the IF (intermediate frequency) stage. To reproduce good APT pictures, the bandwidth must be wide enough to pass the entire signal or distortion and loss of picture resolution will occur. Excessive bandwidth, however, will introduce excessive noise into the signal. The APT signal bandwidth is influenced by two factors — the satellite transmission deviation and the doppler effect, which causes a frequency shift as the rapidly moving satellite approaches and passes the ground station. The signal deviation of the TIROS series transmission is ± 17 kHz. It is ± 15 kHz for the Meteor series. The doppler frequency shift for these satellites is about ± 4.5 kHz during an overhead pass, where the effect will be most severe. Using these parameters, for ideal APT signal reception, the bandwidth of the receiver should be about 40 kHz (± 20 kHz). However, receivers with bandwidth of 30 kHz (± 15 kHz), give adequate results. Most commercial high band receivers on the market have more narrow bandwidths and modification of this portion of the receiver would be necessary.

The sensitivity of the receiver is of prime importance in APT signal reception. Since noise-free signals produce the best satellite pictures, it is essential that the noise level be kept at a minimum. Sensitivity refers to the ability of the receiver to detect weak signals through the noise level of the receiving system which includes antenna and internal thermal noise of the receiver. Generally, this is referred to as the signal to noise ratio — where the signal strength is given in microvolts and the noise in db (decibels). A good receiver for APT direct readout stations will have a sensitivity of about 0.2 to 0.3 microvolts for 20 db of quieting. However, with the addition of a low noise preamplifier, receivers with less sensitivity, on the order of 0.6 microvolts, can produce noise-free signals when used with the antenna and transmission system described in this publication.

In most cases, acquiring a receiver for the APT direct readout station will be influenced by cost. Since the basic requirements of frequency, bandwidth, and sensitivity are not unreasonable; a radio adequate for receiving APT should not introduce cost factors out of line with school budgets. Generally, there are three practical ways of obtaining radio receivers:

1. Purchase a new receiver of the proper sensitivity, frequency and bandwidth
2. Modify a surplus (used) high band receiver
3. Obtain a government surplus receiver of the proper type

At the Chambersburg Senior High School direct readout station, the first two of these suggestions have been used. During the initial assembly of the station, a used, Regency TMR-1H, single channel (one receive crystal) monitor was modified for APT reception. This radio was originally designed to receive FM signals at frequencies between 148 and 174 MHz and has a sensitivity of 0.6 microvolts. The original bandwidth was ±7 kHz. Both the bandwidth and receiver frequency were modified to conform to APT reception requirements. The total cost, including purchase, modification, and two crystals, was less than $75.00. Whenever this receiver was used with the antenna system and preamplifier, good results were obtained.

There are also solid state receivers that are either designed specifically for or meet the requirements for APT reception that can be purchased new. At Chambersburg, a Vanguard Labs FMR 260-PL receiver was purchased and has given excellent service. It has space for eleven crystals (with manual selection), a sensitivity of 0.3 microvolts for 20 db quieting, and can be ordered with a 30 kHz bandwidth. The cost, including one crystal, is about $160.00. Further information on this receiver can be obtained from:

Vanguard Labs
196–23 Jamaica Avenue
Hollis, N.Y. 11423

MODIFICATION OF RADIO RECEIVERS FOR APT RECEPTION

The Regency models (TMR-1H, TMR-4H, TMR-8H) are examples of popular solid state monitors that can be adapted as APT receivers. These radios are generally designed to receive VHF frequencies from about 150 to 174 MHz that carry public service transmissions such as police and fire companies stationed in local areas. The TMR-1H is a one channel receiver. The remaining receivers mentioned here are designed to scan a number of frequencies.

With the popularity of this type of receiver, used units should be available in many locations at a reasonable cost. If available, purchase and modification costs should not be excessive. Generally, the modification requires lowering the receiver frequency to the 137-138 MHz range and changing the bandwidth to receive the wider APT transmissions. These changes do not require extensive technical skills. Access, however, to an accurate signal generator operating in the 137-138 MHz range is needed for re-tuning the receiver to the proper frequency.

MODIFICATION OF THE REGENCY TMR MODELS

Refer to Figure 10 for the following:

A. Frequency Modification

1. Remove capacitor C201 (8.2 pf, 10%, NPO, Disc) and replace with a capacitor of similar type and a value of 18 to 22 pf.
2. Remove capacitor C203 (5.6 pf, 10%, NPO, Disc) and replace with a capacitor of similar type and a value of 6.8 to 10 pf.

B. Bandwidth Modification

1. Remove filter CF-1 (Murata Type D, 455 kHz ceramic filter) and replace with a Murata type A filter. This replacement filter has a bandwidth of ± 15 kHz.

C. Re-tuning Procedure

1. Place a crystal with a receive frequency of 137.5 MHz (the frequency of NOAA-6) in the receiver.
2. Preset the slugs L201, L202, L203 and L204 four turns from the outer ends of the coil forms.
3. Connect an AC voltmeter across the speaker terminals.
4. With nothing connected to the antenna input, adjust the volume control until the AC voltmeter reads 1.0 volt of noise.
5. Connect the signal generator to the antenna input jack and set the generator accurately to the frequency of 137.5 MHz. Turn the modulation off.
6. Adjust the output of the signal generator until the AC voltmeter reads 0.2 volts.
7. Adjust L201, L202, L203 and L204 in that order, for maximum quieting (lowest meter reading). Adjust the signal generator to maintain a reading of between 0.1 and 0.2 on the AC voltmeter. Repeat adjustments until no further improvements can be made.

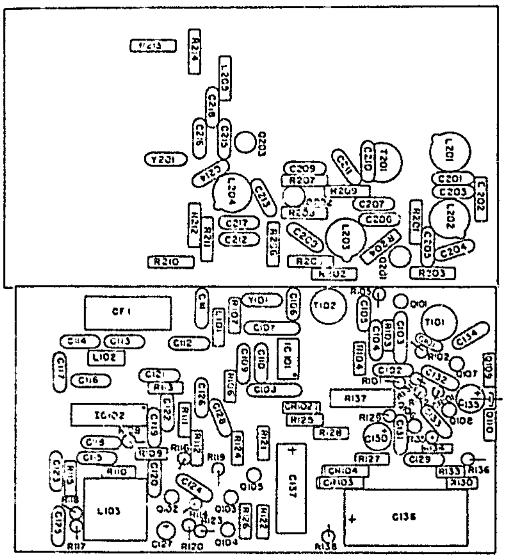

FIGURE 10
IF and RF Board Parts Placement Diagram for Regency TMR Monitors.
L201, L202, L203, L204, C201, C203 and CF-1 Components Have Same Location on Models TMR-1H, TMR-4H and TMR-8H.

If this procedure is accurately done, no further adjustments should be necessary. Whenever the receiver is used with the antenna and transmission system discussed earlier, good APT reception should result using crystals for the other frequencies that are presently being used by TIROS-N and Meteor series satellites.

GOVERNMENT SURPLUS RECEIVERS

Another approach to obtaining a receiver for an APT station is a search of government surplus sources available to educational institutions. Most schools will have some access to surplus outlets. There are, however, some disadvantages to obtaining a radio receiver through these sources; surplus receivers will not always be available and they will only be on an "as is" basis. The distinct advantage here, however, is that if a receiver is available, it will probably be at an extremely reasonable price. Therefore, if cost is a major concern, this source should not be overlooked.

POWER SUPPLIES

Most receivers discussed here will operate on either 120 volts AC or 12 volts DC. The Vanguard Labs FMR 260-PL operates only on 12 volts DC. In all cases, it is recommended that a good 12 volt DC power source be used. Many receivers, when operated on 115 volts AC, will have internal AC hum that will interfere with the quality of picture that is reproduced. This interference will appear as vertical lines through the picture causing poor results in the final product. Batteries will also suffice for DC supplies.

VI

Reproducing Satellite Pictures

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VI. REPRODUCING SATELLITE PICTURES

Obtaining or building the components necessary to reproduce pictures from APT video for a direct readout station may present the greatest problems and perhaps, the largest expense. At the present time there are three practical ways of displaying the weather satellite pictures received via APT:

1. CRT (Cathode Ray Tube) monitors
2. Photographic drum recorders
3. Electrostatic recorders

The first two of these will probably require some construction of the necessary components. Methods of construction are available in the literature, and proper construction should provide good results. Electrostatic printers are more adaptable for classroom use. Unfortunately, these are impractical to build and purchase of new ones will almost certainly exceed school budgets. Some electrostatic recorders are, however, available as surplus items; but they may require some modification before they can be used to reproduce APT video.

CRT DISPLAYS OF APT

With modification, it is possible to adapt an oscilloscope with its cathode ray tube (CRT) into an APT facsimile display device for weather satellite video. The printing process involves tracing, line by line, the demodulated APT signal across the tube at the proper rate of speed and line deflection. In this way, a picture is "painted" across the screen in a way similar to television picture reproduction, but at a much slower rate than a standard television picture. The maximum APT signal produces a bright trace while the minimum signal produces no trace. Intermediate signals produce various shades of gray. This tracing occurs at a relatively slow rate, 120 lines per minute, so the entire screen is not lighted at the same time. Therefore, it is not practical to view

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the screen directly. Instead, a time-lapse photograph of the screen must be taken while the signal is being fed into the display unit. Almost instant pictures can be viewed with the use of a Polaroid camera or negatives can be made with a standard camera and prints can be produced at a later time. In either case, the final product is a photograph of the CRT containing the satellite video.

Methods of construction of CRT facsimile monitors are found in articles 8, 24, 26 and 31 in the references. The published results using this type of display appear good; and if construction materials and expertise are available, this method should not be overlooked. Building a unit such as this would make a good project for students interested in electronics and photography.

PHOTOGRAPHIC FACSIMILE USING DRUM RECORDERS

High quality APT picture reproduction can be accomplished using rotating drum facsimile machines. This method of picture display is largely mechanical. Generally, a sheet of photosensitive paper (photographic enlargement paper) is wrapped around a drum which is rotated by a motor. A light source with a fine point focus is then moved along the rotating drum, causing fine lines to be drawn across the photographic paper. By modulating the light source with the APT signal from the satellite, the video signal is transformed into variations of brightness. This in turn causes variations of exposure on the light sensitive paper. After the photographic paper has been exposed, it must be developed by standard darkroom techniques to produce a photographic record of the satellite video transmission.

In order to produce satellite pictures by this method, accurate design considerations of the mechanical equipment must be undertaken. The drum motor, the light source drive, and the modulated signal must all be properly synchronized. Also, the light source drive must move along the rotating drum smoothly and the brightness of the light source must be matched to the sensitivity of the photographic paper to assure proper exposure. There must also be electronic components to process the satellite video signal for proper modulation of the light source.

In spite of the care needed in their construction, many amateur-built ground stations use drum facsimile for APT display with very high quality results. References (8, 10, 11, 12, 13, 14, 20, 26, and 31) contain detailed information on the construction of these facsimile recorders.

There are some disadvantages of using this method of APT display in the classroom. First, at least some of the procedure requires darkroom facilities, which for convenience would need to be close to the other components of the direct readout station. Also, real-time printing is not as practical as other methods of APT display discussed here. Most stations using drum recorders tape-record the satellite video and then reproduce the picture from this recording. The entire process of tape recording the satellite APT, exposing the photographic paper on the drum recorder, and then processing the photographic paper may require more time than is allowed in student schedules. Therefore, it may be difficult for students to participate in the entire process.

ELECTROSTATIC RECORDERS

Electrostatic facsimile recorders have been used for a number of years to reproduce facsimile transmitted to news facilities throughout the world. These pictures are transmitted most often by telephone line in the form of an amplitude modulated tone in a line by line sequence which the recorder can reproduce as a photograph, chart, or printed material on electrosensitive paper.

The electrosensitive paper is moved with a constant speed between a steel writing blade on one side of the paper and a rotating helix wire on the other side of the paper. With this arrangement, the paper touches the blade and the helix wire at only a single point at any one time. If an electrical current is passed through the paper at this point, a chemical action occurs causing a coloration of the electrosensitive paper. The amount of coloration is directly related to the amount of current flow. In electrostatic recorders, this current is determined in other associated electronic circuits by the amplitude variations of the incoming signal. The rotation of the helix and the movement of the paper causes the point of contact to move across the paper creating a series of horizontal lines forming various shades of coloration corresponding to changes in the amplitude of the signal. In this way a photograph is built, line by line.

In all types of satellite APT video display devices, the scan rate must match the line rate-per-minute of the signal being reproduced. Therefore, the helix speed (RPM) must accurately match the satellite APT rate. Since the polar orbiting TIROS-N and Meteor series weather satellites are transmitting video at 120 lines-per-minute, picture reproduction requires a helix rotation of 120 RPM. Very slight variations in helix speed will cause the video display to drift across the paper. Greater variations will result in complete picture loss. Exact multiples of transmission rate (i.e. 240 lines-per-minute) reproduced at this 120 lines-per-minute helix rate will result in two pictures side by side.

In electrostatic recorders the helix speed is accurately controlled by an internally produced frequency standard. This frequency is usually established by a tuning fork or crystal-controlled oscillator and amplified. The resulting voltage is fed to a helix drive motor which turns the helix at a rate determined by the frequency. The D-611-P recorder used at this station was originally designed with a 1000 Hz frequency standard to drive the helix motor at 100 RPM. A newer version of the D-611-P, the K-550 facsimile recorder uses a 50 Hz frequency to drive the helix at 100 RPM. It is possible to modify these recorders to run at the desired 120 RPM rate. These modifications are discussed in this section. Other recorders, such as the Unifax I, already include a 120 lines-per-minute rate and should not require modification to reproduce the 120 lines-per-minute APT video.

While it is critical that the printing rate match the line rate of the incoming APT signal, it is also important that the start of each scan line fall at or near the edge of the paper. If this phasing is not done, it is possible that the edge of the picture will fall somewhere toward the center of the paper with a portion of the picture on either side. The satellite video includes syncronization pulses for picture phasing. Portions of the electronic circuitry described in the references for CRT and photographic drum recorders include phasing mechanisms for the APT video. Electrostatic recorders also have picture phasing circuits. Unfortunately, the phasing sequences required are not the same as contained in the satellite video. There is, however, a simple method to overcome this problem. The on/off toggle switch on the external frequency generator can be used to briefly interrupt the helix. The operator can then momentarily switch the helix off and then on to move the picture across the paper until proper alignment is accomplished. This method, of course, requires that the operator be able to see the picture as it is being printed. An additional modification is necessary in electrostatic recorders designed to pass input signal frequencies other than the 2400 Hz video carrier transmitted by the TIROS-N and Meteor satellites. The D-611-P and K-550 recorders contain voice immunity circuits designed to pass a 2000 Hz signal. Minor changes in this circuit are needed to allow these recorders to respond to the 2400 Hz carrier frequency transmitted by the satellite.

CRT, photographic drum recorders and electrostatic recorders all offer certain advantages and disadvantages when used to display weather satellite video. However, electrostatic recorders offer several advantages for instruction and classroom use:

1. The recorders are generally easy to operate and require a minimum of instruction for successful operation.

2. Electrosensitive paper is the least expensive material for picture reproduction.
3. The operator gets immediate results without the need for photographic processing or darkroom facilities.
4. Students can view real-time displays which aid in satellite tracking.
5. Where student scheduling limits time, photographs can be studied immediately after reception.
6. These recorders offer the same flexibility as the other methods of APT display in that the signal can be tape recorded and additional photographs can be reproduced immediately after the satellite passes.

AVAILABILITY OF ELECTROSTATIC RECORDERS

Electrostatic recorders suitable for video reproduction of weather satellite APT should be available in either new or surplus condition from a number of sources. A few may be available through government surplus channels or, with luck, one may be located locally at low cost or perhaps at no cost to the school. Local newspaper offices and amateur radio operators should not be overlooked. Some recorders that do not have a printing rate of 120 lines-per-minute will need modification. Also, some adjustments may be needed for the recorder to respond properly to the 2400 Hz satellite carrier. These changes in most cases should not be difficult and any components necessary should be inexpensive.

At the present time there are surplus recorders available from the following sources:

D-611 Mufax Recorder (AP Photofax)

The D-611-P is an old type electrostatic recorder that is no longer available from any commercial source. There is some possibility that this model can be obtained from private individuals such as electronic experimenters, amateur radio operators or, perhaps, newspaper offices.

K-550-A Mufax Recorder

A number of these receivers are available as surplus. Contact:

Mr. John Gibbons
16 Elkins Road
East Brunswick, N.J. 08816
Telephone: (201) 238-2130

UNIFAX I

From time to time, UNIFAX I receivers become available as surplus and can be purchased on an "as is" basis. Prices are dependent upon condition of the equipment. Contact:

Ian H.H. Smith
Director of Marketing-Facsimile Products
United Press International
News Building, 220 East 42nd Street
New York, N.Y. 10017
Phone: 201-273-3261

The basic operating characteristics of these three electrostatic recorders are given in Table 2.

Electrostatic paper is available from:

Muirhead Inc.
1101 Bristol Road
Mountainside
N.J. 07092
Phone: 201-233-6010

TABLE 2
Characteristics of Electrostatic Recorders

	D-611-P	K-550 A	UNIFAX I
Index of cooperation	380	380	440
Helix speed	100 RPM	100 RPM	120 RPM
Recording medium	H-P 11 Electro-sensitive paper	Mufax electrotype H	Electrolytic paper
Width of record	28 cm (11 in.)	25.4 cm (10 in.)	
Nature of input signal required	AM 2 kHz	AM 2 kHz-Nominal carrier	2448 Hz
Scanning pitch	108 lines/in. 144 lines/in.	119.4 lines/in.	150 lines/in.
Input circuit	600 OHMS 2-wire	600 OHMS 2-wire	600 OHMS 2-wire

MODIFICATION PROCEDURES FOR THE D-611-P AP PHOTOFAX RECEIVER

Two aspects of the D-611-P normal operations must be modified to reproduce TIROS-N and Meteor series weather satellite APT video. These modifications involve establishing a helix speed of 120 RPM and changing the voice immunity circuit to pass the 2400 Hz amplitude modulation video input signal. The following modifications were developed and suggested by William Watt, WB3BMY.

I. Helix Motor Speed Modifications

a. Insertion of externally produced 1200 Hz Frequency Standard

The schematic in Figure 11a shows some of the components associated with the internally produced 1000 Hz frequency of the D-611-P. These components are located in the lower Auto Unit Chassis accessable from the back of the machine. Figure 11b shows the same components after modification for 120 lines-per-minute operation. The externally produced 1200 Hz frequency is inserted on the positive side of variable resistor RV 7. The original wire carrying the 1000 Hz tone from the fork frequency generator is disconnected. The center conductor of a small shielded cable is soldered to this terminal on RV 7. The shield of this cable should be grounded. This cable can be run to some convenient location on the back of the machine and terminated with a small female jack. One method for producing an accurate 1200 Hz frequency is discussed in the next section.

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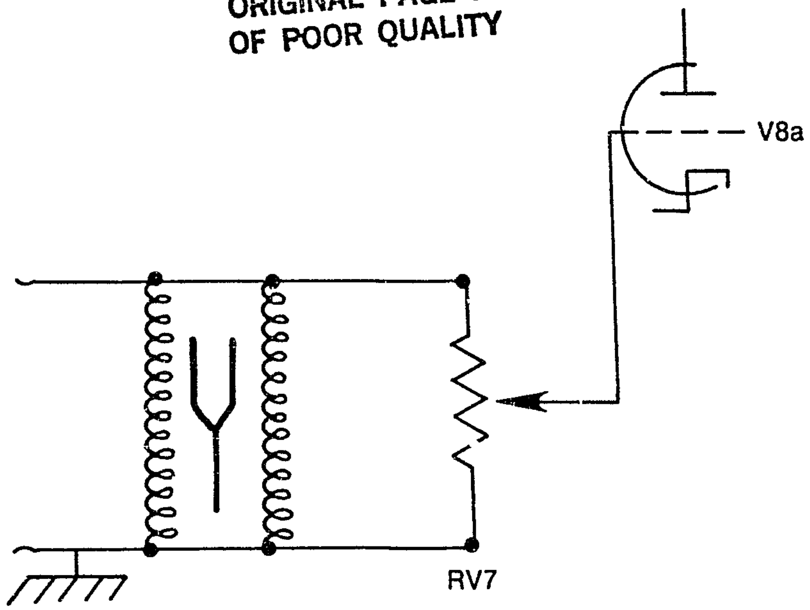

FIGURE 11a
Schematic of a Portion of 1000 Hz Frequency Generator of D-611-P. Unmodified.

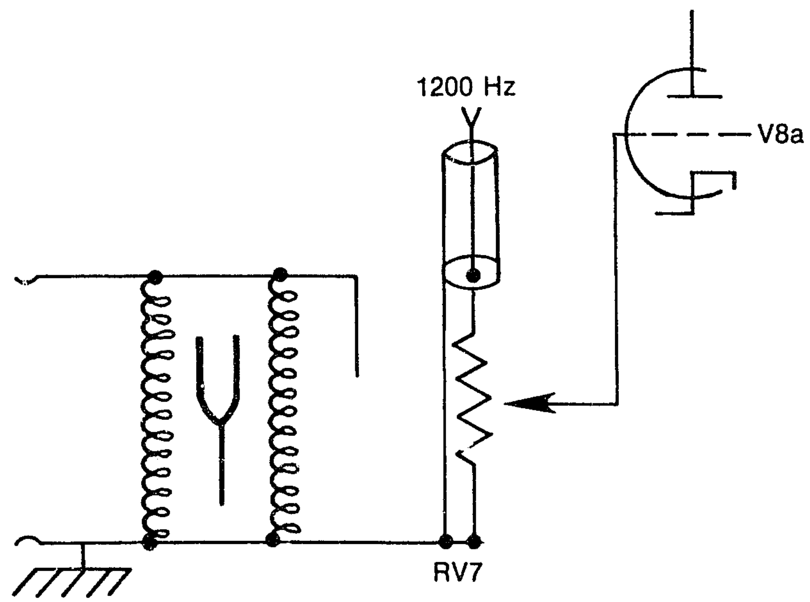

FIGURE 11b
Schematic Showing Insertion of Externally Produced 1200 Hz Frequency.

During operation, the 1200 Hz frequency generator is fed first to one channel of a stereo tape recorder input and then from that channel output to the jack that was placed in the back of the D-611-P. See Figure 12.

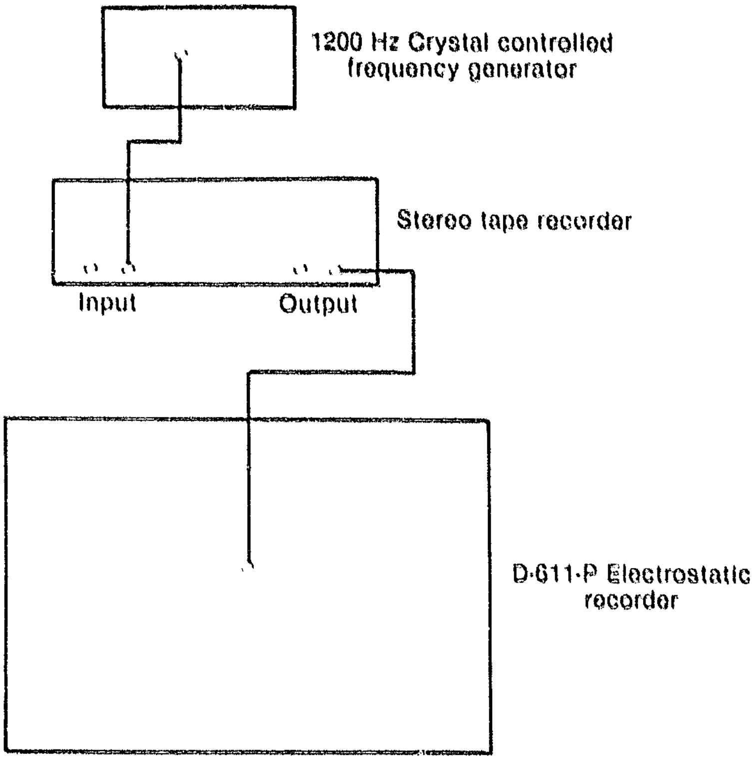

Figure 12
Connections for 1200 Hz Frequency
To Drive Helix Motor at 120 RPM.

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b. Capacitor Modifications for Helix Motor

Capacitors C57, C58, C59 and C60 are contained in a large capacitor housing located behind the helix and accessable from the front of the machine after the helix is removed. A schematic of this section before modification is shown in Figure 13a. To remove the helix drum, open the cover and remove the protective plate which is held in place by two lugs. Press the helix drum to the left and lift out; right hand end first.

The frequency change, from 1000 Hz to 1200 Hz, necessitates placing a 300 ohm 10 watt resistor across C57 so that the phase shift in the currents of the two motor windings of M01 generate maximum torque. Capacitors C59 and C60 were not connected into the circuit of the D-611-P modified at this station. If, after all modifications are complete, the helix motor does not function with sufficient torque, one (C59) or both (C59 and C60) can be connected to C58. Figure 13b represents the schematic of these modifications.

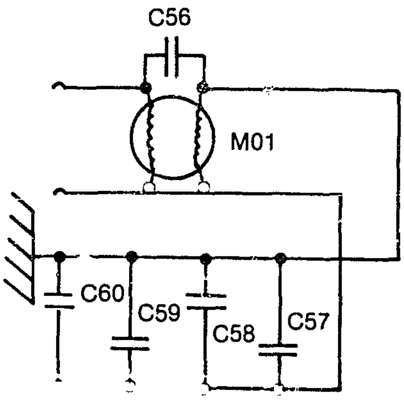

FIGURE 13a
Schematic Showing Unmodified Hysteresis Motor Components of D-611-P.

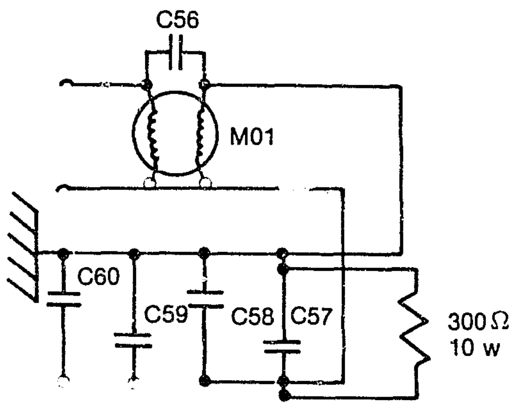

FIGURE 13b
Modification of Hysteresis Motor Components for 120 Lines-Per-Minute Operation

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II. Modification of Voice Immunity Circuit for Receiving 2400 Hz AM APT Satellite Signal

Figure 14a is a schematic of T1 and T2 and associated components which are part of the D-611-P voice immunity circuit. These are located in the lower auto unit chassis. The original circuit was designed to receive an input signal of 2000 Hz AM video. The modifications shown in Figure 14b are made to adjust this circuit for a 2400 Hz input frequency. Modifications include replacement of capacitor C4 with a 0.01 μF capacitor. In most D-611-P recorders the original C4 is exposed on the underside of the chassis and easily removed. In a few machines, it will be located in the lower left hand corner of the T-2. In this case .64 mm (1/4 inch) holes can be carefully drilled and one of the wire leads of C4 pulled through the hole and cut. It is not necessary to remove the original C4 as long as it is disconnected from the circuit. The new 0.01 μF capacitor can be soldered in the circuit externally. Also, run a straight wire from #3 to #4 terminal of T1.

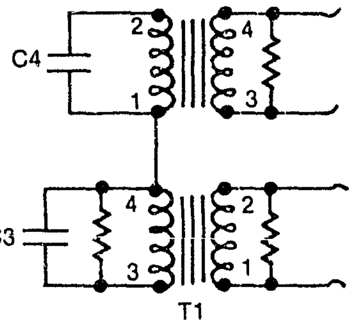

FIGURE 14a
Schematic of a Portion of the Voice Immunity Circuit of D-611-P. Unmodified.

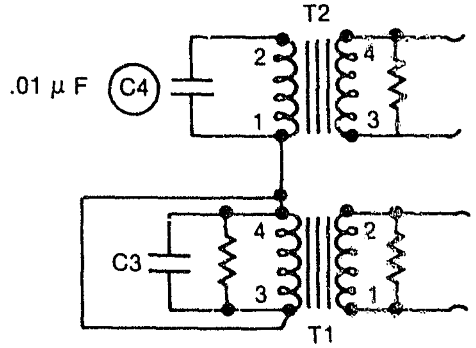

FIGURE 14b
Schematic Showing Modifications to Adjust Bandpass for 2400 Hz Satellite Video.

MODIFICATION OF THE K-550 ELECTROSTATIC RECORDER FOR WEATHER SATELLITE APT REPRODUCTION

The K-550 recorder is designed to reproduce facsimile at a rate of 100 lines per minute. The helix speed is determined by an internally derived frequency standard established by a 3.2 MHz crystal controlled oscillator circuit and a series of integrated circuits which divide the 3.2 MHz frequency down to a 50 Hz square wave. This 50 Hz signal is then amplified by the motor amplifier circuit. All of these components are located on a printed circuit board PC 1443 'E'. The amplified signal from this board is then fed to a pair of capacitors and diodes that rectify the 50 Hz pulses and drive the helix motor (MO 1) at a rate of 1500 RPM. The helix motor, through a gear arrangement, turns the helix at 100 RPM. A diagram of these components is shown in Figure 15.

The modification of the motor speed for reproducing APT facsimile at 120 lines per minute requires two easy and inexpensive changes. The first of these requires a change of the internal frequency standard from 3.2 MHz to 3.84 MHz in the crystal controlled oscillator circuit. This new frequency of 3.84 MHz, when divided by the same integrated circuits, will produce a 60 Hz square wave which will increase the helix motor speed to 1800 RPM. Then, through the existing gear arrangement, the helix will turn at 120 RPM. This change of frequency can be accomplished by removing the original 3.2 MHz crystal on printed circuit board PC 1443 'E' and replacing it with a 3.84 MHz (3840.0 KHz) crystal. (Specifications: 3.84 MHz, ± .005%, 30 pF — available from: Sentry Manufacturing Co., Crystal Park, Chickasha, Oklahoma 73018, Phone order toll free: 1-800-654-8850).

Because of the frequency change from 50 to 60 Hz, the electrolytic capacitors C1 and C2 (320 μF, 64 V) shown in Figure 15 will no longer function properly to drive the helix motor at the desired 1800 RPM rate. Based on the formula for inductive and capacitive reactance:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

f = frequency
L = inductance in henrys
C = capacitance in farads
π = 3.14

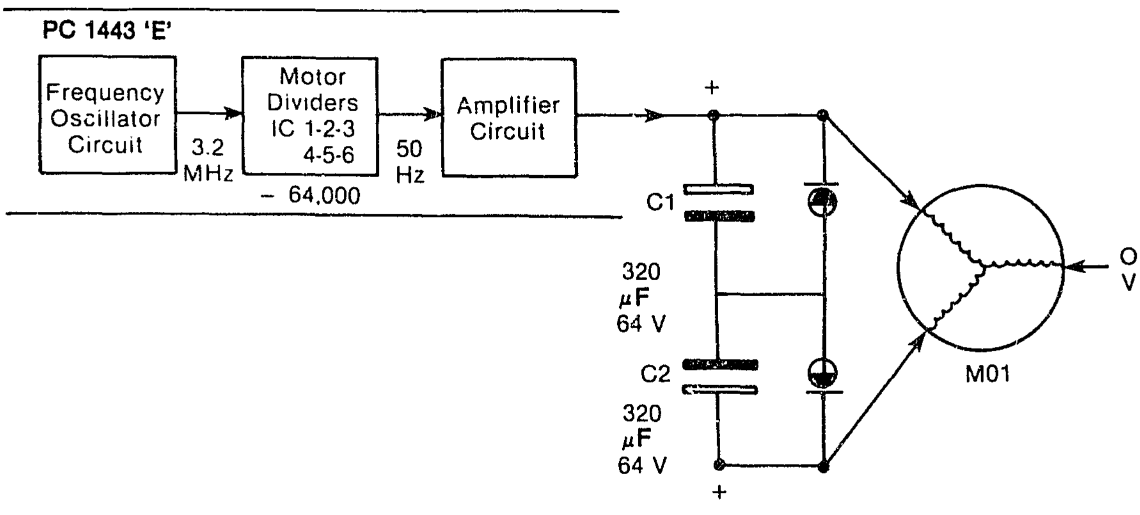

FIGURE 15
Unmodified Version of K-550

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resonance at 60 Hz requires that the capacitors C1 and C2 be replaced by capacitors of 220 μF values. The original 320 μF capacitors are located below a plate accessable from the back of the K-550. These should be removed and replaced by two 220 μF capacitors of similar voltage. (50 volt capacitors have been used successfully). The two original diodes in this circuit can be retained and used with this modification. Care should be taken to assure the same circuit configuration is maintained with respect to capacitor polarity and diode direction. Also, the incoming line carrying the 60 Hz signal from PC 1443 must be replaced in the same position or the motor direction will be reversed.

These changes, shown in Figure 16, should now produce an exact 1800 RPM motor speed with the resultant helix speed of 120 RPM. Any slight variations from the vertical picture reproduction can be adjusted by the variable capacitor CV 1 on PC 1443.

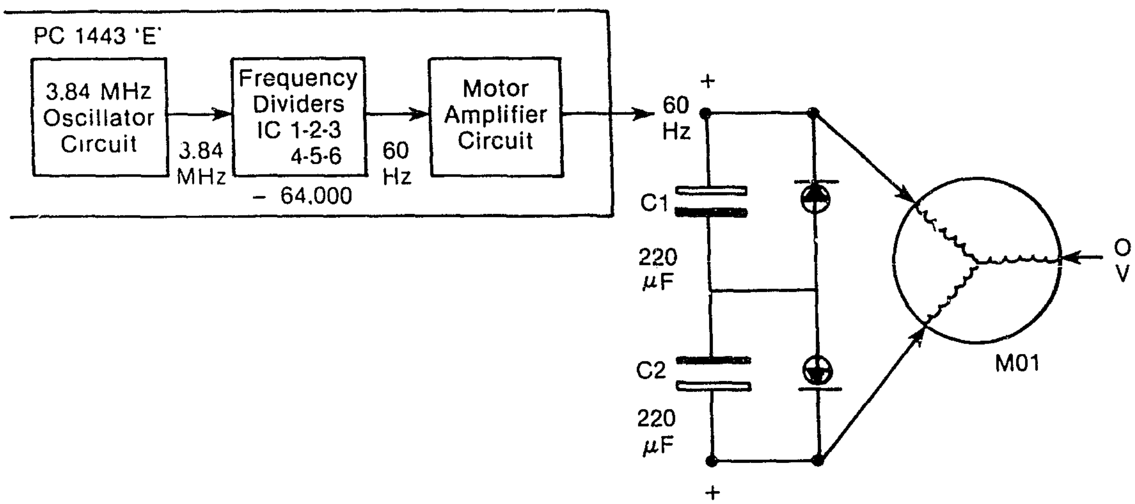

FIGURE 16
Modified Version of K-550

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MODIFICATION OF K-550 FOR USE WITH STEREO TAPE RECORDER

After completion of the modification for 120 lines per minute operation, weather satellite APT can be reproduced without further changes. However, if this electrostatic recorder is to be used with a stereo tape recorder, changes will be necessary to allow the 60 Hz sync signal to be recorded and to be played back. As with the D-611, this will allow for slight variations in the tape speed.

Since it is possible to change the frequency of the K-550 internal frequency standard, it is not necessary to construct a frequency generator. Instead, the 60 Hz frequency can be obtained from the K-550 and tape recorded on one channel of a stereo tape unit. This signal can then be reinserted on playback to drive the helix motor. It also can be used while recording which allows picture reproduction in real time. Refer to Figure 17 for the following changes:

1. Disconnect the short solder link between PIN 8 of IC 6 and resistor R 10. If a soldering iron is being used, do not overheat this area. This will break the connection between the output of the Frequency Divider Circuit and the input to the Motor Amplifier Circuit.
2. Solder a wire to PIN 8 of IC 6 to carry the 60 Hz signal to a phono jack outside the K-550.
3. Solder a second wire to the input point of R 10 and to a second phone jack. This will form the input to the Motor Amplifier Circuit from the tape recorder.
4. Connect a ground wire beween both phono jacks and from this point to a 0 volt point on the printed circuit board such as PIN 11 of IC 6.
5. Standard connector cables can be used to link the phono jacks that are installed to the stereo tape recorder.

NOTE: The output voltage from the tape recorder to the Motor Amplifier stage should be 4 volts. If the output voltage is low, the helix motor will not operate. In this case, a small DC powered audio amplifier will be needed. Also, higher voltages at this point, should be avoided.

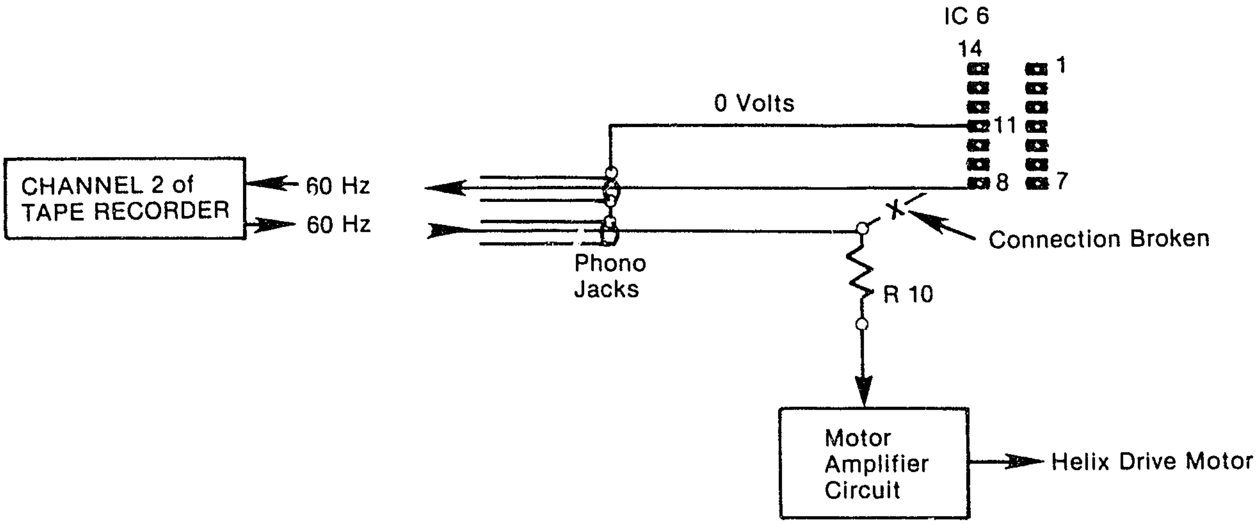

FIGURE 17
Diagram of Foil Side of PC 1443 Showing Modifications To Record and Replay Sync Signal

Figure 18 is a diagram showing the connections between the APT radio receiver, stereo tape recorder and the K-550 electrostatic recorder. Due to impedance mismatches between the radio receiver and the tape recorder and between the tape recorder and the 600 ohm video input to the K-550 small audio line matching transformers or other matching components may need to be added to these lines.

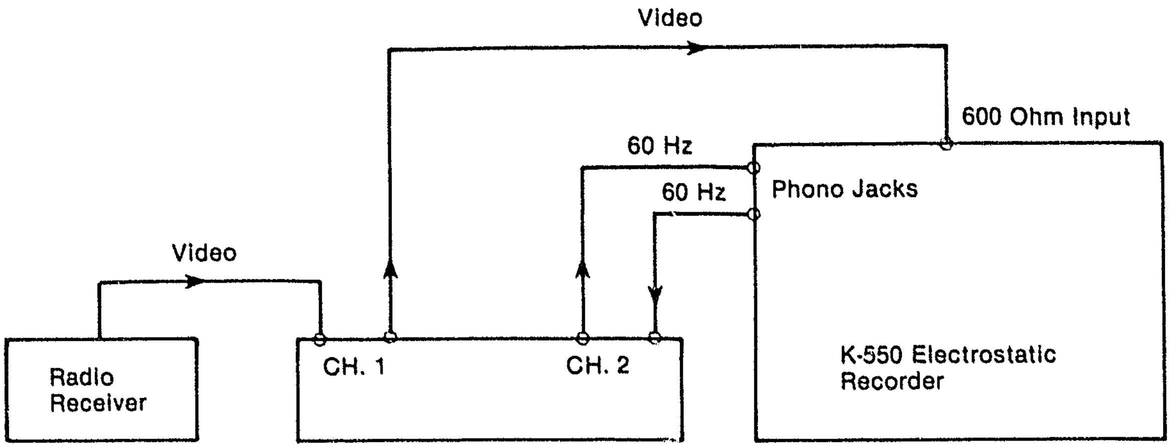

FIGURE 18
Diagram Showing the Connections Between the APT Radio Receiver, Stereo Tape Recorder and the K-550 Recorder.

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OPERATION OF THE K-550 ELECTROSTATIC RECORDER

Because the K-550 was designed for facsimile via telephone line, the automatic sequencing is determined by a series of events at the transmission site. These sequences are not the same as contained by the satellite APT. When the unit is turned on, it remains in a "stand-by" condition. At this time, the helix motor is not running. When a "white" signal (Maximum signal) is detected at the input terminals, relays apply power to the motor circuits and the motor begins to run. Whenever the "white" signal is interrupted for 5 milliseconds or more, the helix gears are activated and the printing begins. When the signal is terminated for about 5 seconds, the machine returns to the stand-by condition.

Since the satellite video does not present a solid "white" signal, the K-550 will not activate with the satellite signal alone. It is possible, however, to activate the proper relays manually by using the test switch Si located on printed circuit board 1477 'D'. Under standard operating conditions, this switch is set to NORMAL. When this switch is turned to WHITE, the helix motor will activate. If the switch is then returned to the NORMAL position with the satellite APT signal present, the printing process will begin and continue throughout the satellite pass as long as sufficient video signal from the satellite is present. Loss of this signal will terminate the printing and the machine will return to the stand-by state. Other methods may be possible.

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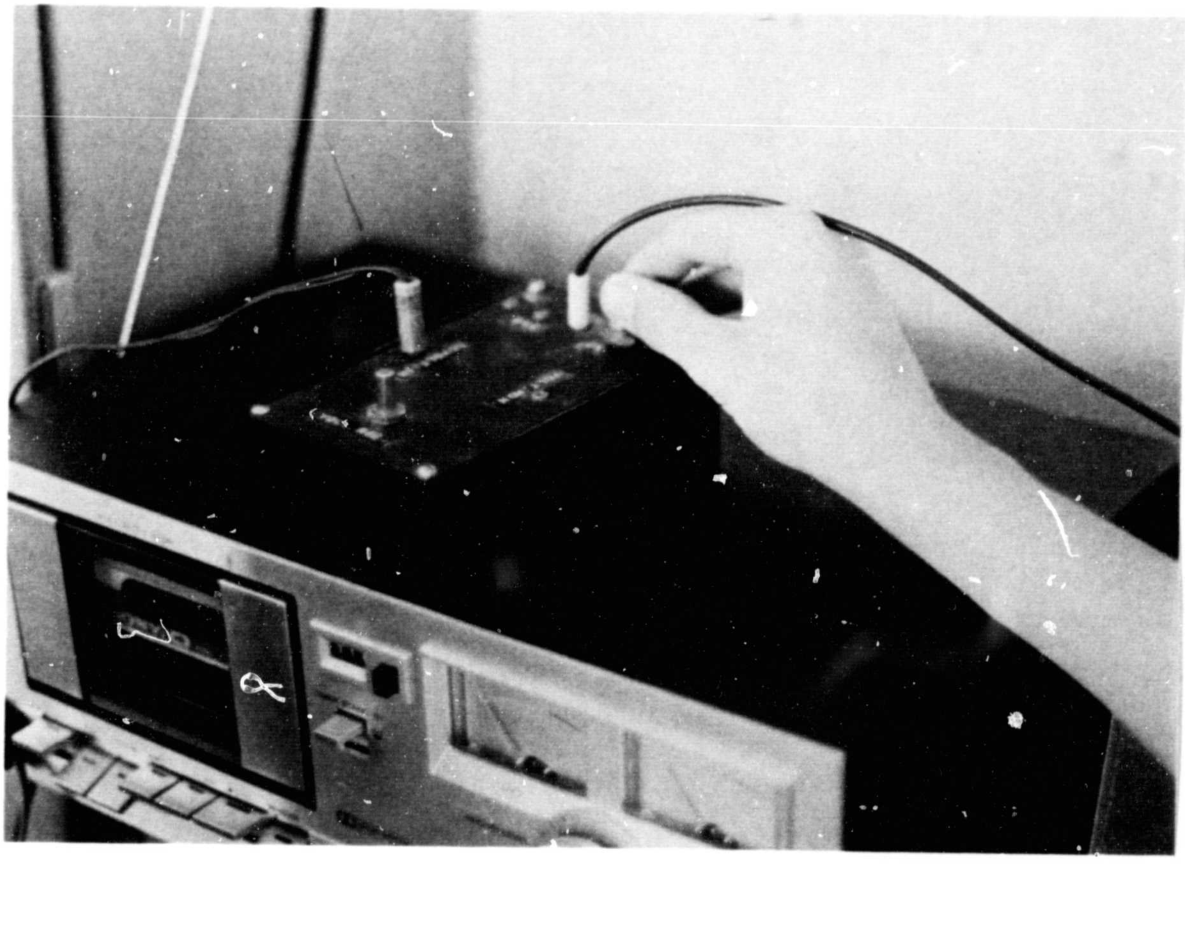
VII

Tone Generator for D-611-P Electrostatic Recorder



VII. TONE GENERATOR FOR D-611-P

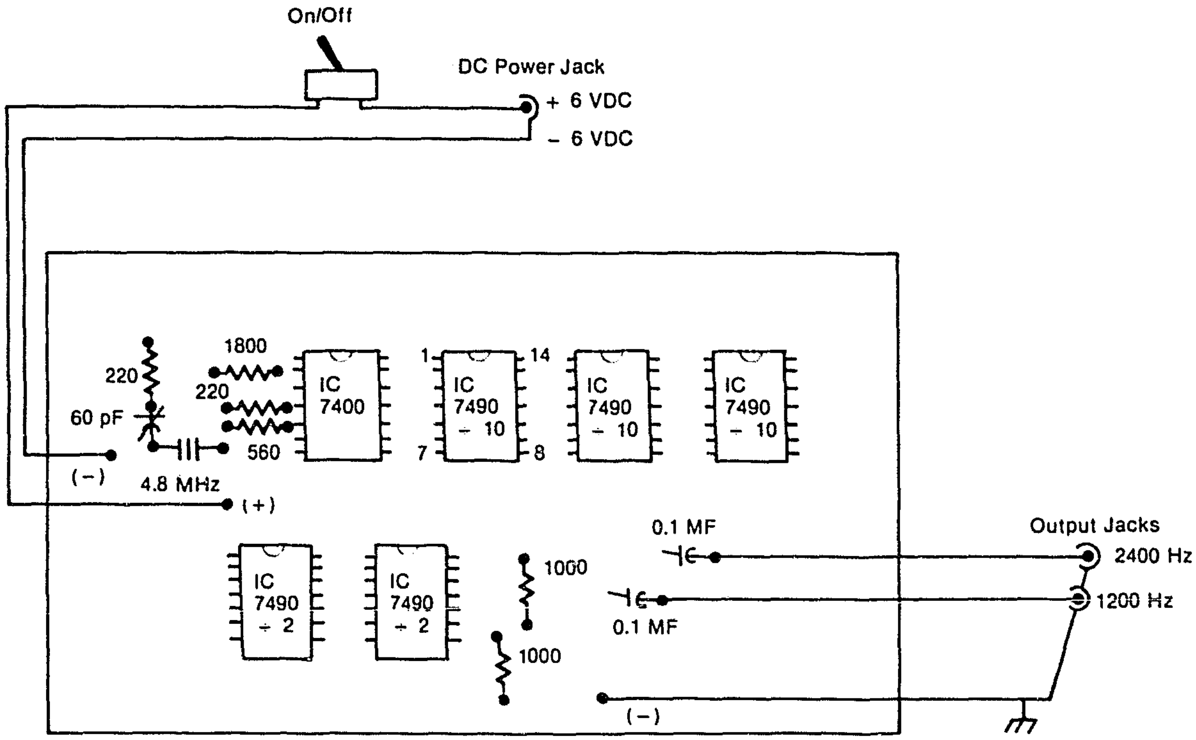
The D-611-P Photofax printer is designed with an internal tone generator to produce a 1000 Hz frequency to drive the printing motor at 100 lines per minute. To adapt the D-611 for a printing rate compatible with the 120 lines per minute video transmissions of the TIROS and Meteor satellites, minor modifications must be made. Generally, these modifications consist of disconnecting the internal 1000 Hz generator and inserting an externally produced 1200 Hz frequency. This will cause the hysteresis motor of the printer to operate at the increased speed of 120 lines per minute. This frequency, however, must be extremely accurate and stable for the printer to operate properly.

The 1200 Hz frequency generator shown in Figure 19 will function well in this system. This generator includes a 4.8 MHz crystal-controlled, integrated circuit (IC) oscillator and a series of divide-by-ten and divide-by-two, integrated circuits to reduce the oscillator frequency output to 2400 Hz and 1200 Hz. Although the 2400 Hz tone is not needed for the APT format of the satellites discussed in this publication, it is included here so that the station could later be expanded to receive GOES pictures which are transmitted at 240 lines per minute.

To aid construction of the 1200 Hz frequency generator, a printed circuit foil pattern is provided in Figure 20. Many electronic stores have materials for reproducing copper foil printed circuits from art work in publications. The final product is a copper foil pattern on the printed circuit board. The board can then be drilled so that the various components can be inserted and soldered into the correct position following the layout shown in Figure 19. A list of components is also given.

Care should be given to the correct placement of all components and proper soldering. It is highly recommended that 14 pin, IC sockets be used. This will add a little to the cost of the project but will eliminate heat damage that is possible whenever soldering the IC's directly and permits easy replacement of them if necessary. Do not insert the IC's into the sockets until the final stages of construction and be sure that they are placed in the proper positions and orientation so that pins 1 thru 14 are in their proper location in the layout.

The 4.8 MHz crystal will probably have to be ordered from a crystal manufacturer. When ordering the crystal, specify that it be a resonant series AT cut and allow some time for delivery. A socket can be used to support the crystal or it can be soldered directly. If direct soldering is used, avoid prolonged heating and use a heat sink to prevent damage.



Components:
Integrated circuits
7400 - 4.8 MHz crystal controlled oscillator
7490 - divide by 10 and 2
Resistors - ¼ or ½ watt, 10%
Crystal — Precision series resonant AT cut, 4.8 MHz
Capacitors — 0.1 μF 1 V mylar, 600 pF variable (Note: after construction the 60 pF capacitor should be set to produce 1200 Hz or 2400 Hz at the output jacks)
Power Supply — 5 to 6 volts DC

FIGURE 19
Component Layout of 1200 Hz Tone Generator

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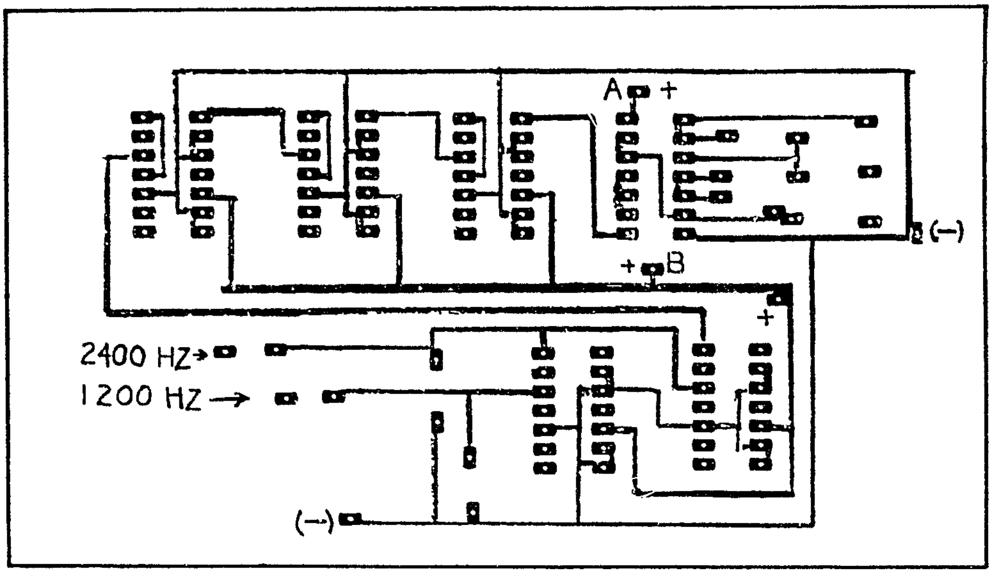

FIGURE 20
Printed Circuit Foil Pattern for 1200 Hz Frequency Generator.
(Note: Jumper Wire Needed Between A and B)

Although most wiring is completed by the printed circuit pattern, a few additional wires are necessary to complete construction:

1. A short jumper wire must be soldered between points A and B on the printed circuit side of the board. This provides the + DC voltage to IC 7400.
2. The DC voltage is supplied through a subminiature jack. A 6 volt calculator charger will work well. It is important that the positive and negative polarity is correctly positioned. A SP ST toggle switch is positioned in the positive voltage line and functions as an on/off switch.
3. The 1200 Hz and 2400 Hz outputs are connected to two subminiature jacks. These should be wired so that the center conductors receive the tone outputs and the ground side of the jacks are connected to the negative portion of the printed circuit board.

VIII

Recording and Reproducing of APT

VIII. RECORDING AND REPRODUCTION OF APT

Photographs can be produced on a Photofax line printer in real time by running the satellite video from the radio receiver to the video input of the printer while simultaneously running the signal from the tone generator to the motor synchronizing stage of the printer. Although this method of printing photographs in real time produces satisfactory results; for reproduction and storage of pictures, a stereo tape recorder is used. By recording the satellite's signal on one channel and the tone generator signal on the other channel, additional photographs can be produced.

The specifications required of the tape recorder to be used in the APT station can be found in many commercially available models. The high school's audio-visual department could be a source of a tape recorder for the APT station. No modification of the tape recorder is required.

There are several specifications to look for in choosing a tape recorder for use in the APT station. First, the tape recorder must have two track (stereo) capabilities. This is necessary to isolate the two separate signals which are to be used in picture reproduction. One channel or side is used to record the satellite's video subcarrier from the radio receiver. The other channel is used to record the 1200 Hz signal from the tone generator. Both tones can be replayed simultaneously to produce pictures on the Photofax line printer. On replay, variations in the speed of the tape drive will produce alterations in the pitch of this tone which, in turn, will change the printer's speed which will cause the picture to remain aligned on the paper.

However, extreme variations in motor speed during replay will cause the picture to drift across the page or to have wave-like squiggles from border to border. For this reason, the tape recorder must have a very constant motor speed. The specification that measures the amount of variation from a constant speed is called "wow and flutter" and is expressed in percentage values. A commerical firm that provides APT stations to international clients provides a tape recorder with their installations that has wow and flutter measurements of .3%.

Tape recorders with the required specifications for use in the APT station are available in both cassette and open reel formats. The cassette format offers the advantages of ease of operation, convenient storage and cataloging of tapes, and a more compact size. The Chambersburg station uses a Sanyo cassette recorder that is priced at about $130.00.

The open reel format is a bit more clumsy to operate and requires a little more shelf space than the cassette. Many open reel recorders provide a choice of tape drive speeds. A two speed recorder will give the option of 3-3/4 ips (inches per second) and 7-1/2 ips. A three speed model will add 1-7/8 ips or 15 ips to these choices. The speed choices will allow the original 120 lines per minute transmission to be reproduced in a different format. For example, if a 2400 Hz motor synchronizing tone is recorded at 7-1/2 ips and replayed at 3-3/4 ips, a 1200 Hz tone will be produced driving the Photofax at half the speed.

It is useful to have separate level controls for both record and playback on each channel. Some recorders have level controls which affect record only and provide replay at a fixed volume. Volume control on the playback is most useful for matching levels with the Photofax inputs. Level meters are also useful in giving the station's operator a visual reference for duplicating or improving results.

A tape recorder which has the required specifications of constant tape drive speed, level controls, and meters will normally have excellent specifications in terms of frequency response. However, the video signals in the APT and line printer are constant frequencies in the middle range of the audible spectrum. The wide frequency response of most of today's high fidelity tape decks generously supersedes the requirements of the APT system. A high fidelity feature which may have some bearing on the performance or quality of the pictures is that of reproducing accurate dynamic levels, since the APT video signal produces light and dark areas of the photograph corresponding to soft and loud variations in the level of the tone.

A high fidelity tape recorder will provide the user with the ability to monitor the tape while it is being recorded. This is accomplished by the placement of a separate playback head immediately beside the recording head and "playing" the tape a fraction of a second after it has been recorded. This monitor signal can be fed directly to the Photofax, and a copy can be produced while the satellite is passing over the station. The recorded tape is not affected by this monitoring, and further photographs can be made by rewinding the tape to the point of the beginning of the transmission and playing the recorded signal and synchronizing tones into the Photofax.

The APT signal from the American satellites TIROS-N and NOAA—6 carries two pictures multiplexed from two different parts of the spectral scan, usually visible and infrared. These two pictures are printed side by side, on the Photofax line printer; but when contrast and brightness tunings are made for one of the two photographs, the other one is effectively cancelled out and is unusable. The use of the tape recorder will enable both pictures to be printed in useable fashion making two separate replays of the tape and adjusting the Photofax controls as needed.

Another procedure that treats the same problem is called "line-blanking." This procedure blanks out one-half of the video line and allows the other half to pass so that only one of the two multiplexed photographs is produced at a time. A tape recorder is required for line-blanking. This procedure has not been used at the Chambersburg station. Refer to 9 and 30 for details on this subject.

The tape that is used for recording signals in the APT station is conventional audio recording tape. More expensive, high quality tape is most satisfactory if the tape is to be erased and reused a number of times. However, if the the transmissions are to be stored on tape for printing at a later time, a less expensive tape will be adequate. Such a procedure will require a greater quantity of tape and the expense of the higher quality tape can be saved if the tape is not going to be erased and reused a number of times.

IX

Locating and Tracking Polar Orbiting Satellites

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IX. LOCATING AND TRACKING POLAR ORBITING SATELLITES

In order to obtain high quality APT video using the direct readout station discussed in this publication, accurate information concerning locations, movements and times that the satellites can be received must be available. This is necessary because reception is possible only while the satellites are above the station horizon. Although all polar orbiting satellites have basic orbital characteristics in common, each spacecraft is unique in its orbital parameters and needs to be considered individually. The data necessary to locate and track these satellites is generally not difficult to obtain. The generation of future orbital information necessary for the daily operation of the station can be calculated by students. Antenna tracking of the satellite azimuth and elevation as it passes through the station's area of reception is a relatively easy task after the basic orbital patterns are understood.

Figure 21 shows a typical orbital path of a TIROS-N series satellite. A polar orbit, in strict terms, would carry the satellite directly over the north and south poles with an inclination of 90° to the equator. Both the TIROS and Meteor series satellites have near polar orbits that pass within 10° of the pole regions. These orbits will have slight inclinations relative to the equator.

The time required to complete one orbit is called the satellite NODAL PERIOD. This is measured from the time the satellite crosses the equator (0° latitude) moving northward (ASCENDING NODE) until the next northbound equator crossing. The southbound equator crossing is known as the DESCENDING NODE. During the NODAL PERIOD the earth rotates .25° per minute. This results in the next equator crossing occuring further west. This distance between equator crossings, given in degrees of longitude at the equator, is known as the satellite longitudinal INCREMENT. (INCREMENT = NODAL PERIOD [in minutes] X .25°).

If a satellite PERIOD, INCREMENT, and the equator crossing time are know, it is not difficult to predict future orbits for that satellite for days or months in advance. This is done by adding increments to a western hemisphere equator crossing and subtracting increments from eastern crossings. Also, nodal periods are added to determine the time of subsequent equator crossings. This is, however, a time consuming task if each orbit is calculated and recorded by hand. A pocket calculator is of some help, but a small computer would be of greater value. Students with some knowledge of programming can develop and run computer programs which will accurately predict orbits. These programs can take a variety of approaches from simple listings of equator

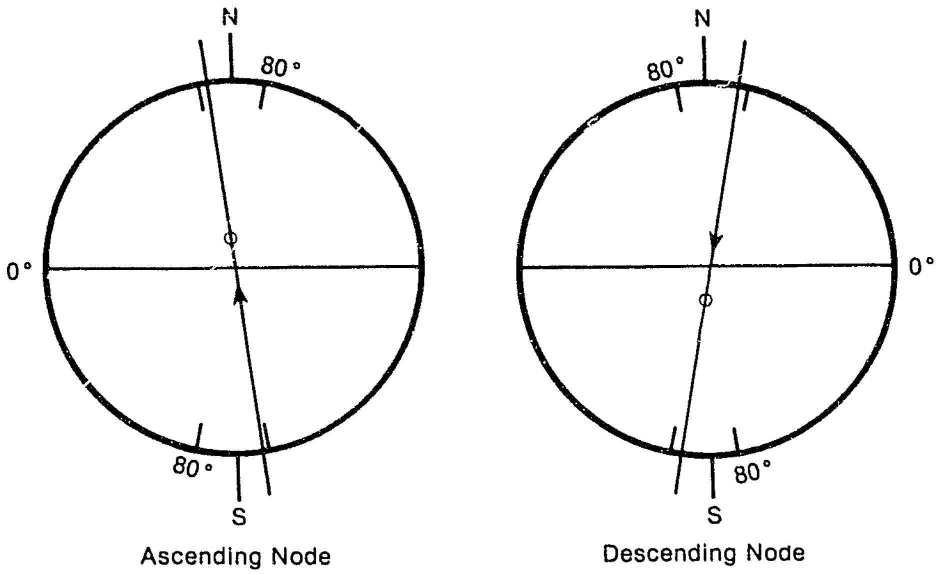

FIGURE 21
Typical Polar Orbit of United States
TIROS-N Series Satellites

crossing longitudes and times to more advanced programs giving antenna tracking information during each pass. Table 3 contains a flow chart that can be used to develop a program for basic orbital information. References 7, 23 and 27 can also be used for information on developing computer programs.

Current data concerning the status and equator crossing reference orbits for the U.S. polar orbiting satellites are available from a variety of sources. Similar data for the Russian satellites is not as easily obtained. APT Information Note 78-6 (Receipt and Use of Satellite Orbital Predict Information 6 Nov. 78) contains a number of sources of current data for both the TIROS-N and Meteor satellites. This and other valuable data on the TIROS-N series is available from:

Robert Popham, Coordinator
Direct Readout Services
U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Environmental Satellite Service
Rockville, Maryland 20852
Phone: (301) 763-8062

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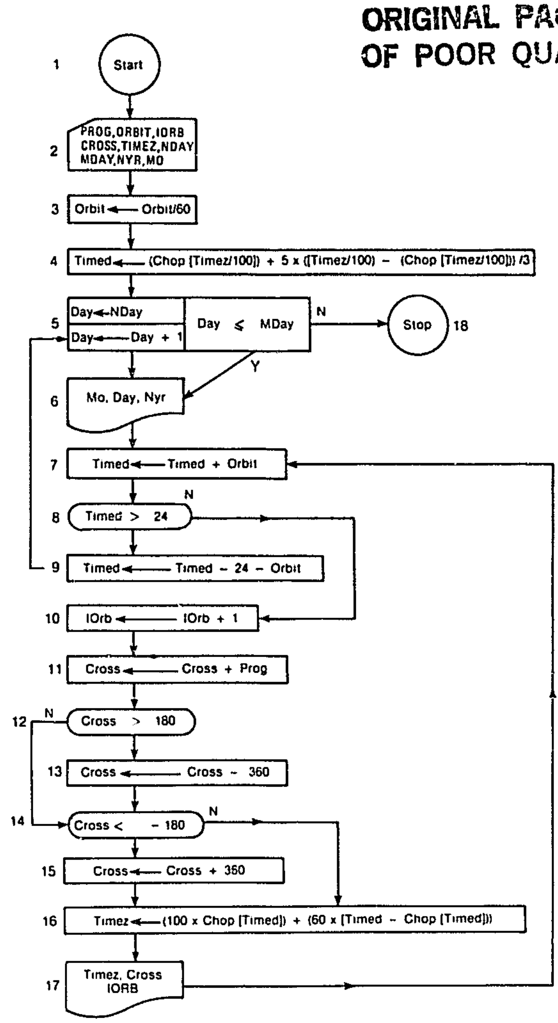

Table 3
Flow Chart for Developing a Program for Prediction of Basic Orbital Information

2. Input variables
   PROG "increment" of the orbit in degrees, positive for west negative for east
   ORBIT the period of the satellite's orbit in minutes and decimal fraction of minute
   IORB "orbit number" sequential integer value that counts the orbit
   CROSS the longitude of the satellite's equator crossing on an ascending node
   TIMEZ Time of the satellite's crossing in Greenwich Mean Time N
   NDAY Date of the reference orbit
   MDAY Number of Days in the month of the reference orbit
   NYR The year
   MO The integer number of the month
3. converts ORBIT in minutes to hours and decimal fraction of hour
4. converts ZULU time to hours and decimal fraction of hour
5. establishes loop to compute orbit information from the day of the reference orbit until the last day of that month
6. print the date
7. computes the time of the next crossing by adding the orbit's period to the last crossing time
8. if the time has become greater than 24, the orbit has moved into the next day
9. if the time was greater than 24, subtract 24 and the period from the time and advance into the next day by returning to 5
10. serial orbit counter
11. finds the longitude of the crossing by adding the increment to the last crossing
12. if CROSS is greater than 180 the increment has moved the crossing into the eastern hemisphere
13. the negative value derived from this operation represents an Eastern longitude
14. if CROSS is less than -180 the increment has moved the crossing into the Western hemisphere
15. the positive value derived from this operation represents a West longitude
16. convert the time in hours to Greenwich Mean Time
17. Print Time, Longitude of equator crossing, and Orbit number and return to 7 to compute next crossing.

Comments on Orbit Prediction Flow Chart

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This office will provide, upon request, a variety of information on the current status of the NOAA satellites including INFORMATION NOTES and monthly PREDICT DATA. The following is an example of the PREDICT DATA that is provided:

SATELLITE	ORBIT NO.	DATE/TIME	ASCENDING NODE LONGITUDE	NODAL PERIOD
NOAA-6	1797	1 Nov. 1979 0101.32	89.95° W	101.3052

INCREMENT	FREQUENCY
25.32	137.5

NOTE:

DATE/TIME: Time is given in Greenwich Mean Time (GMT) in hours, minutes and decimals of minutes. (01 hr. 01.32 min.)

ASCENDING NODE LONGITUDE: Equator crossing longitude of this reference orbit.

NODAL PERIOD: Time given in minutes and decimals of minutes.

INCREMENT: Given in degrees (NODAL PERIOD X .25° = INCREMENT)

This data is available monthly and can be used as a reference orbit from which future orbits can be predicted with good accuracy. Table 4 gives an example of each orbit, after this reference orbit, for a 24 hour period.

TABLE 4
Successive Orbits for NOAA-6 from 1 NOV. 79 to 2 NOV. 79

ORBIT NUMBER	DATE	ASCENDING NODE TIME (GMT)	ASCENDING NODE LONGITUDE IN DEGREES
1797	1 NOV. 79	0101.32	89.95 W
1798		0242.64	115.27 W
1799		0423.96	140.59 W
1800		0605.23	165.91 W
1801		0746.6	168.77 E
1802		0927.92	143.45 E
1803		1109.24	118.13 E
1804		1250.56	92.31 E
1805		1431.88	67.49 E
1806		1613.20	42.17 E
1807		1754.52	16.85 E
1808		1935.34	8.47 W
1809		2117.16	33.79 W
1810		2258.48	59.11 W
1811	2 NOV. 79	0039.8	84.43 W
1812		0221.12	109.75 W

Computed from reference orbit 1797:
Ascending node equator crossing time (GMT): 0101.32 (1 hr. 1.32 min.)
Ascending node longitude at equator: 89.95
Nodal period: 101.3052 min.
Increment: 25.32°

Note: When times are given in Greenwich Mean Time (GMT) it will be necessary to convert to local station time.

Table 5 contains the location in degrees of longitude and latitude, of NOAA-6 (orbit number 362) for every two minutes during this orbit. These locations are known as the satellite suborbital points. The suborbital points change with each orbit, but the orbital track which is traced over the earth's surface does not appreciably change during any orbit of this satellite. If these subor-

TABLE 5
NOAA-6 Sub-Point Track (Orbit 362)

ASC. NODE TIME 0232:57
ASC. NODE LONG. 105.5 W

HR.	MIN.	LAT.	LONG.	ALT. (Km)
2	34	6.5N	106.9W	828.8
	36	13.5	108.6	828.8
	38	20.6	110.2	829.2
	40	27.6	112.0	829.9
	42	34.6	114.0	830.9
	44	41.6	116.3	832.0
	46	45.5	118.9	833.1
	48	55.4	122.3	834.1
	50	62.2	126.8	834.8
	52	68.7	133.6	835.3
	54	74.9	145.5	835.3
	56	79.8	169.8W	835.0
	58	81.8	146.6E	834.1
3	00	77.6	111.8	832.7
	02	71.9	95.0	831.0
	04	65.5	86.2	823.8
	06	58.8	80.7	826.4
	08	51.9	76.8	823.9
	10	45.0	73.9	821.3
	12	38.0	71.4	818.9
	14	31.0	69.3	816.7
	16	24.0	67.5	815.0
	18	16.9	65.7	813.7
	20	9.8	64.1	813.0
	22	2.8N	62.5	813.0
	24	4.3S	60.9	813.7
	26	11.4	59.3	815.0
	28	18.5	57.6	817.0
	30	25.5	55.9	819.4
	32	32.6	53.9	822.3
	34	39.6	51.8	825.5
	36	46.5	49.3	828.8
	38	53.4	46.1	832.1
	40	60.2	42.0	835.3
	42	66.9	36.0	838.1
	44	73.2	26.1	840.5
	46	78.6	6.6E	842.4
	48	81.3	32.3W	843.7
	50	79.0	72.9	844.4
	52	73.7	93.8	844.5
	54	67.5	104.3	844.0
	56	60.9	110.5	843.0
	58	54.1	114.7	841.6
4	00	47.2	117.9	839.8
	02	40.3	120.5	837.9
	04	33.3	122.7	835.9
	06	26.3	124.6	833.9
	08	19.3	126.4	832.2
	10	12.3	128.0	830.7
	12	5.2	129.7	829.6

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bital points are plotted on a polar projection map, they form a track as shown in Figure 22. If this track is copied on a transparency and placed on the polar map shown in Figure 23 so that this transparency can be rotated about the north pole (X on Figure 22), a simple but effective satellite

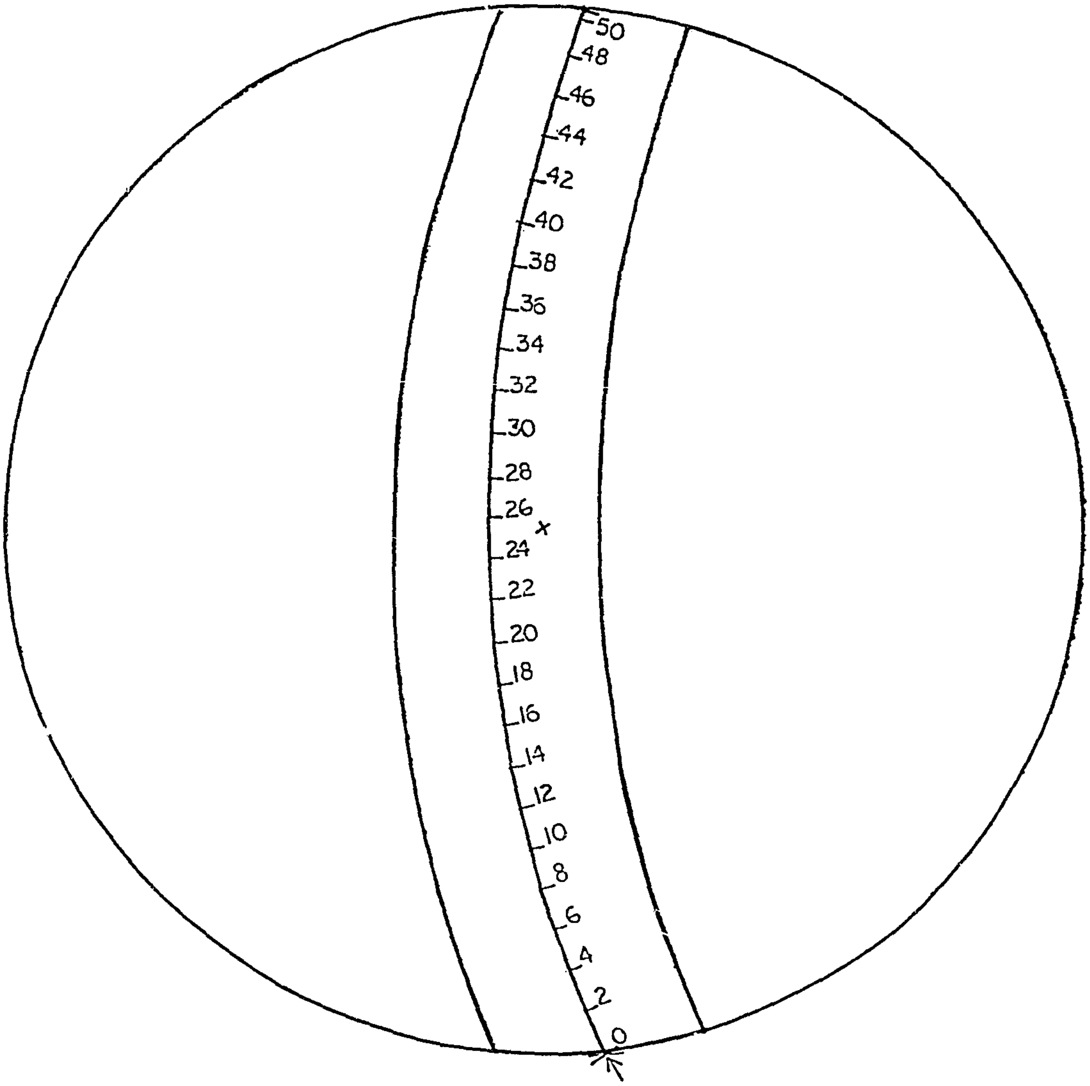

FIGURE 22
NOAA-6 Sub-Point Track Based on Orbit 362.

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tracking system is formed. By placing the arrow at any ascending equator crossing longitude, the path that the satellite will follow across the northern hemisphere during that orbit can clearly be seen. Each mark along the center track of Figure 22 represents 2 minutes of satellite travel after the equator crossing time. Also, the lines on either side of the satellite track represent the approximate area of video coverage that can be expected while the satellite APT is being received. (Scan width is approximately 2700 km).

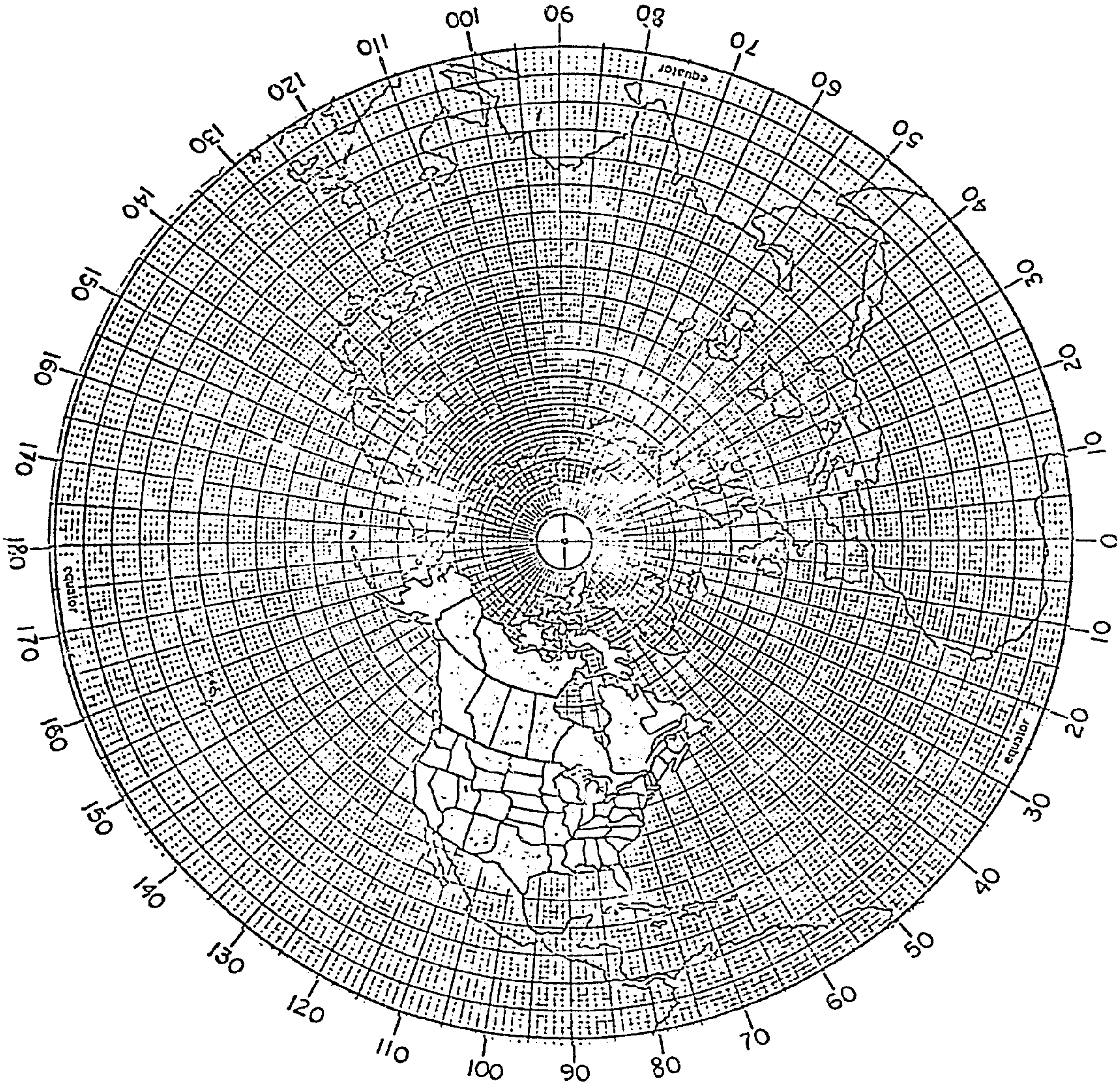

FIGURE 23

Table 6 gives the planned TIROS and approximate Meteor series orbital parameters. At the altitudes given, the APT station can expect to receive data from these satellites as they pass through a circular area with a radius of about 3100 km with the direct readout station at the center.

Figure 24 is a diagram of the satellite receiving area based on the general parameters of the TIROS satellites and drawn for a station location of 40° N latitude. This figure, drawn to the scale of the polar map in Figure 23 can be copied as a transparency and placed with the center of the circle at the direct readout station location. The outermost of the concentric circles represents the approximate receiving range of the station (radius = 3100 km). A satellite passing through this circle can be received with the antenna at the proper azimuth setting and at 0° elevation. The inner circles marked 2, 4, 6, and 8, represent the approximate antenna elevations X 10, in degrees, needed to receive the satellite as the satellite track intersects these circles. A satellite track crossing the center of the station will require a 90° elevation setting. Although these elevations are approximate, they are within the tolerances of the antenna beamwidth. This tracking map has also been used successfully with the Meteor satellites presently in operation.

TABLE 6
Nominal Orbital Parameters Planned for TIROS and Meteor Meterological Satellites

SATELLITE	ORBIT ALTITUDE (km)	INCLINATION	NODAL PERIOD	INCREMENT
TIROS SERIES	833	98.739°	101.38	25.40°
	870	98.899°	102.37	25.59°
Meteor Series	900	80°	102	25.5°

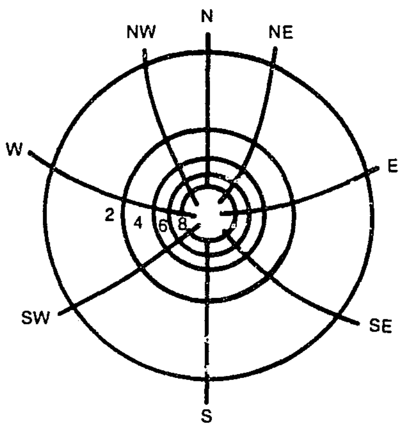

FIGURE 24
Satellite Receiving Area Drawn for a Station at 40° N Latitude

Figure 25 shows the tracking materials arranged for the direct readout station located at the Chambersburg Area Senior High School, Chambersburg, Pennsylvania. (Station location is 39.9° N/77.7 ° W). The satellite track is positioned for an ascending equator crossing of 63° W. This is a typical crossing for TIROS-N which has an afternoon ascending node at approximately 3:00 P.M. local standard time. The actual equator crossing time would be obtained from orbital predict data. Table 7 provides a tracking procedure for this pass.

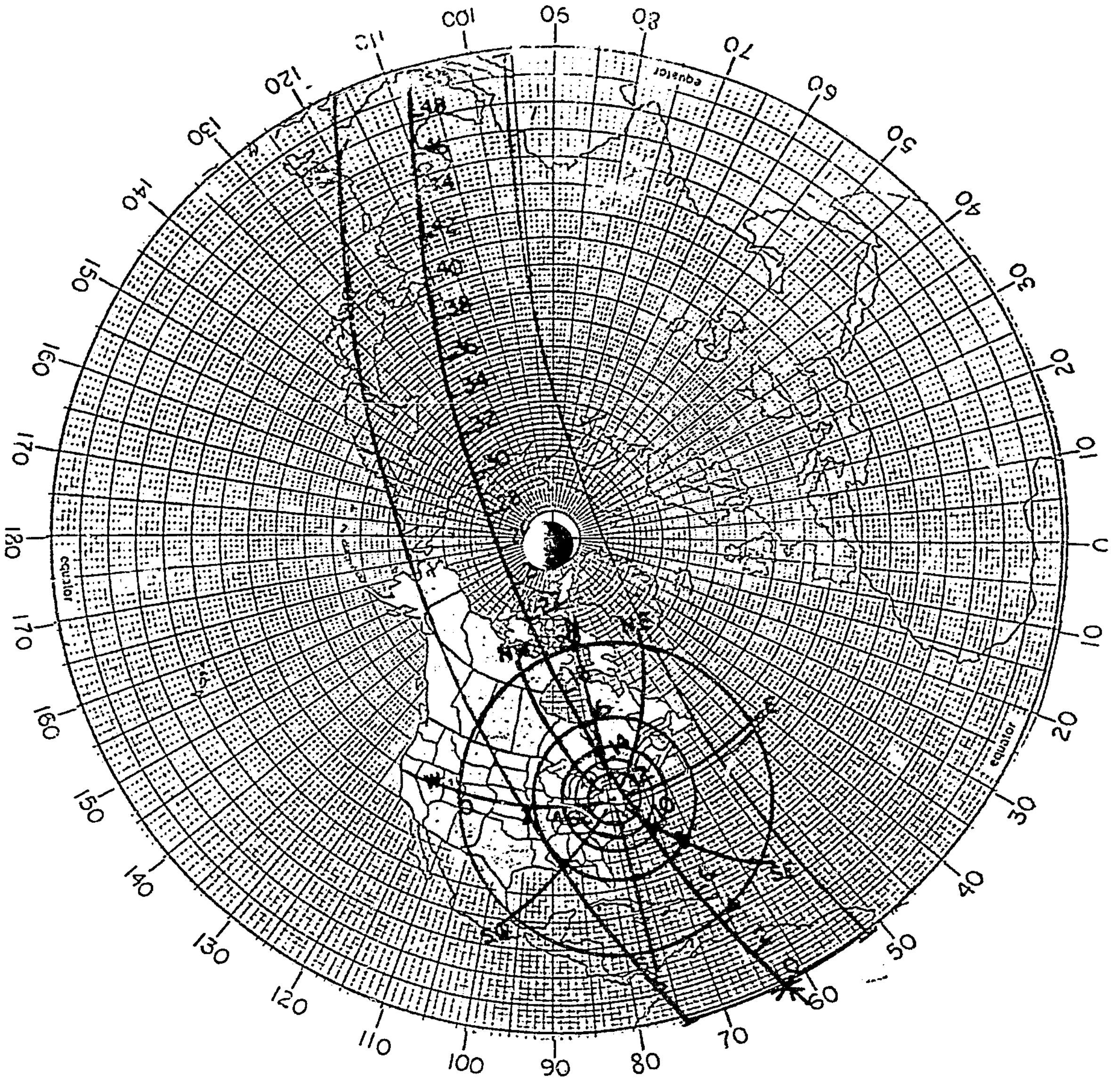

FIGURE 25
Tracking Materials Arranged for a Satellite Pass with an Ascending Node Equator Crossing of 63° W.

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TABLE 7
Antenna Tracking Procedure for Ascending Equator Crossing of 63° W As Shown in Figure 25

TIME	ANTENNA AZIMUTH AND ELEVATION		OBSERVATIONS DURING REAL-TIME PRINTOUT
0	EQUATOR CROSSING		
+ 4 min.	S/SE	0°	APT Signal Received
+ 6	S/SE	10°	Haiti, Cuba
+ 8	S/SE	20°	Florida
+ 9	SE	30°	
+ 9.5	SE	40°	
+ 10	SE	50°	East Coast—U.S.
+ 11	E/SE	60°	
+ 12	E/NE	80°	Overhead Pass—Long Island
+ 13	NE	70°	Great Lakes
+ 14	N/NE	50°	
+ 15	N	30°	James Bay
+ 16	N	20°	
+ 17	N/NW	10°	Hudson's Bay
+ 18	N/NW	10°	Loss of Signal

THE TIROS SATELLITES

This latest United States polar orbiting meterological satellite system, as with previous systems, is a NASA and NOAA cooperative program. The first satellite of this series, TIROS-N, was launched on October 13, 1978. The second spacecraft of this series, NOAA-6, was launched June 27, 1979. Both of these satellites are presently in operation. However, TIROS-N experienced an on-board computer failure in January of 1980 and subsequently operated on a back-up system. Replacement of this satellite was planned. This will be the practice throughout the series whenever failure occurs. Whenever TIROS-N is replaced, the next satellite of this series will be designated NOAA-7. The INFORMATION NOTES available from the office of the Coordinator of Direct Readout Services of NOAA is one of the best sources of the current status of the satellites in this program.

Throughout the TIROS series program it is planned to maintain two satellites in sun-synchronous orbits at all times. The nominal orbital parameters of this pair have been given in Table 6. These two different sets of orbital parameters are designed to keep the orbital periods sufficiently different so that the satellites do not both view the same point on the Earth at the same period each day.

NOAA-6 is operating with a descending node equator crossing occurring between 0600 and 1000 Local (Solar) Time. Thus, the visual passes of this satellite occur during the morning hours of the day. Night time ascending nodes are available to the direct readout station about 12 hours later transmitting infrared pictures. TIROS-N, was placed in orbit so that it has an ascending node equator crossing between 1400 and 1800 Local Solar Time. This satellite, then passes the direct readout station during the afternoon hours each day. The descending node passes also occur about 12 hours later, in the early morning night time hours.

A complete description of these satellites, systems, etc. is not possible here. The publication:

The TIROS-N/NOAA A-G Satellite Series
NOAA Technical Memorandum NESS 95
Washington, D.C. March 1978

contains most of the information of interest to a direct readout station. This and other printed material related to environmental satellites is available from:

Environmental Science Information Center (D822)
Environmental Data Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce
6009 Executive Boulevard
Rockville, Maryland 20852

Table 8 gives the general information on some of the APT characteristics of the TIROS satellites.

TABLE 8
APT Characteristics for the TIROS-N Series Satellites

Carrier Frequency	137.5 MHz 137.62 MHz	Both frequencies are available on each spacecraft, one will be used as the primary frequency.
Modulation	Frequency (FM)	
Deviation	± 17 kHz	
Transmitter Output Power	5 watts	
Sub-carrier Modulation	AM	
Scan Speed	120 Lines/minute	
Picture Phasing	7 pulses at 1040 pulses per second, for channel A 7 pulses at 832 pulses per second, for channel B	

THE RUSSIAN METEOR SERIES OF APT SATELLITES

Prior to 1977, the Russian Meterological satellites were turned on only within the borders of the U.S.S.R. During the summer of 1977, it was discovered by Charles Vermillion's Direct Readout Applications Group at NASA that the Russian Meteor APT system was transmitting video at 137.3 MHz. Another Russian satellite, transmitting high resolution pictures at 137.15 MHz in a 240 line/minute video format, was received intermittently while passing over the United States. This satellite, however, began showing video abnormalities and has no longer been received at this station. This satellite was first reported by amateur radio operator W.J. Watt WB3BMY of Conyngham, Pennsylvania.

Current operational status of the Russian Meteors and up-dated information of orbital parameters of these satellites are not routinely made available from the U.S.S.R. There are, however, sources of orbital information available, mainly from radio amateurs who track these satellites on a daily basis. Some of these sources are available from Robert Popham, Coordinator, Direct Readout Services, NOAA. Table 9 gives general information on the APT characteristics of the Meteor series satellites.

TABLE 9
APT Characteristics of the Meteor series satellites:

Carrier Frequency	137.3 MHz
Modulation	Frequency (FM)
Deviation	± 15 kHz
Transmitted Output Power	5 watts
Sub-carrier	2400 Hz
Sub-carrier Modulation	AM
Scan Speed	120 lines/minute
Picture Phasing	90-100 milli-seconds of AM subcarrier at a frequency of 256 Hz.

X

The Use of Direct Readout Stations and Weather Satellite Products in Science Education

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X. THE USE OF DIRECT READOUT STATIONS AND WEATHER SATELLITE PRODUCTS IN SCIENCE EDUCATION

The construction of a direct readout station for weather satellite APT requires some effort and expense. The results of this effort will provide an unusual and effective tool for science education.

Current uses of weather satellite products are numerous. They include studies of weather systems and prediction, frost dangers, snow and ice mapping, agriculture applications, forest management, marine studies and training forecast personnel. The degree to which students can utilize a local station's products will depend on the quality of the satellite pictures and the skill the students develop in the interpretation of these pictures. Essentially, the station can be a source of original research material that can be used to develop student projects.

Although there are many ways that teachers can utilize a direct readout station in the science classroom, one approach can be to use the station and its products as the focus of a program of instruction. A number of peripheral projects could be developed that would allow students, with a variety of abilities and interests, to obtain a first-hand experience in working on a real scientific project. The supporting activities could encompass different fields of scientific endeavor and be as extensive or as limited as necessary within the confines of the local school and its available resources. The activities could include:

1. The development of electronics and hardware of the station with emphasis on construction and improvement of various components.
2. Training of students to operate station equipment.
3. The development of computer programs for orbit predictions.
4. Development of tracking maps to locate the spacecraft during its orbits.
5. Studies of satellite orbital mechanics.
6. The development of map overlays to conform to the pictures received at the local station.

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7. Analysis of photographs with studies of:
   a. Local patterns and weather predictions.
   b. Geographical studies of landforms.
   c. Ice and snow development and melting.
   d. Severe weather development and tracking.
8. Maintaining daily records of local weather conditions for correlation with satellite photographs.
9. Development of original scientific papers concerning various aspects of weather satellite projects.
10. The development of daily weather reports.
11. Providing facilities for fieldtrips of visiting students.

Specific classroom/laboratory study programs in which satellite data acquisition and use have been made include electricity and electronics, physics, mathematics, computer sciences, astonomy, meterology, oceanograpy, hydrology, geography, and geology.

XI

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XI. REFERENCES AND SUGGESTED READING

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XII

Glossary

XII. GLOSSARY

amplitude modulation	AM—the strength (amplitude) of a signal is varied (modulated) to correspond to the information to be transmitted. As applied to APT, an audible tone of 2400 Hz is amplitude modulated, with maximum signal corresponding to light areas of the photograph, the minimum levels black, and intermediate strengths the various shades of gray.
analog	a system of transmitting and receiving information in which one value (i.e. voltage, current, resistance, or, in the APT system, the volume level of the video tone) can be directly compared to the information (in the APT system, the white, black, and gray values in the photograph). Compare to digital.
APT	Automatic Picture Transmission—one function of weather satellites which transmits earth scan photographs to direct readout stations in real time in an analog video format. Transmission consists of an amplitude modulated audible tone which can be converted to photographs when fed to an appropriate line-printing device.
ascending node	the portion of a polar orbiting satellite's orbit which passes over the earth from south to north.
azimuth	compass direction.
AVHRR	(Advanced Very High Resolution Radiometer)—A five channel scanning radiometer on the TIROS series satellites sensitive in the visible, near infrared and infrared spectural regions. TIROS Automatic Picture Transmissions are derived from this instrument.
bandwidth	in FM, radio frequency signal bandwidth is the amount of deviation of the signal.
carrier	in radio, an rf frequency capable of being modulated with some type of information.
circularly polarized rf	radio frequency transmissions where the wave energy is divided equally between a vertically polarized and a horizontally polarized component.

db	decibel—the unit of measuring the intensity of a sound expressed as a ratio to a reference level. The decibel is also used to measure relative strengths of antenna and amplified signals and always refers to a ratio or difference between two values.
descending node	the portion of a polar orbiting satellite's orbit which passes over the earth from north to south.
digital	a system of transmitting and receiving information in which the source is periodically sampled, analyzed, and converted or coded into numerical values. These numerical values are then transmitted and must be decoded at the receiver's end. Digital transmissions typically use the binary coding used by electronic computers and require rather expensive hardware to decode. Many satellite transmissions use digital formats because noise will not interfere with the quality of the end product and therefore, clear and higher resolution photography is possible.
Doppler shift	Doppler effect—the shift in frequency of a radiated signal due to relative motion between the transmitting source and receiving position.
elevation	angle above the horizon.
facsimile (FAX)	a process where graphic or photographic information is transmitted or recorded by electronic means.
frequency modulation	FM—the frequency of a transmission signal is varied (modulated) from a given center frequency to correspond to the information to be transmitted. As applied to APT, the radio signal from the satellite is broadcast on an FM band of the radio spectrum, requiring an FM radio receiver for proper reception.
Hertz—MHz—kHz	Hertz is the unit of measuring the frequency of any radiated signal. One Hertz equals one cycle per second. Radio frequencies are expressed in the decimal multiples of Megahertz (1,000,000 cycles) and Kilohertz (1,000 cycles).
IC	integrated circuit—a solid state electronic circuit which consists of several micro components constructed to perform a specific function.
ips	inches per second—unit of measuring tape transport speeds in tape recorders. From slowest to fastest, the usual tape speeds available are 1-7/8, 3-3/4, 7-1/2, and 15 ips.
kilometer	metric unit of distance equal to 3,280.8 feet or .621 miles.
Meteor	the Soviet Union's series of polar orbiting weather satellites. The Meteor satellites transmit photographs in a system compatible with the NOAA and TIROS satellites.
MHz	Megahertz—see Hertz
NASA	National Aeronautics and Space Administration
nautical mile	a unit of distance equal to 1/60 of a degree or about 6,076 feet.
NESS	National Environmental Satellite Service.
NOAA	National Oceanographic and Atmospheric Administration.
ohm	the unit of electrical resistance.
printed circuit	a fiber card on which integrated circuits and other electronic components can be mounted. Connections between the components are etched in the correct circuit patterns.

signal to noise ratio how much a signal stands out above the receiver noise. Usually given in microvolts per db of quieting.

Sun-synchronous describes the orbit of a satellite which provides consistent lighting of its earth scan view. The satellite passes the equator and each latitude at the same time each day. For example, a satellite's sun-synchronous orbit would cross the equator twelve times a day, each time at 3:00 P.M. local time. The orbital plan of a sun-synchronous orbit must also precess (rotate) approximately 1° degree each day to keep pace with the seasons. The satellite's orbital plane always intersects the sun and the earth's surface.

TIROS Television Infrared Observation Satellite

yagi a type of receiving antenna which has several rod elements mounted on a beam. Its directional pattern of sensitivity and ease of construction make it ideal for APT direct readout stations.

NASA-Langley, 1981