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A technique for receiving expanded scanning radiometer (S.R.) pictures

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ABSTRACT. The modified versions of Improved TIROS Operational Satellite Series ITOS-D(NOAA.2) and subsequent future satellites of U.S.A. shall have a Scanning Radiometer (S.R.) on board for direct read out of data both in the day as well as night time. The transmission from satellite equipped with S.R. consists of signals for infrared as well as visible picture portion, which are recorded side by side, to yield pictures of a width which is only one third of the AVCS pictures of ESSA-8 satellites. As these pictures of such narrow size are of only limited use to the forecasters, therefore a method has been developed to expand these pictures. It uses an APT recorder working at 48 r.p.m. with double the normal speed of paper take and replacement of 360°-helix (full helix) wire by 180°-helix (half helix) wire on the drum of the dimension recommended for normal reception of NOAA-2 pictures.

1. Introduction

USA weather satellites of the TIROS operational series employed Automatic Picture Transmission (APT) by Vidicon camera. This series is now being replaced by modified version of improved TIROS operational satellite series, which like the present NOAA-2 satellite, will be using a two channel Scanning Radiometer (S.R.) to provide APT at 48 lines per minute, thus eliminating the initial scanning rate of 240 lines per minute of the earlier satellites (NOAA Technical Memorandum NESS-25 April 1972). The recorder used in India Meteorological Department for recording the satellite Vidicon camera pictures of scan length 8·0 inches at a recording speed of 240 r.p.m. employs a 360-degree (one revolution) helix and 2·4 inches per minute paper pulling speed to give 8 inch vertical picture length. For reception of S.R. pictures, it is required that APT recorder used for Vidicon camera pictures be modified to suit the scanning rate of 48 lines per minute in the first place and secondly it also calls for adjustment of marking current for the new conditions so that proper grey scales on the electrosensitive paper could be obtained. The pictures so received contain both infrared and visible portions recorded side by side. The width of the strips of these pictures, *i.e.*, infrared and visible, is so narrow (about one-third of width of the corresponding display from a Vidicon camera, *i.e.*, 8 inches) that it becomes difficult to draw the details of a weather system. Expanding these strips to double the normal size in each direction somewhat facilitates this task.

Vossler (1968) accomplished this by doubling the helix speed to 96 r.p.m. and suppressing the signals in alternate lines by a blanking circuit to avoid interlocking of infrared and visible picture signals.

The technique described in the present paper is rather simple and involves neither any electronic circuit for blanking alternate scan lines nor any change in the recording speed of 48 r.p.m. For recording expanded NOAA-2 (ITOS-D) pictures, only the speed of the Paper Pulling Roller (P.P.R.) was doubled to that required for the normal NOAA-2 reception and 360°-helix wire was replaced by 180°-helix wire on the drum of the dimension recommended for normal reception of NOAA-2 pictures.

2. Theory of operation

Scanning radiometer transmits pictures automatically at 48 r.p.m., *i. e.*, 48 lines per minute. These include infrared as well as visible pictures transmitted side by side. The time span for every scan is 1·25 seconds (1250 milli-seconds) and this contains one line of infrared data (378 milli-seconds) followed by one line of visible data (378 milli-seconds). The width of each of the strips of infrared and visible portions so produced is one-third the width of the corresponding display from Vidicon camera as shown in Fig. 3. For producing expanded pitures of NOAA-2 (ITOS-D) 360°-helix wire was replaced by 180°-helix wire on the drum of the dimension recommended for the normal reception, and the paper pulling rate was doubled with the help of a new gear combination to provide expansion in a direction perpendicular to the scan line. When this 180°-helix (half helix) is rotated at 48 r.p.m., both infrared as well as

GEAR NO	NO. OF TEETH	GEAR NO.	NO. OF TEETH
1	40	9	110
2	120	10	22
3	120	11	66
4	20	12	110
5	105	13	22
6	35	14	66
7	120	15	96
8	30	16	32

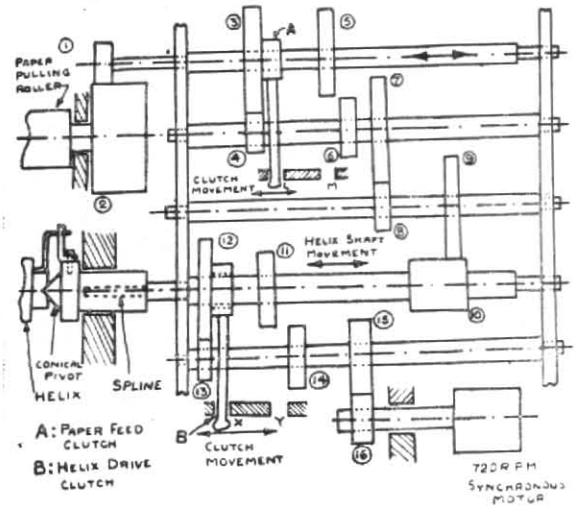

Fig. 1. Modified gear box. Principal drawing not to scale

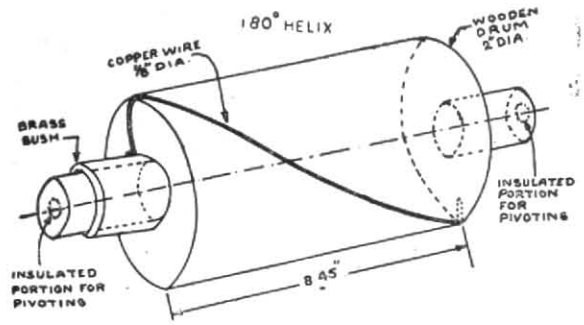

Fig. 2. 180° helix

visible picture signals are received, but the recorder is capable of recording for 0·625 seconds (625 milli-seconds) only. During this period of 0.625 seconds, the point of contact between half helix and writing blade (also called wiping bar) moves from one end of the electrosensitive paper to the other producing a record of data for 0·625 second thus marking a 8·45″ line parallel to the axis of the drum. If the 0° point of the helix be synchronized with the start of the signals of a particular portion of the picture, *i.e*, either infrared or visible than the line produced will contain in addition to the borders, grey scale etc associated with the picture, a record of data for 378 milli-*seconds*, *i e.*, over a length of 5·1″, pertaining to that particular picture portion for which the synchronisation is made, as shown in Fig. 4. The synchronisation is made by momentarily slowing down the speed of the helix motor with the help of the phasing switch which brings down the supply to the motor below the rated value. This applies for first half revolution of the drum from 0° to 180° along the conducting portion of the helix. During the next 0·625 sec (during the other half revolution of the drum) the wiping bar will be on the insulated portion of the helix, hence no signal current will flow and no record of the other half of the transmitted signal will occur on the paper. During the same period the paper will advance which will result in a blank line. Thus the other half revolution, *i.e.*, 180° to 360°, is completed. When the first half of the second revolution will begin, a picture line will again be recorded for 0·625 sec followed by a blank line for the next 0·625 sec. The picture so produced shall be double the normal size in both the dimensions but with alternate blank lines. If both infrared and visible pictures are required, a second recording set can be used. Alternatively satellite signals can be tape recorded and replayed to produce the second picture. Both infrared and visible pictures can also be recorded simultaneously on expanded scale by employing a helix of 16·9″ in length with full one turn of 360°, but with such recorder ESSA-8 picture will be distorted to twice the actual length along the scan line. Thus same recorder cannot be used for both ESSA-8 and NOAA-2 pictures.

3. Discussion of technical details

The ground equipment set up used in I.M.D. for reception of APT pictures of ESSA-8 and NOAA-2 (ITOS-D) satellites has been modified to record expanded NOAA-2 pictures and this is in addition to its capability of recording ESSA-8 and normal NOAA-2 pictures. Depending upon the type of reception and satellite, the helix and paper pulling roller speeds are varied as explained in Table 1.

(a) *ESSA-8 pictures* — ESSA-8 satellite transmits APT pictures at 240 lines per minute. The picture frames received on normal reception measure 8″ square and transmission for each frame lasts 200 seconds (*i.e.*, 800 scan lines). In order to match the transmission rate of 240 lines per minute, the helix (360°) speed has to be maintained at 240 r.p.m. This speed is obtained by reducing the 720 r.p.m. speed of the highly stabilized synchronous motor through a gear train of 3 : 1 ratio. The helix speed is further reduced through various gear trains (shown in the gear box Fig. 1) to provide a speed of 0·665 r.p.m. to the paper pulling roller of diameter 1·15″. The paper pulling roller of this diameter provides 8″ paper take in 200 seconds. The length of the scan line which is also 8″ in length is obtained by 360°-helix of 8·45″ pitch. The pitch is kept on the higher side by 0·45″ to provide margin for border of the picture.

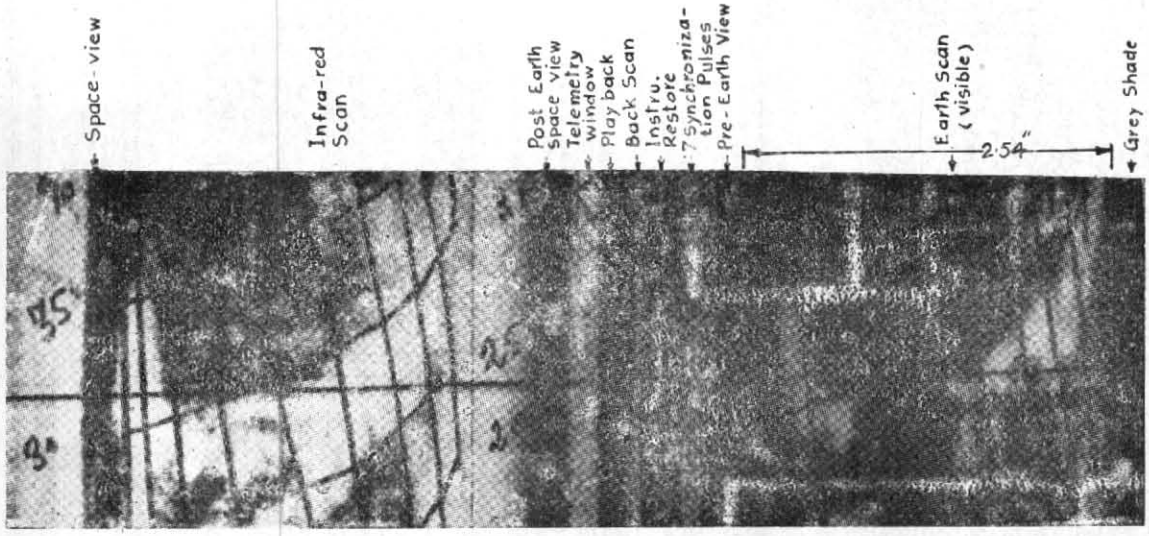

Fig. 3. Example of normal size of NOAA 2 (S.R.) pictures recorded at 48 r.p.m. with 0·48″ per min. Paper pulling rate and 360° (full) helix

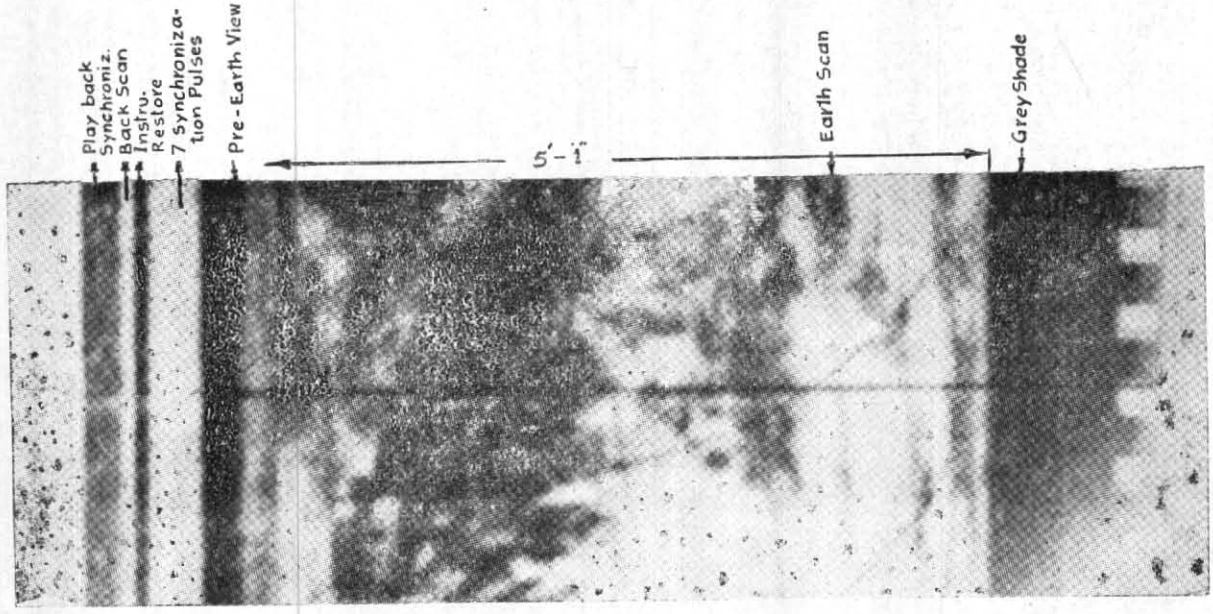

Fig. 4. Example of expanded NOAA-2 pictures taken with 180° (half revolution) helix with double paper pulling rate (0·96″/min)

(b) *Normal reception of NOAA-2 pictures* — The gear trains were modified to give an additional helix speed of 48 r.p.m. [Transmitting speed of NOAA-2 (ITOS-D)]. This was accomplished by using gear trains of 3 : 1 and 5 : 1 ratios to drive the helix drive shaft and the paper pulling roller (P.P.R.) automatically from the speeds 240 r.p.m. (helix speed) and 0·665 r.p.m. (P.P.R.) when in position Y to speed 48 r.p.m. (helix speed) and 0·133 r.p.m. (P.P.R.) when shifted to position X for normal reception of NOAA-2 pictures.

(c) *Expanded NOAA-2 pictures* — For receiving the expanded pictures of NOAA-2, the helix speed of 48 lines/min is required, which is already existing in the recorder for normal NOAA-2 reception. A normal NOAA-2 picture is 2·5 inches in width, and this is required to be expanded to double the present size both along the horizontal (cross track) scale as well as along the vertical scale. The expansion along the horizontal scale is accomplished by 180-degree helix (half-helix) which is of recommended dimension (*viz.* 8·45″ length, 2″ diam.). The vertical expansion of the picture is carried out by modifying the recorder to give a speed of 0·265 r.p.m. to the P. P. R. This is accomplished by inserting gears 5 and 6 of 105 and 35 teeth respectively together with a paper feed clutch (P.F.C.—Fig. 1) when P.F.C. clutch is at position L (for ESSA-8 & normal NOAA-2 reception) gears 3 and 4 get engaged and gears 5 and 6 get disengaged, thus driving the P. P. R. at 0·133

TABLE 1

Picture reception	Position of H D C P F C	Helix & motor speed relations (r.p.m.)	Paper pulling roller and helix speed relation (r.p.m.)	Paper take (inch/min)*
ESSA-8	Y L	$\frac{s.G_{16}.G_{11}}{G_{15}.G_{14}}$	$\frac{240.G_{10}.G_8.G_4.G_1}{G_9.G_7.G_3.G_2}$	2.4
		$=\frac{720\times32\times66}{26\times66}$	$=\frac{240\times22\times30\times20\times40}{110\times120\times120\times120}$	
		$=240$	$=0.666$	
NOAA-2 normal reception	X L	$\frac{s.G_{16}.G_{13}}{G_{15}.G_{12}}$	$\frac{48G_{10}.G_8.G_4.G_1}{G_9.G_7.G_3.G_2}$	0.48
		$=\frac{720\times32\times22}{96\times110}$	$=\frac{48\times22\times30\times20\times40}{110\times120\times120\times120}$	
		$=48$	$=0.133$	
NOAA–2 expanded picture reception	X N	Do.	$\frac{48.G_{10}.G_8.G_6.G_1}{G_9.G_7.G_5.G_2}$	0.96
			$=\frac{48\times22\times30\times35\times40}{110\times120\times105\times120}$	
			$=0.266$	

* With a roller of 1·15″ dia. s=motor speed

r.p.m. (helix drive is 48 r.p.m.). At position M (expanded NOAA-2 only) gears 3 and 4 get disengaged and gears 5 and 6 get engaged and drive the P. P. R. at 0·265 r.p.m. This doubles the picture in the vertical scale.

Table 1 provides a summary of the helix and P. P. R. speeds and the paper take, in relation to the motor speed, and position of P. F.C. and H.D.C. (Helix Drive Clutch).

3.1. *The helix* — The single turn 360-degree helix used for recording ESSA-8 pictures at 240 r.p.m. and ITOS-D (NOAA-2) picture at 48 r.p.m. was a copper wire (1/8″ dia.) wound over the wooden cylinder as shown in (Fig. 2). This new helix provides an expanded picture and also acts to blank one half of the signal, either the I. R. or the visible portion.

3.2. *Scan line synchronization* — Since the initial sta of the record is unknown, either the infrared or the visible or both the portions of the pictures are recorded. In order to record either of the two pictures, speed of the helix drum is adjusted by means of a phasing switch which momentarily slows down the speed of the helix till the desired signals start. Once the start of helix revolution is synchronized with the start of desired signal, the other half of the transmitted signal is naturally blanked out.

3.3. *Size of the picture* — The feed roller plays a major role in producing a correct sized picture. The roller used in this recorder is made of hard carbon of exactly 1·15″ dia. to produce an exact paper take of 0·48″/min for normal NOAA-2 pictures and 0·96″/min for the expanded picture. The expanded picture so produced is 5·1″ wide.

3.4. *Marking current adjustment* — A separate power supply unit is used for providing the marking current. With the arrangement the helix voltage and the reading current can be adjusted according to the need. When the recorder is used at lower scan rate, marking current is adjusted suitably to avoid the burning of the paper due to excessive current.

3.5. *Picture aspect compensation* — With the recorder printing every other line, it may be desired to fill the every alternate blank line to obtain a better grey shade appearance. This can be done by doubling the width of each recorded scan line. The simplest method of doing this is to replace the standard wiping bar (writing blade) which is made of stainless steel with one that is twice as thick or by placing two regular bars together and grinding off the extended edge of the inside bar.

4. Advance of the technique

(1) Picture produced is double the present size, *i.e.*, of 5·1″ width.

(2) This technique of producing expanded pictures requires only a minor mechanical modification to the recorder.

(3) Cost involved in modifying the recorder for receiving expanded picture is nominal and no special electronic circuit is required.

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