Reception of Pictures from the Weather Satellites Using Homemade Equipment

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Part II: Equipment and Results

In Part I the satellite orbit and the way in which it views the entire earth were described. In this part we shall consider the transmission of the pictures and their reception at a station on the earth, and see some examples of the results.

The system used for transmission is similar to that of television. In ordinary TV the entire picture area is scanned (525 horizontal lines) every 1/30 of a second. In the transmission from the satellite 200 sec are required for the picture area to be scanned once. There are 800 horizontal lines in the satellite picture. If this were put on a TV tube or an oscilloscope tube, one would not see a picture, because the persistence of the eye is not long enough to store the image for 200 sec. Only by photographing the screen, with the camera left open for the 200 sec, does one get the picture. That is essentially the way it is done, as I explain later.

Up in the satellite, the image is scanned off a small (1 in. × 1 in.) vidicon tube. The image is put on the sensitive surface of the tube by a snapshot exposure of the earth below, and the tube has enough persistence so that it remains there for the 200 sec required for scanning. After the transmission of the picture there is a waiting period of about 3 min. At some time during this interval the old image is removed from the vidicon tube. Then a new exposure is made and the scanning begins again. The way in which the successive pictures just overlap was explained in Part I.

The anatomy of my receiving station is shown in Fig. 1, as a block diagram. I will go through it, briefly, starting from the antenna.

Let me preface the description by stating one fact that pervades all of the design: it is that electrical power in the satellite is at a great premium, and for that reason the whole system is designed so that the received signal is just strong enough for excellent pictures, provided everything at the ground end operates at near the maximum attainable signal-to-noise ratio. I do not want to scare you, if you are planning on building a station, but you may as well be prepared for this fact. To merely hear the satellites go over, quite a poor receiver will suffice, and that is in fact what I worked with at the beginning. The transmission is truly amazing. The power is only 5 W, and it is received with reasonable picture quality as soon as the satellite comes over the horizon, which is some 2000 miles away. Compare this with your local TV station, perhaps 50 miles away, and using 100,000 W! Part of this difference comes from the fact that pictures are transmitted at only about 1/600th the rate, and part of it comes from the fact that the transmitter is 900 miles above the earth, in line of sight. (It makes one realize that the talk about having our TV programs transmitted from satellites in the future makes a good deal of sense.)

In order to gain signal strength, one must use an antenna that is highly directional. The sharpness of mine is

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Fig. 1. Block diagram of the system.
seen as the upper deck of the piece of equipment in the center.

The output of the FM receiver is a 2400-cps (Hz) tone, whose amplitude varies to control the brightness of the scanning spot on the cathode ray tube. The horizontal sweeps (4/sec) of the oscilloscope are triggered by pulses obtained from a scaling circuit which scales the 2400-Hz sub-carrier down by 1/600. This keeps the oscilloscope synchronized with the scanning of the vidicon tube in the satellite. The vertical sweep of the oscilloscope is produced by a local R–C discharge circuit. The spot has to move from top to bottom in 200 sec, or in 800 vertical sweeps. The scaler, vertical sweep circuit, and other necessary trimmings are seen as the lower deck of the 2-deck piece of equipment in Fig. 3. This has been a very sketchy description of the electronics, and it is not intended to be

indicated by the fact that the power drops to half if it is off its aim by 19 deg. The polarization of the radiation received from the satellite also has to be considered. It is elliptically polarized, of varying degrees of ellipticity, and the plane of the maximum E-vector changes with the aspect of the satellite as it goes by. The sense of the elliptical polarization is, almost all of the time, right-handed. It would be difficult to try to follow the changing polarization, and the best compromise is to use an antenna that is designed to receive right circular polarization. My antenna is shown in Fig. 2. It is the familiar Yagi construction, the main difference from a commonly used antenna being that at each position there are two elements at right angles, to achieve the circular polarization. The wavelength is 2.2 m (137.5 MHz) and the elements are therefore 1.1 m long.

The 137.5-MHz signal is frequency modulated. This is not far in frequency from the FM broadcast band (90–105 MHz) and it would not be difficult to modify an ordinary FM receiver to receive the satellite. A preamplifier might have to be added, to improve the sensitivity. The frequency is also close to that of the “2-m” (145–148 MHz) ham band. Being a ham, I chose to start with some cast-off 2-m equipment and to modify its frequency. Since the ham equipment was AM rather than FM, it was necessary to wire up an FM detector to follow the rf amplifiers and converter. In Fig. 3 the FM receiver can be

Fig. 2. The author inspecting the tracking antenna. The two rotors, remotely controlled, permit coverage of the entire sky. The plastic bag over one rotor is to keep the rain out. (It is not water-tight when horizontal.) The antenna is made of aluminum tubing and is counter-balanced.

Fig. 3. Foreground, left to right: Antenna controls, receiver (upper deck), scaler and sweep circuits (lower deck), tape recorder, and 4 in. × 5 in. camera with Polaroid adaptor. In rear: plotting board (described in Part 1), 3-in. oscilloscope for monitoring synchronization, and 5-in. oscilloscope for pictures.

Fig. 4. Picture from ESSA 6, 15 April 1968. Lake Michigan shows clearly through the large hole in the cloud cover. Parts of Lakes Superior and Huron are also visible. The regularly spaced bands running diagonally were produced by a slight amount of 60-cps ripple in the voltages of the oscilloscope. The fiducial crosses and the USA are transmitted from the satellite.
down the times, keep the receiver tuned, and maintain the
signal output volume at constant level, against some rather
rapid fluctuations in rf signal strength. My ears are occu-
pied also, as I listen to the 2400-Hz signal on a loudspeak-
er, to check the quality of reception. You can see why I
want to store the signal on tape at the output of the recei-
er!

Later (and it has to be at night because the camera–os-
cilloscope system is not light-shielded) I simply play the
tape into the rest of the circuit, namely the scaler, oscillos-
cope, etc. There is enough to occupy me in that operation
also. Synchronization and phasing have to be established
correctly at the start, the camera has to be opened and
closed, the focus and intensity controls have to be ad-
justed.

The latter is necessary because the oscilloscope is an
antique one. As a challenge I have done the whole show at
once, omitting the taping, but there is a great likelihood
of “goofing” in some detail and losing the picture irretriev-
eably. I might mention that the requirement on the tape
recorder is minimal, as all of the frequency components
are right in the audio range; none are over 4000 Hz.

When I presented this paper as a talk at Temple I was
able to play a sample tape over the loudspeaker. This is
interesting to do, because, as I demonstrated there, one
can tell just by listening, whether the picture is of over-
cast, broken clouds, or clear weather. I have a drawer full
of tape and will be glad to give away pieces to anyone
who wants to demonstrate his skill at hearing the weather.

Two samples of the many pictures received are shown
in Figs. 4 and 5 and explained by their respective captions.

The apparatus is not now operated on a regular basis, but
is only kept in readiness for any unusual weather occu-
rence. It has not yet been operational during a major
hurricane. I do not wish anyone disaster, but I am await-
ing the next hurricane with great interest. The Caribbean
is well within my range of view.

3 C. H. McKnight, QST 52, 28 (April 1968).
4 C. M. Hunter and E. Rich, Jr., Electronics 37, 81 (27 July
1965).
5 “Constructing Inexpensive Automatic Picture-Transmission
Ground Stations,” A Technology Utilisation Report, NASA
SP-5079. (From APT Coordinator—see Part I.)
6 G. Toben, Ham Radio 1, 6 (November 1968).

Fig. 5. Two successive pictures from ESSA 6, 5 May 1968. The Gulf
of California can be seen in the lower one. Great Salt Lake can be
seen to the left of, and below center in the upper picture. The two
pictures together extend approximately as far East as the Great Lakes,
and into Canada to the North. The satellite made the second exposure
at about the time it passed over the Mexican Border. At the end of
the transmission it was over the Pacific Ocean. The horizontal band
of poor quality at the bottom shows that the satellite passed out of
the range of reception from Ann Arbor before the transmission was
completed. As in Fig. 4, the regularly spaced bands are instrumental.

a guide for construction. The latter would require much
more space than the editors would allow me. I have given
some references as to where more detailed information
about circuits may be obtained.\textsuperscript{2,7}

In Fig. 1 and 3 you will see a tape recorder. This is
optional, but since I have only two hands and one head, I
find it almost indispensable. When the satellite is passing
over I have to operate the two antenna controls, write