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A satellite automatic picture transmission (APT) ground receiving station

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ABSTRACT. The paper describes a satellite automatic picture transmission (APT) ground receiving station, designed and developed at the Instruments Division, Meteorological Office, Poona. The station has been in operation at Poona for over six months and has provided good quality visible and infrared pictures from meteorological satellites ESSA-2, ESSA-8, Nimbus-3 and ITOS.

The station uses a high gain right circularly polarized helical antenna, a highly sensitive and selective FM receiver and a Mufax facsimile recorder modified suitably to record the satellite cloud pictures. The paper highlights the design details of the antenna and the FM receiver and also describes the necessary modifications to the 'Mufax' facsmile recorder for recording correct satellite pictures. Future development plans are also briefly discussed.

1. Introduction

The APT subsystem on meteorological satellites is a camera and transmitter combination designed to transmit, slow scan television pictures of the cloud cover below the spacecraft at the time of transmisson. When the satellites cross the day portion of the globe in their near polar orbits, an internal sequence timer exposes the vidicon television camera and begins the readout process a few seconds later to accomplish automatic picture transmission. In the Direct Readout Infrared satellite system (DRIR) designed to take night time pictures, infrared radiometer scanning is used. Nimbus-3 satellite has both the APT and the HRIR (High Resolution Infra Red) systems.

The day time readout is accomplished in a satellite by scanning the stored picture from the face of the vidicon. This picture is scanned 800 times resulting in 800 lines of picture information. For transmitting daylight information the scanning is done at the rate of four lines per second and 200 seconds are thus required to transmit (and receive on ground) one complete picture. An additional 8 seconds period is reserved for each APT picture frame during which a "start" tone and "horizontal phasing pulses" are transmitted. The total picture taking and transmission thus require 208 seconds.

For taking the night-time infrared pictures of the earth, a radiometer effective scan rate of 48 r.p.m. is used. The information is stored either on magnetic tape prior to being transmitted or it is transmitted as it comes, line by line. The DRIR system is designed to take and transmit only one continuous unframed picture during the night-time operation. In the ITOS satellite the format has been changed further to transmit the day light picture immediately followed by the infrared readout and the sequence is repeated.

The current beam resulting from the scanning is used to amplitude modulate a 2400 Hz subcarrier which in turn frequency modulates the APT transmitter carrier for relay to the waiting station. Fig. 1 shows the signal structure from an APT equipped satellite.

The satellite radiates approximately 5 watts of power in a right hand circularly polarized wave and clear signals from the spacecraft are received when it is within acquisition range of a ground receiving station. The basic requirements for building a satellite ground receiving station are thus an appropriate antenna, a receiver and a recorder compatible with slow scan TV transmission from a satellite.

2. The APT receiving station

The station consists essentially of a helical antenna, a 135-140 MHz, crystal controlled FM receiver and a Mufax recorder modified to make the recording helix rotation speed and the helix size compatible to the APT (or DRIR) scan.

2.1. *The antenna*

The antenna is a critical component of the system. The recommended antenna gain is 11 db for elevations from 5 to 90 to 5 degrees. A gain of 9 db for elevations from 15 to 90 to 15 degrees ensures local coverage. A beam width of about 20—40°, wide enough to provide easy tracking, yet narrow enough to yield sufficient gain is recommended.

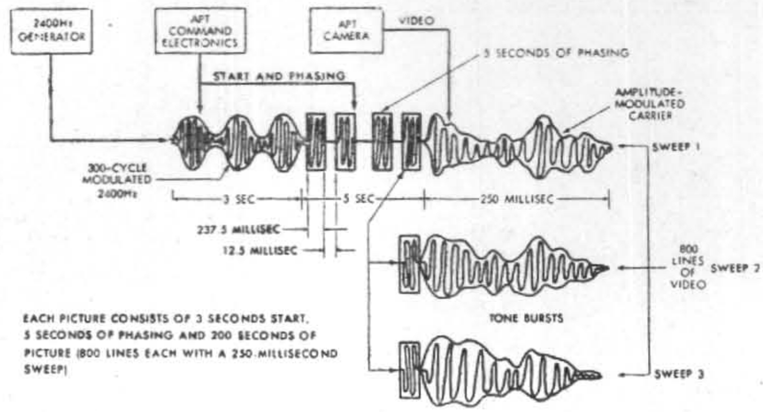

Fig. 1
Signal structure from an APT equipped satellite

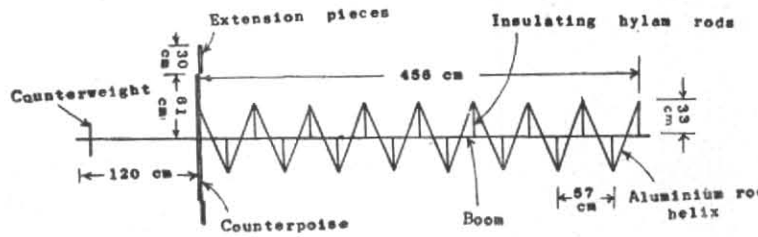

Fig. 2
Antenna dimensions

Fig. 3
APT ground receiving Helical antenna

Fig. 2 gives the antenna dimensions. The counterpoise is a circular aluminium plate, 120 cm in diameter strengthened with three aluminium angle ribs. Fig. 3 shows a photograph of the APT antenna. A 0-90-0 degree scale mounted on the antenna horizontal support and two scales, one graduated in degrees from 0 to 360 and the other a reference scale showing the principal directions N,E,S,W fixed to the pedestal axle hub were used to initially train the antenna for a 'Look Angle' and for tracking. The weight of the antenna with cunterpoise is 35 kg (excluding 80 kg counterweight fashioned from M.S. plates).

2.2. *The FM Receiver*

In the present design, a crystal controlled transistorised FM receiver, made at BEL, Bangalore, is used. The receiver is designed to receive the satellite frequencies 135·6 MHz Weather Facsimile (WEFAX); 136·95 MHz (NIMBUS); 137·5 MHz and 137·82 MHz (ESSA). A double superhet receiver with a sensitivity better than 1 microvolt, and the signal to noise ratio (S+N)/(N) 20 db., it has a ± 10 KHz deviation acceptance, 50 db spurious image rejection, 60 db adjacent channel rejection, and a selectivity of 3 db at ± 13

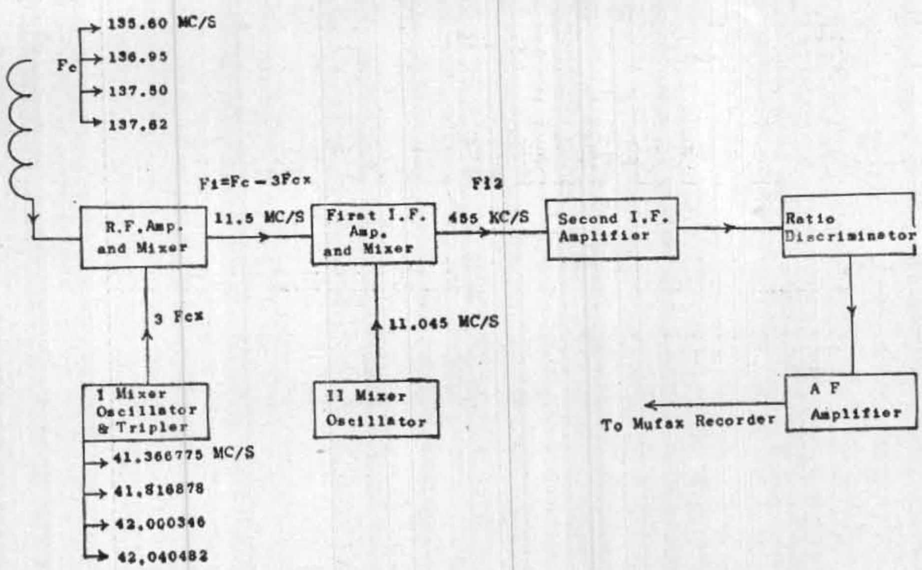

Fig. 4
Schematic block diagram of the receiver

KHz, 6 db at $\pm 17\cdot 5$ KHz and 70 db at ± 30 KHz. It possesses a frequency stability of better than ± 20 ppm over a temperature range of 0° to 45°C. Fig. 4 is a schematic block diagram of the receiver. The channel frequency from the aerial is fed to the RF amplifier having a tuned input circuit. The amplified carrier channel frequency is mixed with a suitable crystal controlled frequency from the 1st mixer oscillator (Fig. 4) to yield a 11·5 MHz first IF. This is further mixed with a 11·045 MHz frequency from second mixer oscillator, also crystal controlled, to yield the second IF, 455 KHz. This is amplified and then detected in a transformer-diode ratio detector. The resulting audio is fed to an audio-amplifier having a complementary symmetrical transistorised output stage. The final output, free of cross over distortion, is fed in parallel to the APT recorder and speaker and is also recorded on a magnetic tape.

2.3. *The Recorder*

For recording the APT /HRIR picture a 'Mufax' chart recorder D-649/18″ was used after some modifications. The satellite video output from the receiver is a standard facsimile format and is adaptable to any 240 r.p.m./48 r.p.m mechanical facsimile recorder. The Mufax facsimile uses a 60, 90, 120 r.p.m. recording. The length of the recording helix in the Mufax recorder is 18″.

The Mufax D-649/18″ recorder uses a 720 r.p.m. hysterisis motor to drive the recording helix. The helix drive was converted from 120 to 240 r.p.m. by modifying the hysterisis motor shaft pinion-gear pair from its initial 32 : 96 teeth ratio to 32 : 48

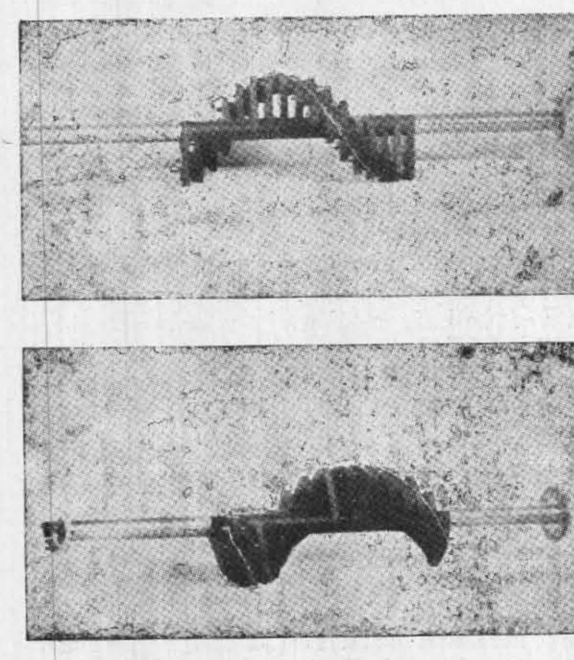

Fig. 5
The 8″ recording Helix

teeth ratio. For HRIR recording the helix drive similarly changed to 48 r.p.m. For obtaining cloud pictures with good black-white contrast, the existing 18″ recording helix was replaced by an 8″ recording helix (Fig. 5).

The recording electronics of the Mufax recorder was also slightly modified. Fig. 6 shows the schematic block diagram of the Mufax recorder. The SCFM/CS converter channel shown in dotted lines is not used for APT recording. In the normal

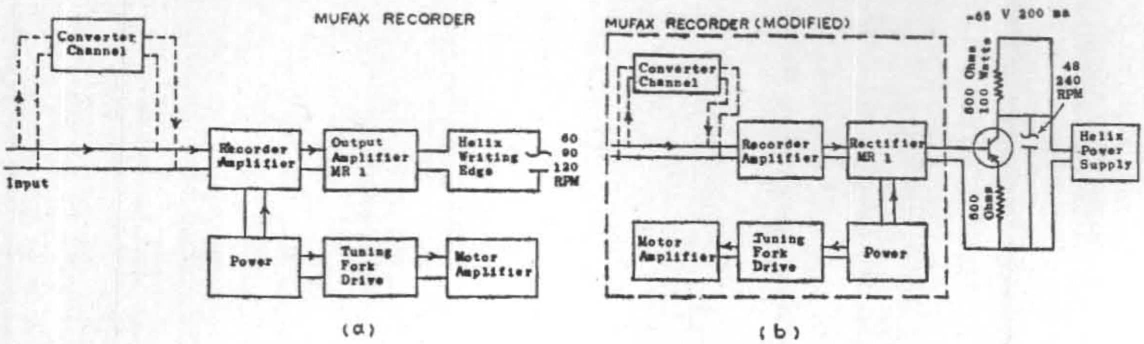

Fig. 6. Schematic diagram

facsimile AM recording, the input signal is amplified and the output signal after rectification is connected to the helix blade (—ve) and the writing edge (+ve) so that a negative high going voltage at the helix blade causes a higher dark current to flow through the electrosensitive recording chart paper. A high voltage input thus corresponds to a high recording current through the chart paper. For proper recording of the APT pictures however, a current through the recording paper inversely linearly proportional to the input facsimile voltage is needed. This is achieved by shunting the chart paper resistance between the helix blade and writing edge with a circuit which would offer a low resistance to the current whenever the rectifier (MRI) output is high thus causing less current to flow through the chart paper for high facsimile input voltages. The helix is now supplied with a recording —ve high voltage from an independent low impedance power supply. Fig. 6(b) shows this modification with reference to Fig. 6(a). With proper adjustments of the helix supply voltage and the other controls of the Mufax chart recorder, *i.e.*, amplifier gain (Marking power) etc., correct APT pictures could be obtained.

The tracking data for the satellites is worked out from the APT 'predicts' originated by NASA, U.S.A. and received at New Delhi. The 'predict' is in four basic sections. The first section contains information on equator crossing time (Ascending Node Time) and longitude (Ascending Node), nodal period and nodal longitudinal increment; the second section gives the predicated sub-point and height data at two minute intervals for the sunlit portion of the orbit north of the equator; the third section gives similar information for the sunlit portion of the orbit south of equator and the last section is reserved for remarks pertinent to the operational aspects of the system. From this information, satellite sub-point tracks are plotted on a plotting board containing a tracking diagram inlay, especially recommended for the purpose by NASA. These sub-point tracks enable one to work out the useful spacecraft orbits within the reception area of the ground station and also the tracking data for these orbits. The APT ground receiving system is switched on a few minutes before the start of a satellite pass and the helical antenna is set to 'Look Angle'. As the satellite rises, clear APT signals are received from elevation 5—10° upwards, and pictures are recorded. The output signal can be monitored on any good CRO connected in parallel to the APT recorder indicating the 'noise', the signal strength etc. The audio speaker output is of great help in good tracking. The receiver output can also be recorded on a good quality stereo tape recorder with one channel for video and the other for 'sync' signal and can be played back again. For use in the study of weather systems and in forecasting, the satellite pictures are required to be adequately gridded after giving due allowance to the deviations resulting from incorrect satellite attitude due to satellite roll, pitch or yaw. Necessary information in respect of the corrections needed to allow for these deviations is contained in part 4 of the APT predict.

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Vermillion, Charles, H. — 1968 *Constructing Inexpensive APT ground stations*— Rep. Tech. Utilization Div., NASA, Wash., D.C.

DISCUSSION

(Presented by S. V. Datar)

SHRI V. BALASUBRAMANIAM : Is there any plan to fabricate photofax equipment?

MISS A. MANI : The cost is prohibitive.

DR. P. KOTESWARAM : Apart from the cost, at almost all centres where photofax is in operation, a paperfax has to be used for monitoring purposes.