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16. Summary/Notes

This report describes the experience acumulated by INPE over the past 10 years in the field of development and operation of ground equipment for reception and processing of information from meteorological satellites.

17. Remarks *Prepared for presentation at the WMO - "Reunião Regional de Coordenação e Implementação de Estações Receptoras de Satélites Meteorológicos" - October 17 to 20, 1977.*

INDEX

INTRODUCTION

CHAPTER I

INTRODUCTION

INPE - Instituto de Pesquisas Espaciais (Institute for Space Research), an organization of the National Council for the Development of Science and Technology (CNPq), is an agency devoted to research and development related to space.

Much of its efforts have been dedicated to the application of space techniques to several areas of human activity. Meteorology and Remote Sensing of Natural Recources are the two areas where the emphasis has been placed.

The program of INPE in Satellite Meteorology has concentrated on the development of ground equipment for the reception and processing of meteorological information obtained by satellites. The program has followed the development of the satellite systems, evolving from low-resolution sensors to high resolution ones and vertical sounders. Acoordingly, the program has resulted in the development of

- Low-cost APT stations;
- S-band WEFAX adaptation Kit;

It has developed and keeps in operation

- VHRR receiving and processing facilities;
- VTPR receiving and processing facilities.

Recognizing the fact that the evolution of satellite systems, toward higher data transmission rates, makes the optimal overall solution to be one in which data are received and pre-processed at a few locations and then transmitted to the users, as opposed to the previous situation in which a large number of receiving stations could be economically installed, an effort is being made to find technical solutions for the problem of

• Real-time Image Transmission

The entire program is being developed, with emphasis on the search for technical solutions which are compatible with the stage of technological development of the country rather than purchasing equipment on a turn-key basis.

The future holds a bright promisse. It is expected that, somehow, over the next decade, Satellite Meteorology will provide the means to fulfill the expectation of improving the quality and extending the range of weather forecasts in South America, by providing information, from oceanic and data-scarce regions, which can be fed into prediction models.

For the near future, over the next year or so, the programs already being developed are the next step in that direction.

The system for

• Reception and Processing of VISSR Imagery, from the GOES and METEOSAT satellites, will be in experimental operation in early 1978.

• Data Collection Platforms will be developd for meteorological uses, among others.

Development is being finalized for the adaptation of the existing facilities to receive

• AVHRR data transmitted by polar-orbitting satellites;

• TOVS data transmitted by the same;

• TIROS-N APT signals.

This document describes in some detail achievements to date.

An annotated bibliography is included at the end of each part, with the purpose of disseminating the experience already established at INPE.

CHAPTER II

APT/INPE GROUND STATION

2.1 - INTRODUCTION

Since 1966 INPE has been receiving APT signals, transmitted by meteorological satellites, with a low cost ground station, that was conceived and assembled at the Institute. The prototype of this station operated for about 3 years, giving satisfactory results. Considering the large potentiality of satellite imagery for Brazil, INPE then decided to order the production of 20 units, that were to be operated by the several Brazilian institutions that are, in some way, related to meteorology. The contract was made with a home industry with financial support from the BNDE (Banco Nacional de Desenvolvimento Econômico), a national organization which supports technological development.

Since its conception, the APT station has undergone a series of modifications and optimizations, mainly to conform to meteorological spacecraft evolution. Meanwhile, software for tracking and making proper use of the satellite images have been created and updated whenever necessary. The resulting material has been made available to any person interested or working with the APT imagery and operation.

In this chapter a description of the APT system developed at INPE is presented, as well as its technical characteristics. Special emphasis is placed on the image display since it differs substantially from the methods commonly used (Calheiros, 1971).

Also presented is an overview of the recent modifications and optimizations that were introduced.

2.2 - APT/INPE SYSTEM

The signal transmitted by the satellite is received by a remotely controlled yagi antenna. There is a low noise pre-amplifier attached to the antenna, which amplifies the signal to be transmitted to a FM fixed tuning receptor, where the first FM demodulation of the carrier is made. The amplitude modulated sub-carrier (2400 Hz) from the receiver is injected to the vertical axis of a CRT oscilloscope and in a stereo tape magnetic recorder, used for play-back. A synchronism generator utilizing a cristal oscillator provides synchronized pulses that trigger the horizontal oscilloscope amplifier at the same rate as lines are generated by the satellite.

The sub-carrier (2400 Hz),modulated by the video signal, scans the oscilloscope screen. Only part of the screen light emmission, that passes through the slit, is concentrated, by an optical system, on a regular 35 mm film. This film is continuously pulled by a synchronous motor such that light from the mask slit exposes the film forming, successively, contiguous lines. These lines, assembled, constitute the picture. The system detects the video signal amplitude in terms of a corresponding light intensity, without the necessity of conventional amplitude detection in the reception circuit. The process is schematically represented in Figure II.1. This amplitude detection is based on the fact that the screen brightness at a point is a function of the speed with which the beam crosses the point. This leads to an inverse proportionality between the light emitted at the screen center and the video signal amplitude. High level amplitude signals correspond to high level luminosity on the photographed object (clouds, for instance) by the satellite, which result in faint film exposure and, consequently, low density on the negative. In the case of small amplitude video signal the opposite happens. Thus, the 35 mm negative constitutes a positive on regular film, reproducing directly the scene photographed by the satellite.

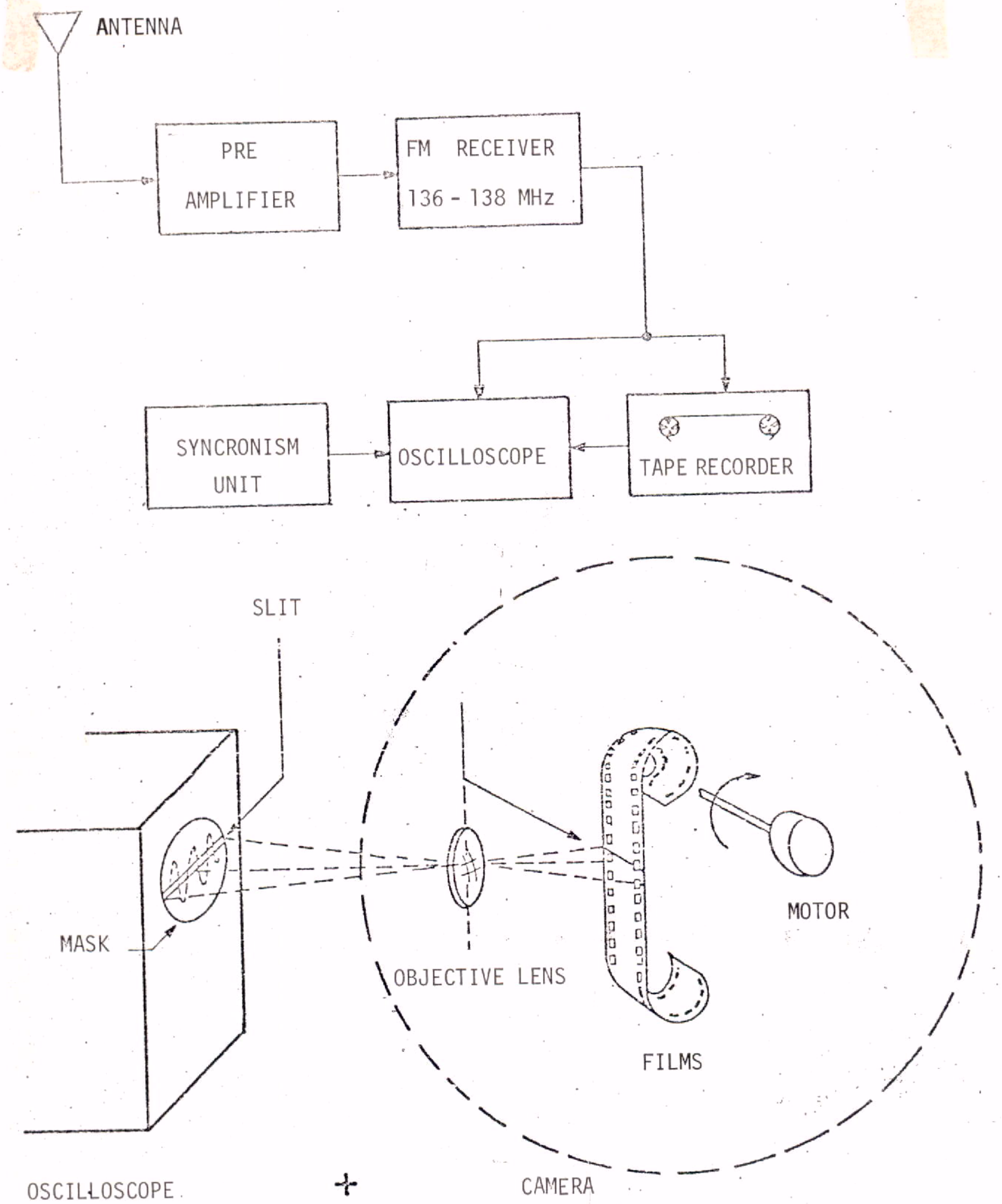


Figure II.1 - APT/INPE Receiving and Reproduction System

Reviewing, the complete process follows the sequence:

- the 2400 Hz signal, modulated by the video signal, scans the oscilloscope screen;
- the light that passes through the slit focused by an optical lens, exposes the film;
- each screen point at the slit has a light intensity which is inversely proportional to the signal amplitude at the point;
- this light intensity corresponds to a given exposure on the film. Large amplitude implies low intensity and "burns" the film a bit, turning it more transparent. Small amplitude implies in high intensity and burns the film a lot, turning it more opaque.

2.3 - TECHNICAL CHARACTERISTICS

The APT/INPE ground station, costing approximately US$ 15,000.00,is basically constituted of the antenna/pedestal assembly, pre-amplifier, receiver, synchronism and oscilloscope/camera assembly. A brief description and the main technical characteristics of each of these sub-systems are given below (Pontes e Morais Cia. Ltda. 1971).

a) ANTENNA/PEDESTAL ASSEMBLY

The antenna is a light crossed-dipole element, yagy type mounted on a pedestal. The motors and reduction devices are installed in the pedestal and sheltered by a metal cover. The pre-amplifier power supply and power relays are arranged inside a box and attached to the pedestal. The main specifications of the antenna/pedestal assembly are the following:

CHARACTERISTICS	SPECIFICATIONS
Type	8 Element YAGI array
Polarization	Right-hand Circular
Gain	11 dB
Bandwidth	135-138 MHz
Motion	Azimuth: 360^o Elevation: 180^o
Speed	6^o/Second
Weight	85 Kg

b) PRE-AMPLIFIER

The low noise VHF pre-amplifier which is utilized, is placed at the pedestal in order to be as near as possible to the antenna. The main specifications of this pre-amplifier are the following:

CHARACTERISTICS	SPECIFICATIONS
Gain	18 dB
Bandwidth	135-138 MHz
Noise Figure	3.5 dB
Supply Voltage	110 A.C
Consumption	< 20 Watts
Size	175 x 70 x 40 mm

c) RECEIVER

A FM conventional VHF five-channel pre-tuned receiver is utilized. The channel selector is placed on the pannel and the relative intensity of the received signal is indicated by a volt-meter. The sub-carrier is reproduced by a loudspeaker for monitoring purposes. The main specifications of this receiver are the following:

CHARACTERISTICS	SPECIFICATIONS
Mode	FM
Bandwidth	130-140 MHz
Number of Channels	5
Frequency Control	Cristal
Sensitivity	1 μV
AM Rejection	> 70 dB
FI Bandwidth	80 KHz
Audio Bandwidth	800-4000 Hz
Supply Voltage	110 VAC
Consumption	20 Watts
Size	480 x 250 x 125 mm
Weight	4 Kg

d) SYNCHRONISM UNIT

The synchronism unit provides the necessary pulses to trigger the oscilloscope synchronously with the satellite received signals. It operates either in real time or in play-back modes, allowing the use of tapes recorders. The time base may be a cristal oscillator (internal) or the 2400 Hz sub-carrier signal. The synchronism unit spedifications are the following:

CHARACTERISTICS	SPECIFICATIONS
Operating Mode	Real Time or Play-back
Output Frequency	4 Hz
Output Level	3V (peak)
Phase Adjustment	Up to 300 Milliseconds
Supply Voltage	110 VAC
Consumption	20 Watts
Size	480 x 250 - 125 mm
Weigh	3.45 Kg

e) OSCILLOSCOPE/CAMERA ASSEMBLY

The APT/INPE ground station image recorder is constituted of a commercial oscilloscope and a photographic camera, specially developed for this purpose. The oscilloscope utilized is the Hewlet Packard model 120-B with a P-11 phosphor screen. The camera assembly is made of two parts; the so called cone and the camera itself (see Figure II.2), sliding over a rail to permit locking (and unlocking) to the oscilloscope screen. The two camera synchronous motors are interchangeable, permitting adjustment of the film pulling speed to the satellite line rate. The main specifications of this unit are the following:

CHARACTERISTICS	SPECIFICATIONS
Oscilloscope	HP Model 120-B P-11 Phosphor Screen
Objective Lens	1:4.5 f: 30 mm
Film	35 mm black and white 120 ASA 30 ft roll
Motor	2rph 4rph
Camera Size	250 x 335 x 175 m
Camera Weight	8,5 Kg

2.4 - OPTIMIZATION AND ADAPTATION

This item deals with the equipment developed at INPE to optimize or modify the original APT/INPE ground station. In each case, according to the necessity, some units were manufactured in order to supply the APT stations operated by other institutions.

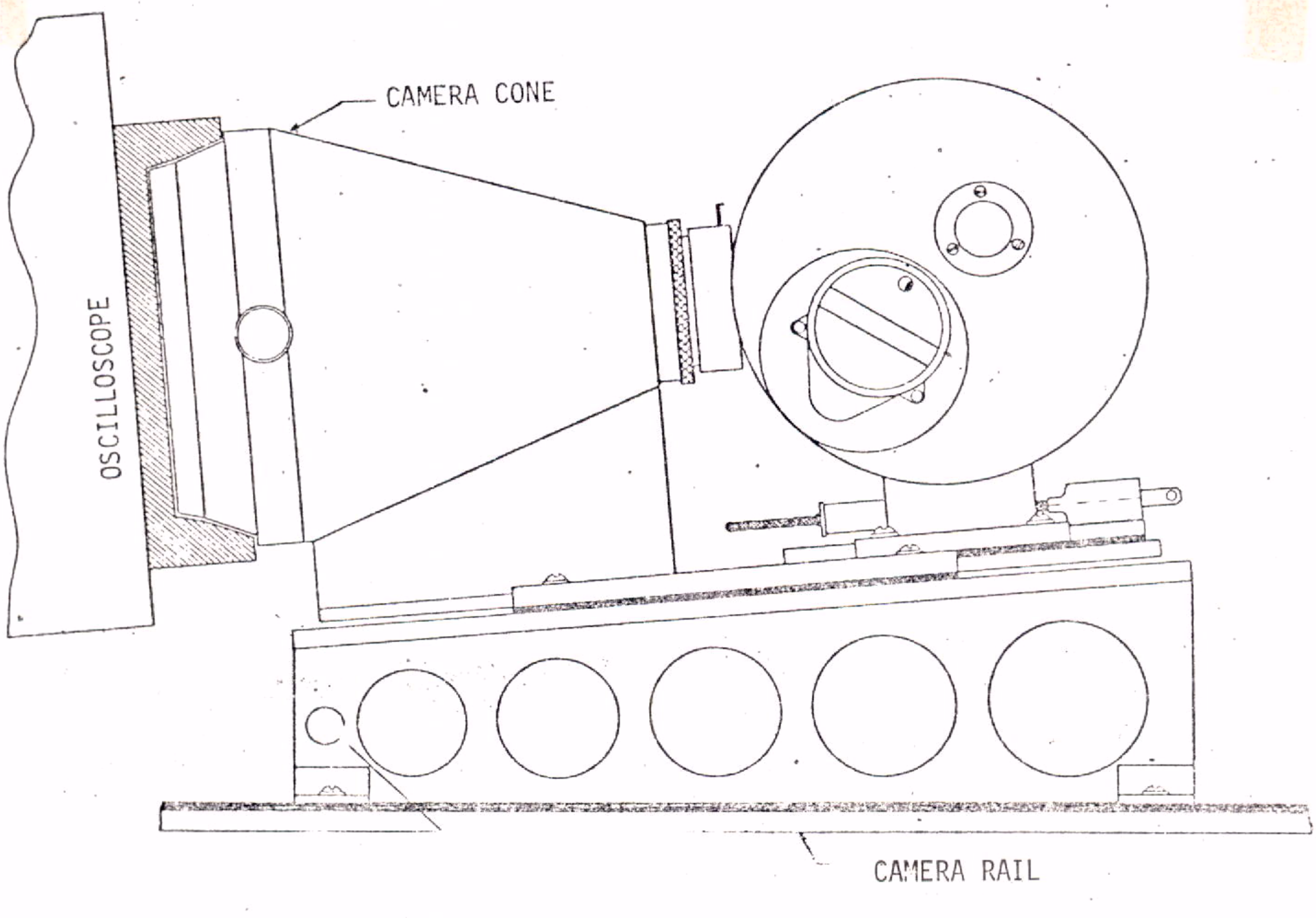


Figure II.2 - APT Camera

a) APT/SR ADAPTER

The original APT/INPE ground station was initially built to receive the ESSA series satellites signals. Upon the advent of the ITOS/NOAA series there was a need to modify the synchronism pulse rate and the video filters. The line rate transmitted by the ESSA satellites was 240 lines per minute and that by the ITOS/NOAA, 48 lines per minute. As a consequence, it was necessary to replace the 4 r.p.h motor by one with 2 r.p.h.The video filter band changed from 1600 Hz to 900 Hz. Twenty units of the APT/SR Adapter were manufactured at INPE's laboratories. These were distributed to all the APT/INPE ground stations. The Portuguese name for this unit is "Sincronismo APT/SR" (Calheiros et al, 1973).

b) HELICOIDAL FILTERS

The APT ground station performance is highly jeopardized by the man-made noise, found in the urban centers, where the FM radio and TV broadcasting and even airport control communications signals are much more powerful than the satellite ones. These signals, although not being in the receiver tuning frequency, due to their high intensity, saturate the APT pre-amplifier causing the so called heterodyne phenomenon. As a result some enter the receiver band. To solve this problem it was necessary to develop a passive filter to be inserted between the antenna and the pre-amplifier. The constraint is that the insertion loss must be the minimum possible. The helicoidal filter fulfills this specification and the ones that were constructed with resulted in approximately a 0.5 dB loss. Five units of this filter were constructed at INPE's laboratories and sent to the APT stations located in urban areas.

c) DOPPLER CORRECTION ADAPTER

As already mentioned, the original APT synchronism unit utilized a cristal time base. This unit worked properly with the ESSA satellites. However, the Doppler effect, which always exists, becomes visible in the APT/SR images. To eliminate this effect, a circuit for Doppler correction was constructed. It makes use of the 2400 Hz sub-

-carrier as time base. The sub-carrier retrieval is made by a VCXO (voltage controlled cristal oscillator) assuring that, even in the case of heavy noise condition the synchronism is maintained. Twenty units of the Doppler Correction Adapter were constructed at INPE's laboratories to improve the image quality of all APT/INPE ground stations (Mammoli, 1975a; Mammoli, 1975b; Mammoli, 1976 e Souza, 1976).

d) ANTENNA

Having in mind the manufacturing of other units of the APT/INPE ground station, a new project was inaugurated for the antenna and its pedestal. The antenna prototype was built according to a method for optimizing Yagi-Uda antennas that was a M.S. thesis topic (Koshima, 1976 and Koshima 1977). Its theoretical gain is 13 db (the old one presents dB gain). Some units were constructed to replace the APT/INPE ground station antennas already deteriorated by the weather. The prototype of the pedestal is presently being constructed.

e) APT SIGNAL PROCESSOR AND THE TIROS-N SATELLITES

Similarly to the case of the antenna, it was decided to design a single unit called "APT Signal Processor" to substitute both synchronisms, the APT and the APT/SR, and the Doppler Correction Adapter. Some other facilities were also implemented such as the digital clock and the automatic equator crossing marker. This marker is necessary for gridding purposes. Besides the prototype, two units of the APT Signal Processor were constructed.

Additional units will soon be developped featuring the TIROS N capabilities. In this new series of operational meteorological satellites, predicted to start in 1978, the main novelty will be the 120 lines per minute line rate. Besides that, there are other relevant differences: the video signal will be derived from the AVHRR (Advanced Very High Resolution Radiometer) sensor; the panoramic distortion caused by the sphericity of the Earth will be eliminated through on-board video signal correction, the video band will be 1700 Hz; the signal transmitted by the satellite will be circularly polarized (right hand). Obviously, these will only demand minor modifications.

2.5 - TECHNICAL SUPPORT

Providing the technical support necessary to guarantee successful operational APT reception, as well as imagery utilization, has been a primary concern of INPE. Similarly to the APT ground station hardware, this support must be conveniently updated or modified, either to attend to the users's demands or the on board APT system evolution. The topics relevant to this matter are presented in this item.

a) ORBIT PREDICTION

Several computer programs have been developped to calculate the necessary elements, to successfully track a polar orbit sun - synchronous satellite on an operational basis (Zamlutti, 1969 and Zamlutti, 1974). All of them were written bearing in mind, first: to furnish the data on a regular basis in a format that would facilitate manual tracking; to help the user to establish in advance the operational program of the APT ground station under his care and, third to save time, even for the user who has within his reach the APT Predict, a coded operational message on orbit prediction sent out by NOAA and transmitted via GTS.

The computer program, conceived for the NOAA satellites, selects, for each geographic location, the satellite orbits and the visible range. For each orbit it calculates the elevation and azimuth angle, minute by minute (see Figure II.3). The calculations are updated once a month, through the use of the bulletins "Orbital Elements" (featuring the updated Brower mean orbital elements) and "Equator Crossings" (featuring observed updated satellite time, date, height and longitude for several equator crossings), both issued by NASA (Elias et al, 1975).

INSTITUTO DE PESQUISAS ESPACIAIS

PREVISÃO DE PASSAGEM DE SATÉLITE

SATÉLITE	MÊS	DATA
NOAA 5	JUNHO	31/ 6/77

ESTAÇÃO RECEPTORA			CRUZAMENTO COM O EQUADOR		
NOME	LATITUDE (GRAUS)	LONGITUDE (GRAUS)	HORÁRIO (TMG)	LONGITUDE (GRAUS)	ALTURA (KM)
S.J.CAMPOS	-23.2	-45.9	10:44:16	-31.0	1519.3

HORÁRIO (TMG) H	MIN.	SEG.	AZIMUTE (GRAUS)	ELEVAÇÃO (GRAUS)	PONTO SUBSATÉLITE LATITUDE (GRAUS)	PONTO SUBSATÉLITE LONGITUDE (GRAUS)	MINUTOS APÓS CRUZAMENTO	ANOTAÇÕES
								4168
10	42		31	3	6.1	-29.2	-2	
10	43		32	6	3.0	-30.1	-1	
10	44	16	34	10	0.0	-31.0	0	
10	45		36	14	-3.0	-31.9	1	
10	46		38	19	-6.1	-32.8	2	
10	47		42	24	-9.1	-33.7	3	
10	48		46	30	-12.1	-34.7	4	
10	49	16	52	37	-15.1	-35.6	5	
10	50		62	45	-18.2	-36.5	6	
10	51		77	53	-21.2	-37.5	7	
10	52		101	57	-24.3	-38.5	8	
10	53		127	56	-27.3	-39.6	9	
10	54	16	148	50	-30.4	-40.7	10	
10	55		162	43	-33.5	-41.8	11	
10	56		170	35	-36.5	-43.0	12	
10	57		176	28	-39.6	-44.3	13	
10	58		180	22	-42.7	-45.7	14	
10	59	16	182	17	-45.8	-47.2	15	
11	0		184	12	-48.9	-48.8	16	
11	1		186	8	-52.0	-50.6	17	
11	2		187	4	-55.1	-52.6	18	
11	3		188	0	-58.3	-54.8	19	

Figure II.3 - Orbit Prediction Issued by INPE

OBSERVAÇÃO: A DATA SE REFERE AO CRUZAMENTO COM O EQUADOR

Presently about 30 APT users receive, on a regular basis, the orbit prediction issued by INPE.

The orbit prediction also furnishes, for each satellite passage, the equator crossing longitude which is an important parameter for gridding purposes, a subject that will be dealt with next.

b) GRIDDING

The method, used for gridding the APT/SR images, makes use of computer generated special grids which are turned into transparencies in a photographic laboratory (Santana et. al, 1974 and Moura, 1975). The gridding is done directly on the print at the time of the exposure by superimposing the grid on the projected image.

The grid may or may not portray the geographical contours. In the first case it is necessary to have at our disposal a set of grids for all the possible equator crossings and in the second case just one grid is sufficient. This is because the inclusion of geographical contours eliminates the longitudinal symmetry (see Figure II.4).

Upon request, grids can be generated at INPE for any location and the charge, if only, only amounts to the cost of the processing material.

c) TRAINING COURSES

INPE offers, at any time of the year, on the job training courses for the APT users, lasting one to two weeks. These courses are structured to familiarize the new operator with all the operational aspects, such as the signal tracking and receiving procedures, orbit predic use, image production in the photographic laboratory and gridding.

Intensive courses lasting about one month are offered once every two years. Other APT aspects are treated in these courses, besides the operational ones, such as satellite imagery interpretation and use on operational basis, the several existing APT systems, elements

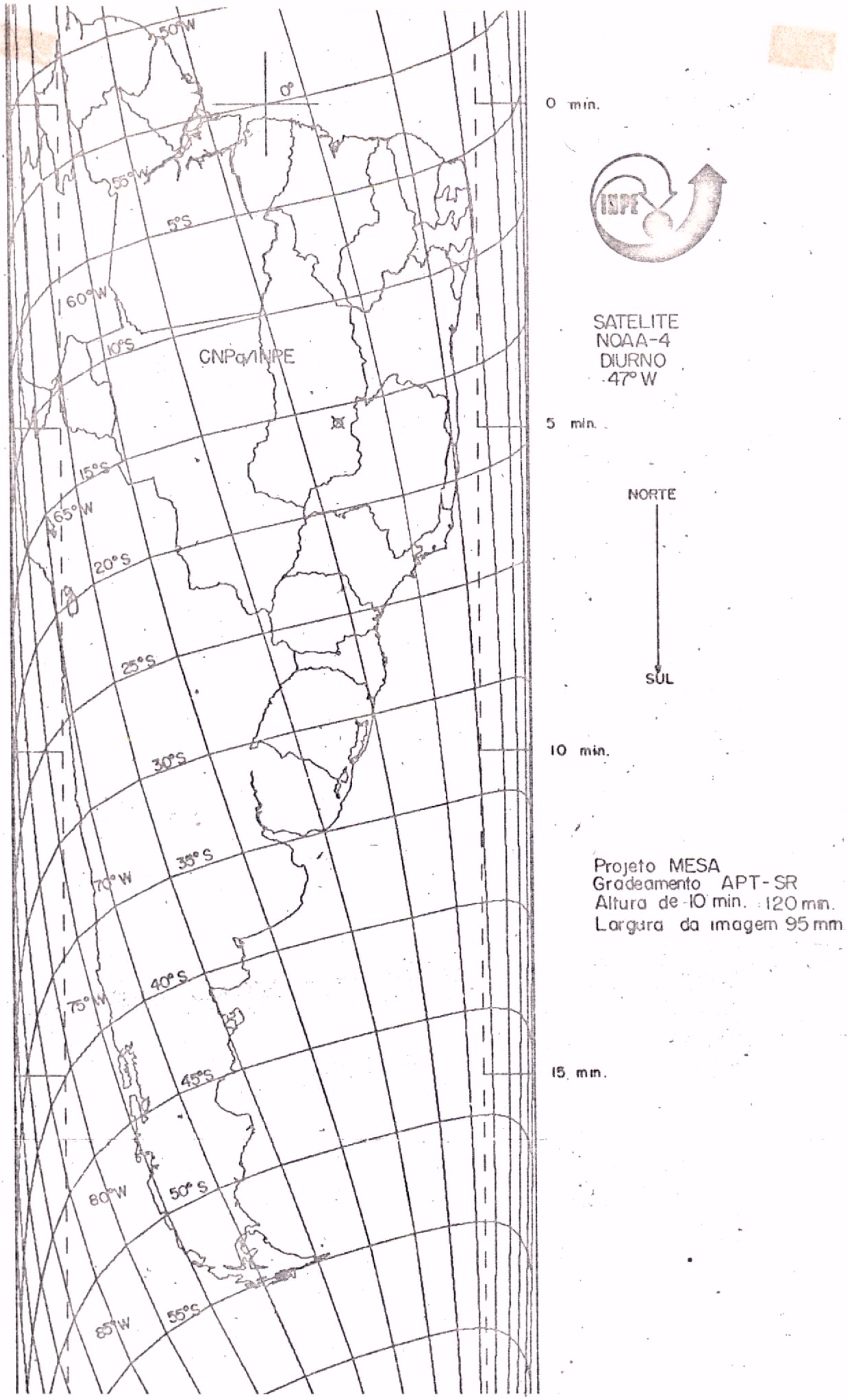


Figure II.4 - APT/SR Grid Issued by INPE of orbital theory, etc. (Calheiros et al, 1971 and Elias et al, 1975). Since 1975 these courses have been opened to all countries of the WMO Region III.

d) APT INFORMATION NOTE TRANSLATION

The bulletin "APT Information Note", issued by NOAA, concerning the operational meteorological status has been, for one year now, regularly translated into the Portuguese language at INPE. The Portuguese version is sent to the WMO Region III Representative, to be distributed among the APT users community.

e) PUBLICATIONS

Since the beginning, INPE has been issuing several publications concerning all the relevant APT aspects and these are made available to the users. At the end of this report, the reader will find a comprehensive bibliography, accompanied by abstracts.

Given that the subject matter is in constant evolution it was found practical to assemble all the APT operational aspects in a single flexible volume. Thus, a manual, similar to the ones published by WMO, was created with a format that enables ready addition and updating. The Portuguese name for it is "Manual do Usuário da Estação APT" and about 80% of what was originally planned has been already published. Any new publication to be inserted in it is automatically sent to the APT users.

f) ARCHIVING

INPE has been maintaining a satellite imagery and data archives since 1967 (Nunes et al, 1974). Although other satellite data may be found, the archive contains the images received and processed at the Institute. These data have been utilized for research and applications studies by INPE's own personnel as well as others. The main APT material classified at INPE's archive is listed below.

SATELLITE	PERIOD
ESSA-8	January 1969 - October 1973
ITOS-I	February 1970 - April 1971
NOAA-3	October 1974 - December 1974
NOAA-4	January 1975 - September 1976
NOAA-5	October 1976 - August 1977

g) TECHNICAL ASSISTANCE

Whenever necessary INPE offers technical assistance to all APT/INPE ground stations. This is done either by sending the equipment to INPE's laboratories or requesting a technician to go to the location where the station will be or is already installed. The technical assistance is free of charge for the APT/INPE ground stations except for travelling expenses and per diem.

2.6 - WEFAX KIT

In 1974 the SMS/GOES satellites operated by the National Environmental Satellite Service (NESS) began the S-band WEFAX (Weather Fac-simile) broadcasting on a frequency of 1691.0 MHz. Until then this broadcasting was only done by the ATS series satellites, in the 137 MHz frequency region.

Although the SMS/GOES satellites transmission frequency is 1691.0 MHz, the modulation type, the video signal characteristics and the image format were not altered. These characteristics define the so called APT/WEFAX system. As a result, a simple frequency conversion, from 1691.0 MHz to 137 MHz, permits a regular APT ground station to receive and produce WEFAX images.

A WEFAX kit (costing approximately US$3,500) has been developed at INPE's laboratories to permit the APT/INPE ground stations to receive WEFAX signals. This WEFAX converter block diagram is shown in Figure II.5. The description of each unit is given below.

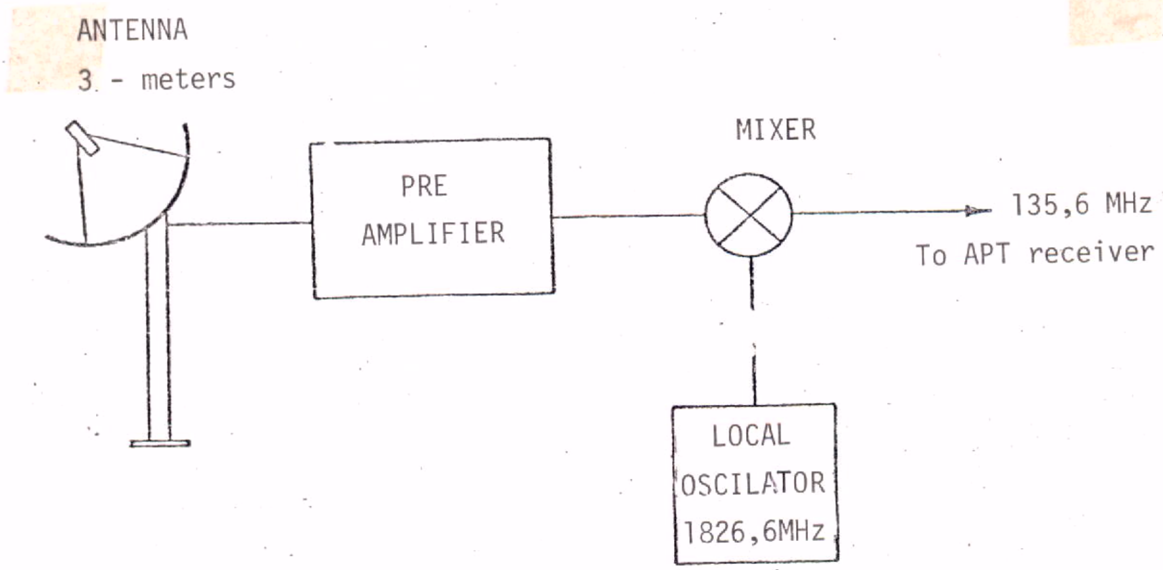


Figure II.5 - Block Diagram of the S-band WEFAX Converter

a) ANTENNA

The antenna assembly is constituted of a 3 m diameter paraboloidal meshed dish with a linearly polarized feed adjustable to any polarization angle. Its gain is approximately 31 dB. The supporting structure of the antenna permits a 360^{0} azimuth adjust.

The elevation is pre-adjusted for each antenna individually, according to the location of installation. There is the possibility of a finer adjustment of 15^{0} which can be done after installation (see Figure II.6).

b) PRE AMPLIFIER

The main specifications of the pre-amplifier prototype are:

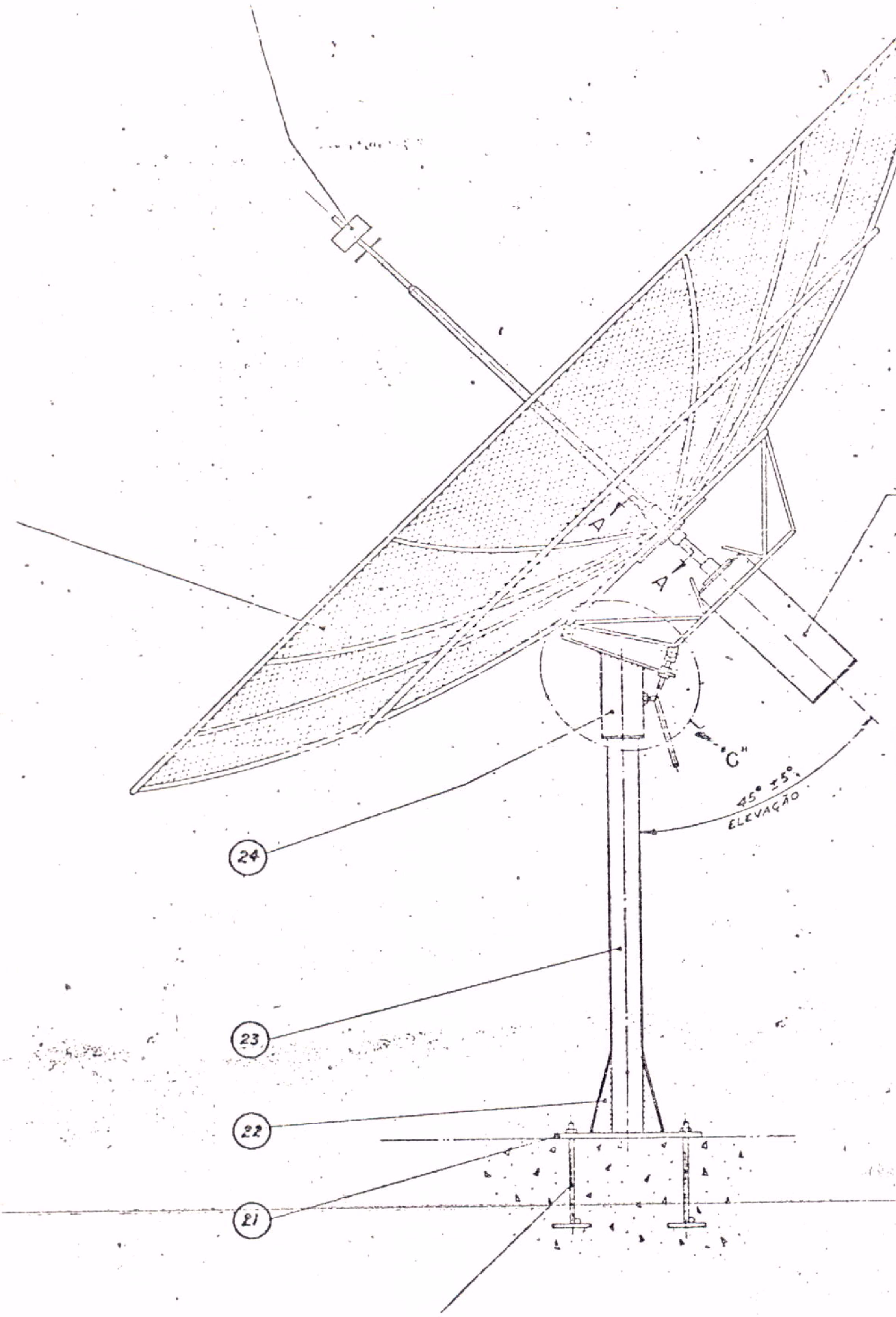
Frequency	1691,0 MHz
Gain	20 dB
Noise Figure	4,5 dB
Bandwidth	4 MHz
Supply Voltage	12 V

c) LOCAL OSCILLATOR

The local oscillator assembly is constituted of a 91.330 MHz cristal oscillator and a x 20 frequency multiplier giving 1826.6 MHz with 3 dBm output power. The difference between 1826.6 and 1691.0 MHz is 135.6 MHz which is the APC receiver channel-5 frequency.

2.7 - CONCLUSION

The cheapest way to get real time meteorological satellite pictures is still through the APT ground station. The American meteorological satellites are supposed to carry the APT system until 1985. This explains the effort to maintain the APT/INPE ground station up to date in order for it to follow the APT evolution.



24	TUBO REGULÁVEL
23	TUBO PRETO ϕ 3" x 1280
22	NERVURA
21	BASE
20	BUCHA INF.
19	PORCA SEXT. ϕ 1/2"
18	ARRUELA LISA ϕ 1/2"
17	PARAF. ESPECIAL
16	ARTICULAÇÃO MAIOR
15	PARÁBOLA
14	FLANGE P/ REGULAGEM
13	PARAF. CAB. ABAUL. FEND
12	ARTICULAÇÃO
11	PORCA ϕ 3/8" NC SEXT.
10	PARAF. CAB. SEXT. ϕ 3/8" x
9	ARRUELA ϕ 5/32"
8	PORCA SEXT. ϕ 5/32" NC
7	PARAF. CAB. ABAUL. FENDA
6	FLANGE DA FIX. PARÁBOLA
5	BUCHA
4	BRAÇADEIRA
3	APÔIO
2	BUCHA APÔIO
1	ALAVANCA

Figure II.6 - WEFAX Antenna

Although not all the APT/INPE ground stations have been working operationally, several benefits resulted from the APT technological development. It gave many users the opportunity for observation technique of unquestionable usefulness for a country like Brazil. Meanwhile all the APT activities that have been carried through the years, created the experience necessary to assure the development of more advanced enterprises, that have been accomplished at INPE. In this connection it is worth mentioning the VHRR and VTPR receiving and processing station, which has been operational since 1976 and the SMS roject, which is partly concluded.

CHAPTER III

VHRR/VTPR GROUND STATION

3.1 - INTRODUCTION

The first series of American Meteorological operational satellites carried on board the APT (Automatic Picture Transmission) system which obtained images with a vidicon camera in the visible channel. In 1971 a two-channel system was introduced, that is the SR (Scanning Radiometer), to obtain the APT products with the same resolution as the vidicon camera.

The fourth satellite of the NOAA series, the ITOS-D, featured two new sensors: the VHRR (Very High Resolution Radiometer) and the VTPR (Vertical Temperature Profile Radiometer). The VHRR, similar to the SR, is a two-channel scanning radiometer: in the visible range (0.5 μm - 0.7 μm) and in the thermal infrared window of the atmosphere (10.5 μm - 12.5 μm), but they are distinct with regard to the ground resolution. The SR system has a resolution of 4 km in the visible channel and of 8 km in the infrared at the subsatellite point. The ground resolution of the VHRR system is, for both channels 0,9 km. The VHRR pictures are also transmitted automatically but, to distinghish from the APT broadcast, the system of transmission is referred to as HRPT (High Resolution Picture Transmission). The HRPT transmission frequency is in the S-band and requires a special local users' ground station.

The VTPR data also are a real time service which makes use of the VHF (136.77 and 137.14 MHz) beacon transmitter on board of NOAA polar orbiting satellites. This real-time beacon service permits local readout stations to process the VTPR date to obtain temperature profiles of the atmosphere.

The original project to develop and assemble the VHRR/VTPR ground station, was conceived at INPE in 1973 and did not include the

VTPR reception. However, later on, because of the equipment which already existed at the Institute,it was found convenient to develop the VTPR capability. Because the available financial support remained the same as initially, this turned out to be a constraint put on the specification of the system.

The display choice was the critical point. The displays then existing commercially, with the capability of producing real time imagery, were very expensive and with doubtful reliability. Such displays were either laser beam recording or fiber optics type. The choice fell upon the Muirhead Photographic Recorder, which presented a compatible cost as well as the desired reliability, given that it had been successfully utilized by NESS for some years. The only drawback presented by this device concerned the processing information rate which is about 4 times lower then the satellite one.

The INPE VHRR/VTPR ground station is described in this chapter.

3.2 - VHRR SYSTEM

The Very High Resolution Radiometer (VHRR) is a two-channel scanning device sensitive to energy in the visible spectrum (0.5 μm - 0.7 μm) and the infrared window (10.5 μm - 12.5 μm). The fields of view of the sensors are schematically represented in Figure III.1. The radiometer is an assembly of a mirror, which rotates at 400 r.p.m., placed in front of a telescope. The visible energy is sensed by a silicon photo-diode detector located at the focal point of the telescope. The IR radiation is sensed by a mercury-cadmium-telluride (Hg-Cd-Te) detector maintained at - 168^{0}C by a radiant cooler. The instantaneous field of view (IFOV) for both channels is 0.6 milliradians, corresponding to 0.9 km at the ground.

The video signals generated by these sensors are time-multiplexed. Each channel uses 75 of the 150 milliseconds available in one rotation of the scanner. Figure III.2 presents the VHRR video signal. A double frequency modulation is used for the signal transmission. The video signal modulates in frequency a 99 kHz subcarrier, with a deviation of ± 29 kHz. A 1697.5 MHz carrier frequency is modulated by the subcarrier, with a deviation of ± 300 kHz. This constitutes the transmission prime mode. There are other back-up modes which will not be mentioned. The interested reader should refer to Schwalb, 1972 and Fortuna et al, 1974.

The main characteristics of the VHRR system are presented in Table III.1. A comparison between the SR and VHRR systems is given in Table III.2.

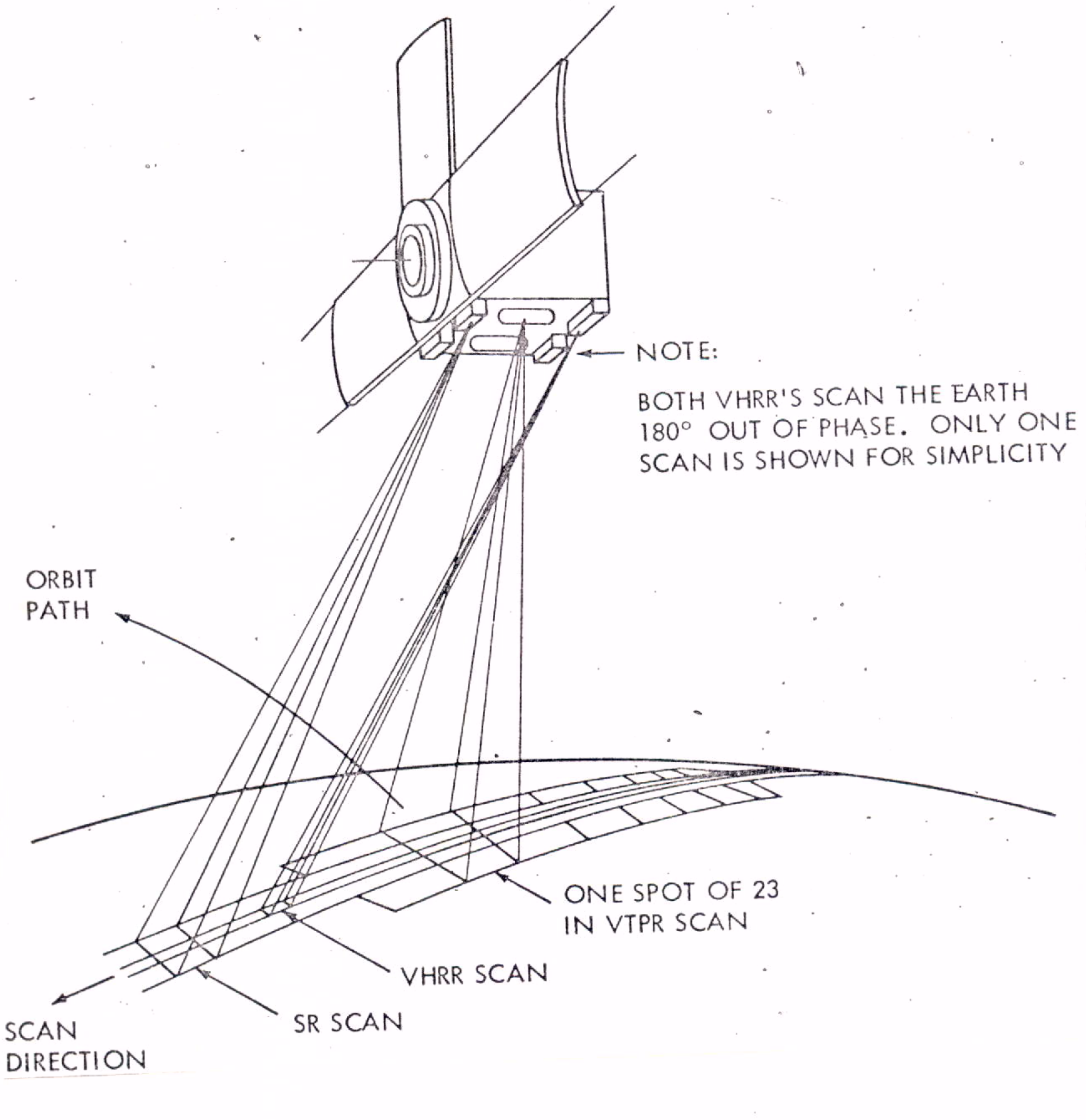


Fig. III.1 - Earth sensors fields of view

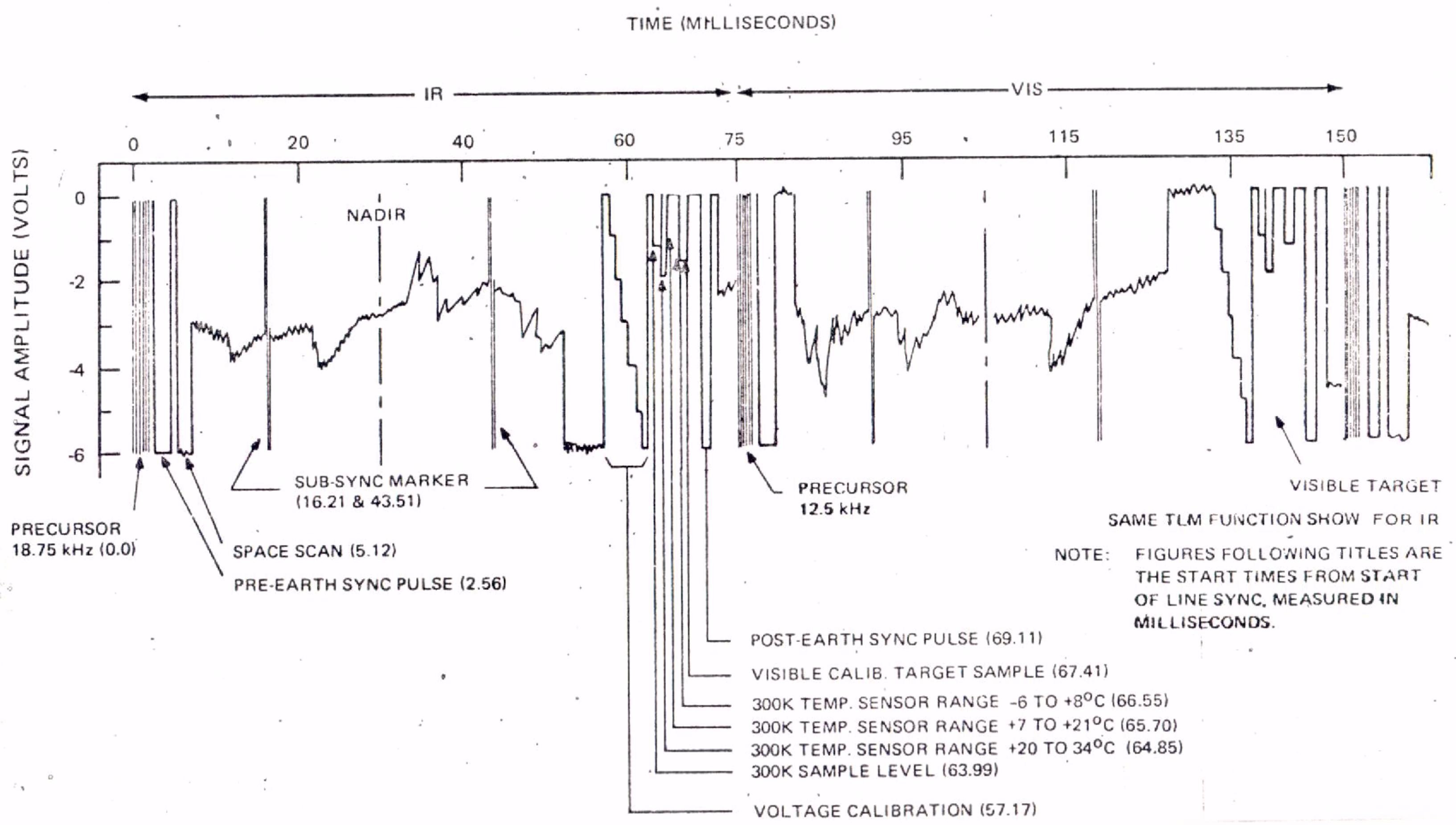


Fig. III.2 - VHRR video signal

TABLE III.1

MAIN CHARACTERISTICS OF THE VHRR SYSTEM

CHARACTERISTICS	SPECIFICATION
VHRR SENSOR	
Spectral	
Infrared	10.5 - 12.5 μm
Visible	0.6 - 0.7 μm
Scanning Speed	400 r/min.
IFOV	0.6 milliradians
Ground Resolution	0.9 km
VHRR TRANSMITTER (HRPT)	
Carrier Frequency	1697.5 MHz ± 0,005%
Power Output	5 watts
EIRP	37.6 dBm (best case) 34.9 dBm (worst case)
Antenna Polarization	RHC
Carrier Modulation	FM
Sub-carrier Frequency	
Normal Mode	99 kHz
Back-up Mode 1 (IR)	99 kHz
Back-up Mode 2	99 kHz e 249 kHz
Sub-carrier Modulation	FM
Baseband Video Bandwidth	35 kHz

TABLE III.2

COMPARISON BETWEEN THE VHRR AND SR SYSTEMS

CHARACTERISTICS	SPECIFICATIONS	
	SR	VHRR
Spectral		
Visible	0.5 - 0.7 μm	0.5 - 0.7 μm
Infrared	10.5 - 12.5 μm	10.5 - 12.5 μm
Resolution		
Visible	4 km	0.9 km
Infrared	7.5 km	0.9 km
Scanning Speed	48 rpm	400 rpm
Carrier Frequency	137 MHz	1697.5 MHz
Modulation	AM/FM	FM/FM
Baseband Video Bandwidth	900 Hz	± 35 kHz
RF Bandwidth	± 20 kHz	± 500 kHz
Transmission System	APT	HRPT

3.3 - VTPR SYSTEM

The Vertical Temperature Profile Radiometer (VTPR) is an instrument projected to measure infrared radiance in eight spectral bands in the range of 11 to 19 micrometers. There are six discrete channels within the 15-micrometer carbon dioxide absorption region, one in the 11 micrometer water vapor window region and one in the 18 micrometer water vapor absorption region. Measurements from these eight channels permit the calculation of the temperature profile from the Earth's surface up to 30 km. The VTPR data are transmitted in a digital format at a rate of 512 bits per second. The spectral characteristics of the VTPR light channels are presented in Table III.3.

TABLE III.3

VTPR SPECTRAL FILTER CHARACTERISTICS

CHANNEL	WAVE NUMBER	BANDWIDTH	REGION
1 (Q branch)	668.5 cm^{-1}	7.0 ± 0.5 cm^{-1}	CO_2
2	695	10.0 ± 2.5	CO_2
3	725	10.0 + 1.0 - 2.0	CO_2
4	535	10.0 + 1.0 - 2.0	Water Vapor
5	835	8.0 + 1.0 - 2.0	IR Window
6	747	10.0 ± 2.5	CO_2
7	708	10.0 ± 2.5	CO_2
8	677	10.0 ± 2.5	CO_2

3.4 - VHRR/VTPR RECEIVING AND PROCESSING GROUND STATION

The VHRR/VTPR receiving and processing ground station developed and assembled at INPE is described in this item (see Figure III.3). The VHF and S-band antennas are assembled on the same pedestal, which exhibits auto-tracking VHRR; signals are recorded by a seven-track tape recorder before further processing, at a speed 4 times slower.

a) VHRR SUB-SYSTEM

The VHRR operation is made in two steps: during the first, the 99 kHz sub-carrier is recorded on the tape; the second step consists of processing the signal at speed 4 times slower than the recording one. During the reception, the 1697.5 carrier is frequency demodulated by the receiver. The resulting 99 kHz sub-carrier is recorded by a seven-track analog recorder (see Figure III.4). Once the reception step is concluded, the recorded tape is rewound up to its initial point. The reproduction takes place right after with a reduced tape transport speed, compatible with the image characteristics. The image recorder can only sensitize the film at a rate of 100 lines per minute, while the satellite line rate is 400 lines per minute.

The 99/4 kHz sub-carrier thus produced is demodulated and the resulting video signal is simultaneouwly sent to a synchronous detector and to an analog/digital (A/D) converter. The synchronism detector generates, from the information contained in the signal, synchronized pulses which are utilized to initialize the A/D converter and to phase-lock the drum rotation, through the servo-control unit.

The resultant words from the A/D conversion are stored temporarily at the mini-computer memory. The retrieval and re-conversion to analog signal is made in time-sharing with the previous step. The retrieval start pulse is derived from the image recorder.

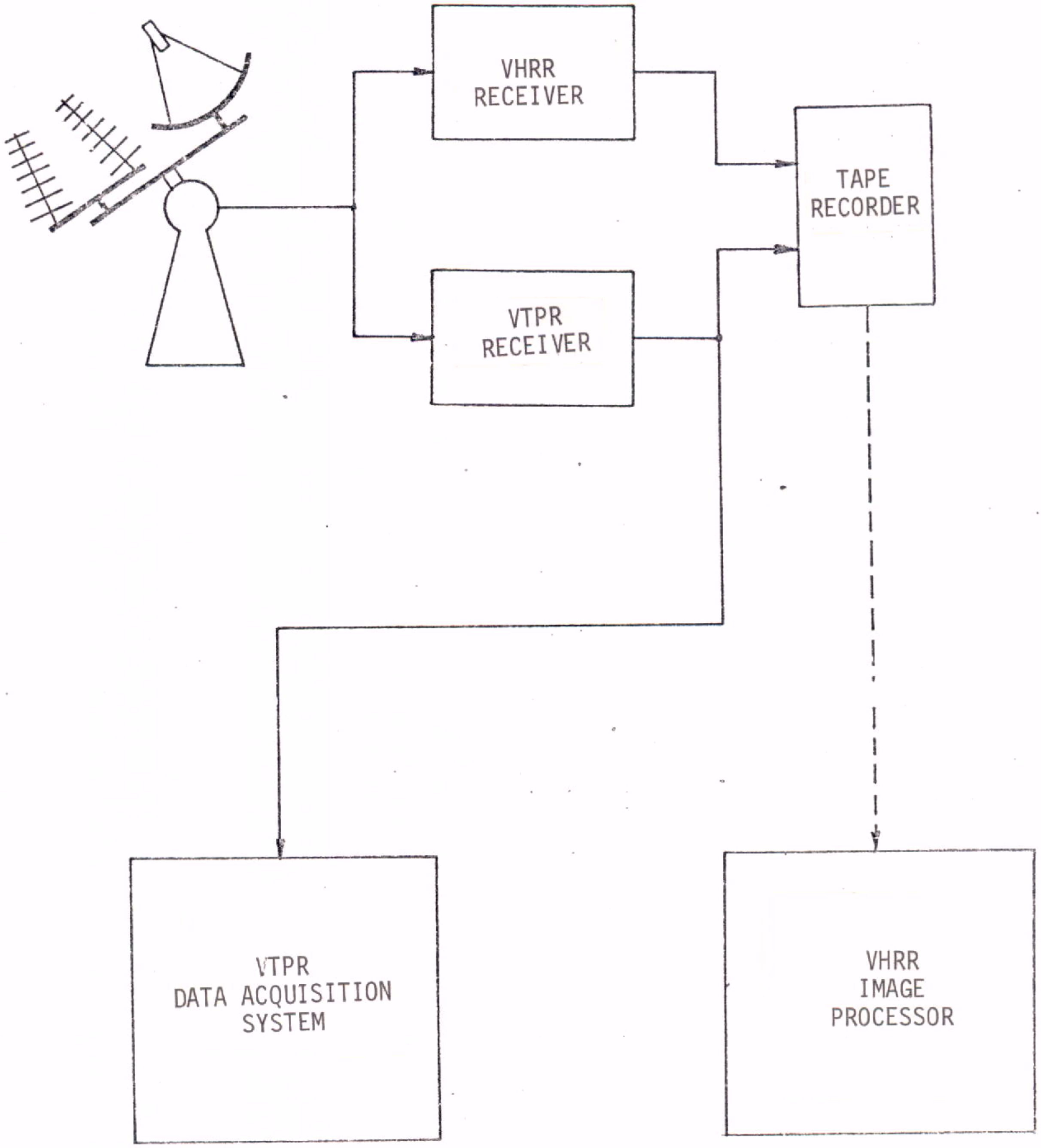


Fig. III.3 - Block diagram of the VHRR/VTPR ground station

b) VTPR DATA ACQUISITION

The VHRR and VTPR signals are received simultaneously. The VTPR data ingestion is carried out by an HP-2116-B mini-computer. As a back-up mode these data may be stored by the same analog tape recorder used during the VHRR reception. The VTPR signals, coming from the receivers, are sent to a diversity combiner, to improve the signal/noise ratio. The diversity combiner output feeds the bit synchronizer which provides the PCM decommutator with a clock and reconditioned data. The existing interface at the CPU of the mini-computer receive the data furnished by the PCM decommutator (see Figure III.5).

The VTPR data are stored on a CCT magnetic tape for further processing.

3.5 - RECENT DEVELOPMENTS AND CONCLUDING REMARKS

After the VHRR/VTPR ground station became operational the following techniques were implemented in order to facilitate the operation.

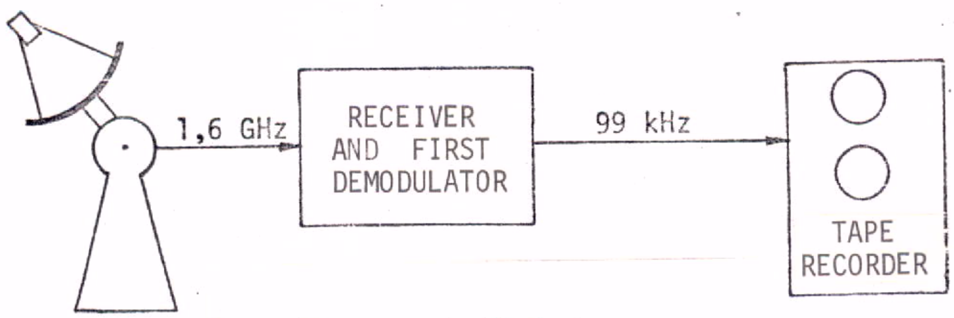
- Computer Image Identification: which consists of printing the necessary information to identify the picture.
- Gridding: special transparency grids were generated to provide the pictures with geographic coordinates. For the gridding procedures it was also necessary to develop a circuitry to generate marks at specific time intervals.
- Second Photographic Recorder: to install this second photographic recorder a buffer memory was constructed with 5K words of 8 bits, which processes the signal in a manner similar to the VHRR mini-computer.

Presently a program for image gridding via computer, as well as an image compressor for transmitting high quality VHRR images via telephone line, are being developed.

The VHRR/VTPR ground station will be conveniently adapted to receive and process the TIROS-N satellite signals. This new series of satellites are supposed to be operational by the second semester of 1978. The TIROS-N will carry on board the AVHRR (Advanced Very High Resolution Radiometer) and the TOVS (Tiros Operational Vertical Sounder) replacing the now existing VHRR and VTPR sensors, respectively.

The experience gained, in this project, created conditions for INPE to develop a SMS/METEOSAT ground station.

RECORDING STEP



Recording speed: 30 in/s
Signal line rate: 400 lines/min.
Recording time: 20 min.

REPRODUCTION STEP

Reproduction speed: 7 1/2 in/s
Signal line rate: 100 lines/min.
Reproduction time: 80 min.

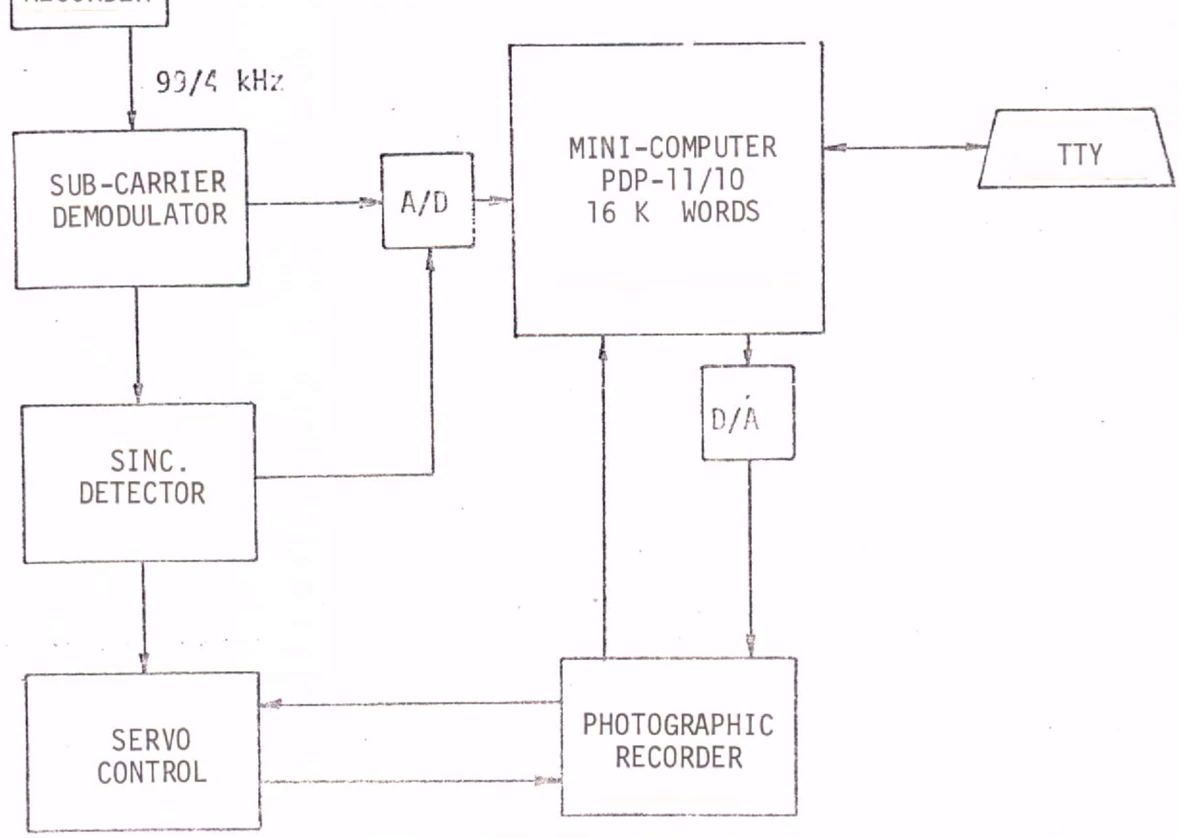


Fig. III.4 - Block diagram of the VHRR sub-system

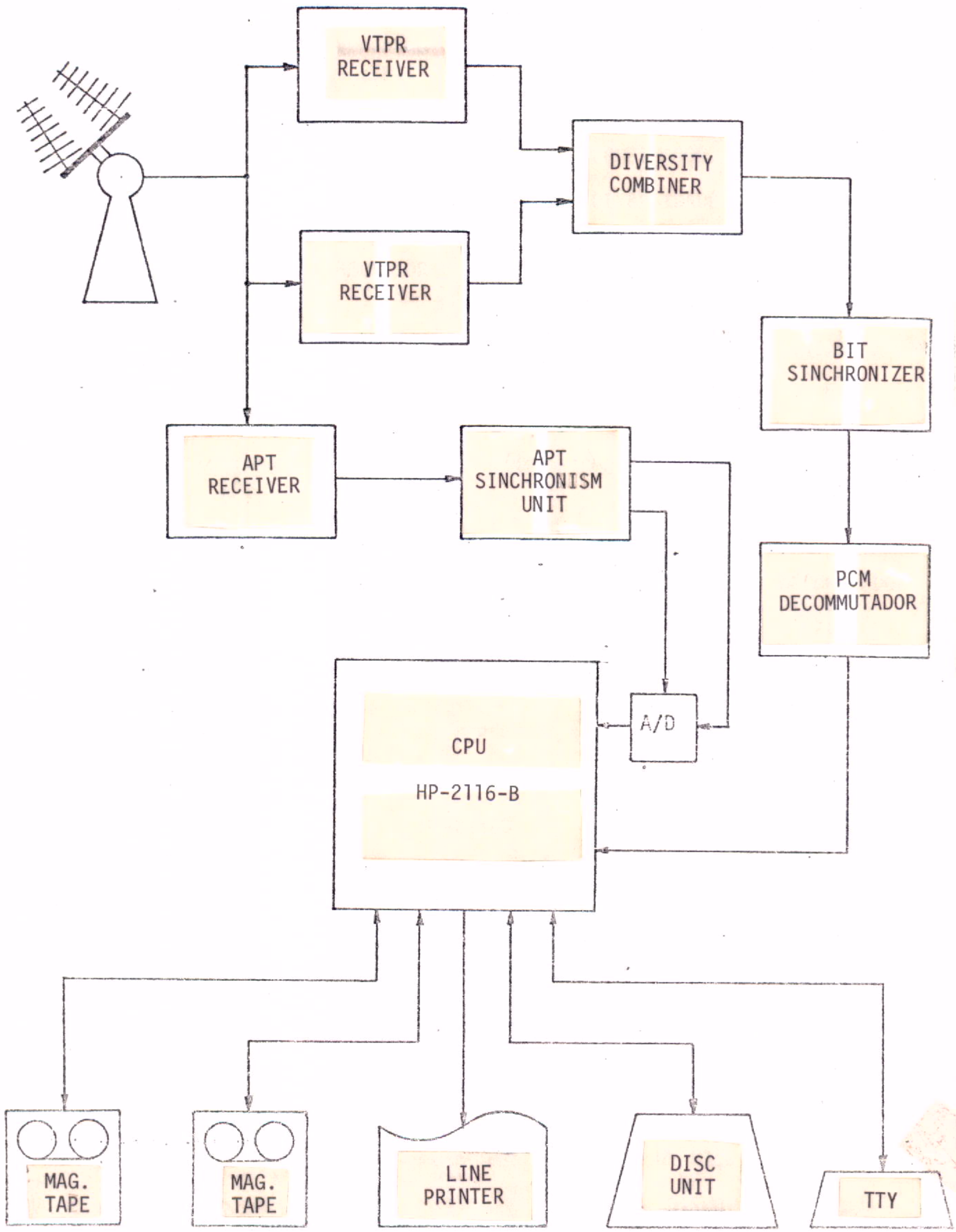


Fig. III.5 - Block diagram of VTPR data acquisition system

CHAPTER IV

IMAGE TRANSMISSION SYSTEM
(Some Considerations)

4.1 - INTRODUCTION

The increasing use of high-quality images, received from meteorological satellites, has brought to the fore the need for their rapid and reliable availability to weather stations and other users, for research, studies and weather prediciton.

Two main alternatives can be envisaged:

Images obtained at a central receiving and processing station would be transmitted to the interested parties; alternatively, the images, as broadcast by the meteorological satellite, would be received directly by satellite tracking and receiving equipment at each location.

The centralized reception and subsequent distribution offers several options (none of them "perfect") as, for example: wire telephony, HF radio, land based microwave routes and satellite relay. A quick overview of the above possibilities follows:

4.2 - WIRE TELEPHONY

The transmission of any kind of data over telephone lines is tied to the bandwidth of the channel. A certain physical link might, for example, transmit intelligence at frequencies ranging from 300 kHz, to 150 kHz. Above this, and below 300 Hz, the signal is too much attenuated to be useful. The 300 Hz to 150 KHz range is the bandwidth of the channel, 149,7 kHz, in this case.

As a further example, Figure I.1 shows the response curve of a 300 to 3400 Hz voice channel. It can be seen that, in this range, the different frequencies are attenuated roughly equally. Outside these limits, the frequencies are so sharply attenuated as not to be usable. The bandwidth, therefore, is 3100 Hz.

Transmission channels have, in general, a bandwidth that is several times that of a single voice channel, although the total bandwidth is electronically "sliced" into 4000 Hz wide slices, each of which becomes one voice channel.

If images are to be transmitted in digital form (or if digital data proper are to be so transmitted) it is necessary to have at each end of the line a "modem" (acronym for modulator-demodulator), which interfaces the line with the transmitter at one side and with the receiver, at the other side of the telecommunication channel. Digital transmission is liable to errors, which degrade the image received; good modems are expensive and their cost goes higher and higher as the speed of transmission (bits/s) increases.

Over short distances it is cheapest to use acoustical couplers instead of modems. The possibility of image degradation, of course, still exists.

4.3 - HF RADIO

When High Frequency radio is used for telegraphy ("fac-simile" transmission uses telegraphy) the degradation of the signals may be more serious than in other types of communication channels. HF radio is subject to severe fading and distortion, especially in times of high sun-spot activity. Because of its high error rate and general unreliability, HF radio should be avoided, as far as possible, for image transmission.

4.4 - LAND BASED MICROWAVE ROUTES

These are, generally, very wide band systems, which allow high transmission velocities with low error rates, in transmitting point to point. Over long routes, the required number of relay stations increases (in the average of one for each 50 km) and this makes for higher costs, the longer the distance.

4.5 - SATELLITE RELAY

The image received and processed at the central station would be sent to an appropriate satellite (usually a geostationary one), which would retransmit it to earth stations of the meteorological (including other users) network.

An example, of this procedure, is the utilization of the WEFAX channel of the geostationary satellites of the SMS series. The WEFAX bandwidth is 30 kHz in a center frequency of 1690,1 MHz. The system has good transmission characteristics, due to practical immunity from noise. It should be pointed out that the system requires the existence of earth stations.

The alternative of having receiving and tracking stations, at several locations, has been in use for about ten years in Brazil.

The appearance of the VHRR system, with the high quality image transmission, has placed stringent requirements in the receiving and processing of the images sent by them, which makes it advisable to have one central receiving station supplying the users.

On the other hand the problem of sending these images with a minimum of degradation, and at an acceptable ratio quality/cost has prompted studies in INPE and this preliminary paper.

4.6 - CONCLUDING REMARKS

The need was pointed out for a faithful retransmission of the VHRR high quality images, received by INPE.

Therefore, a transmission system using telephone lines is in its final project phase, at this Institute. The project contemplates a shortening of the transmission time through an adaptive data compression. The compressor consists, essentially, of a coder which uses delta modulation over regions of small variation in the signal and, automatically, switches to Differential Pulse Code Modulation (DPCM), when the delta mode is no longer capable of following the signal variation. The data, after compression, is sent, by telephone line, through a modem which operates at 4800 bits/s, into the receiving station, where they are decompressed.

It is hoped that this paper has called attention to the fact that image transmission by telephone line is one of the more important options when one takes into account, simultaneously, duration of transmission, cost and reliability.

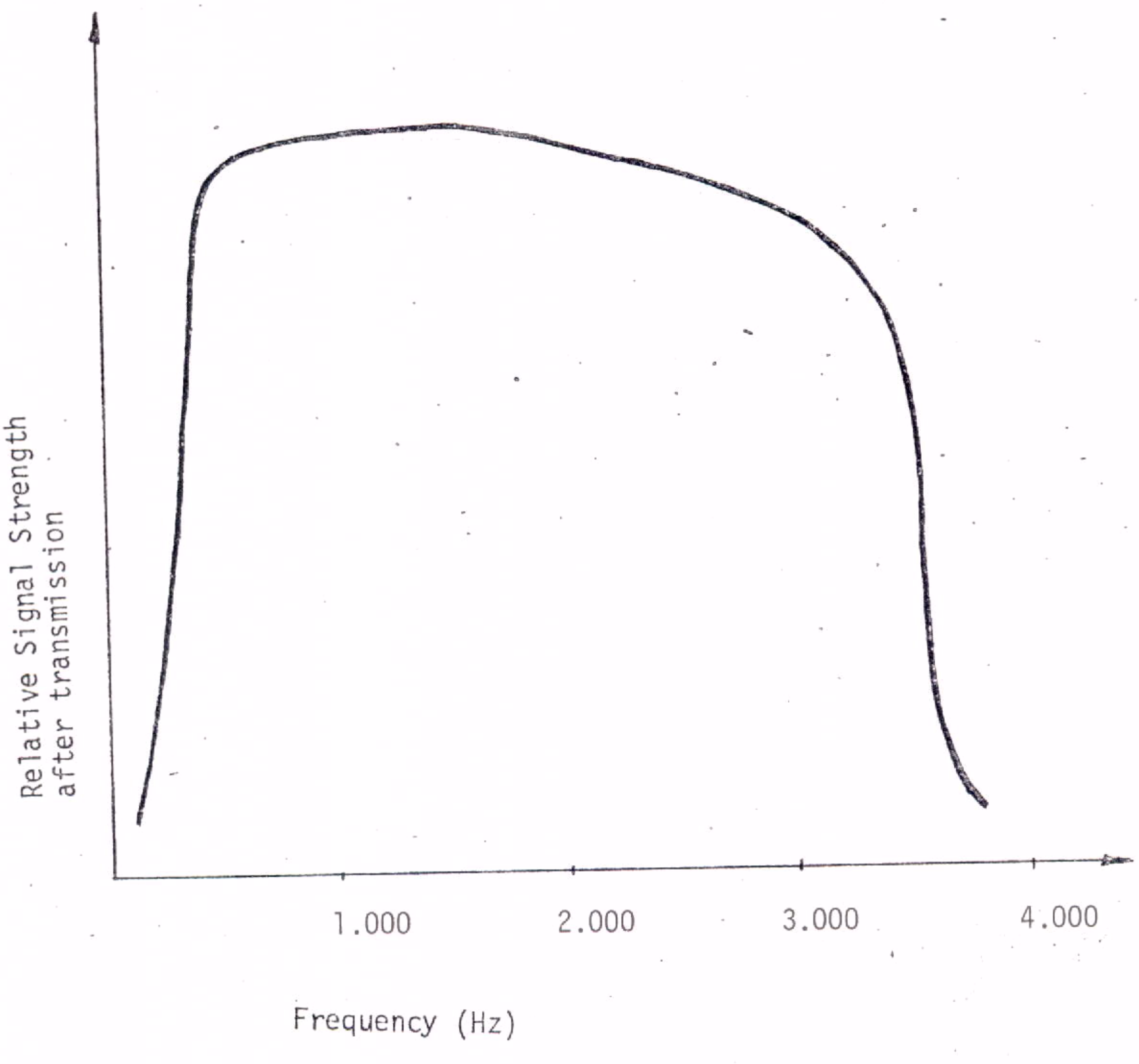


FIGURE IV.1 - Variation in signal strength with frequency after transmission over a typical voice line.

REFERENCES

CALHEIROS, R.V. *A Method for Reproducing Pictures Transmitted by Meteorological Satellites.* São José dos Campos, INPE, Julho, 1972. (INPE-219-RI/020).

——— *Fotodeteção de Sinais de Vídeo.* São José dos Campos, INPE, Julho, 1972 (INPE-220-RI/021).

In this publications a method is presented for photodetection of video signals modulated in amplitude. A mathematical model is formulated for the detection and a relationship between emitted light and corresponding video signal is derived. This relationship is experimentally confirmed and the suitability of the method for the photodetection is shown.

——— *Reprodução de Fotografias de Satélites Meteorológicos por Fotodeteção de Sinais de Vídeo.* São José dos Campos, INPE, Ago. 1972. (INPE-221-RI/022).

——— *Um Método de Reprodução de Fotografias de Satélites Meteorológicos.* São José dos Campos, INPE, Sep., 1971. (INPE-LAFE/60).

This is the M.S. thesis which resulted from developing a simple method to receive and process the APT signals. Here the method is described in which sampling of the APT subcarrier modulated by the video signal, displayed on the Y-axis of a CRT is used to reproduce meteorological pictures without need for an AM detector as in conventional systems. The APT/INPE system is based on this method. An English version of this work was also published and is titled "A Method for Reproducing Pictures Transmitted by Meteorological Satellites" (Calheiros, 1972).

CALHEIROS, R.V.; ABREU, J.T.; OLIVEIRA, J.R. *Modificação de Estação de Rastreio de Satélites Meteorológicos para Recepção de Sinais APT-SR.* São José dos Campos, INPE, Outubro, 1973. (INPE-392/LAFE).

The NOAA satellites which succeeded the ESSA series featured a line rate of 48 lines per minute and a scanning radiometer instead of the vidicon camera. To attend to this modification it was necessary to develop some equipment to adapt the APT/INPE ground stations. The procedures to install and operate the adaptation equipment are presented in this report.

CALHEIROS, R.V.; MOURA, A.D.; SANTOS, R.P. *Curso de Treinamento para Operadores de Estação APT.* São José dos Campos, INPE, Setembro, 1971. 2.v (INPE-LAFE/167).

By the time INPE started offering courses on Satellite Meteorology, it was found convenient, if not necessary, to provide the students with organized notes in the Portuguese language. This was partly due to the fact that most of the existing bibliography on the subject found in Brazil, if available, is highly specialized and in English. On the other hand the notes would constitute a means for divulging the recent accomplishments of INPE in the field of satellite meteorology. The main topics treated in these notes are: elements of orbital theory, image gridding and image interpretation and analysis.

DUTRA, L.V. *Aperfeiçoamento do Sistema para Processamento de Imagens Recebidas dos Satélites Meteorológicos Portadores de Radiometros de Muito Alta Resolução (Sistema VHRR).* São José dos Campos. INPE, Maio, 1977.

This is a technical report on the computer program specifically developped for the management of the VHRR signals processing. The image identification and the conversational capability are the main topics of the repport.

ELIAS, M.; OLIVEIRA, J.R. *Manual do Usuário da Estação APT.* São José dos Campos, INPE, no prelo.

This is a guiding manual which has been specifically written for the APT/INPE ground station operators. Its format permits additions as well as updating and about 80% of what was originally planned has been concluded already, that is: Chapter III(Camera); Chapter V (Clock); Chapter VI (Photographic Laboratory); Chapter VII (Oscilloscope); Chapter VIII (Gridding) and Chapter IX (Operation Procedures). An Appendix has been created to take care of the recent technological advances concerning the APT station. A report on the so called Doppler Correction Adapter has been written already and constitutes the section A of this Appendix.

ELIAS, M.; OLIVEIRA, J.R.; BORUSZENSKI, W. *Curso de Treinamento de Operadores de Estação APT.* São José dos Campos, INPE, Setembro, 1975. (INPE-740-NTE/024).

These are compiled notes on satellite meteorology treating the following aspects: elements of orbital theory, the existing technique for receiving and processing meteorological satellite signals, orbit prediction and imagery gridding. They were specifically prepared for an intensive course on satellite meteorology offered by INPE from September, 15 de October 30, 1975. Also included in this course were infrared and visible imagery interpretation as well as on the job training to operate an APT station. Notes similar to these already existed (Calheiros, 1971). However it was found necessary to write new notes to provide the students with higher level updated information.

FORTUNA, J.J.; HAMBRICK, L.N. *The Operation of the NOAA Polar Satellite System.* Washington, D.C., NOAA, Nov., 1974. (NOAA TM NESS 60).

KOSHIMA, S. *Antenas YAGI-UDA; Descrição de um Programa Computacional,* São José dos Campos, INPE, Abril, 1977 (INPE-1014-NTI/084).

In this report is presented the utilization procedure of a computer program developped to calculate the characteristic elements of a Yagi-Uda antena. The following tasks can be perfomed with this program:

a) To calculate the directivity, front-to-back ratio and radiation diagram of a given Yagi antena.

b) To determine the optimum spacing between the elements.

c) To determine the optimum element lenghts.

——— *Otimização das Alturas e Espaçamento dos Elementos de uma Antena YAGI-UDA.* São José dos Campos, INPE, Julho, 1976. (INPE-920-TPT/034).

This publication constitutes a M.S. thesis and in it is presented a method to maximize the directivity of a Yagi-Uda antena. The current distribution analysis for each antena element is based on the King-Middleton three terms expansion. The directivity maximum is obtained by applying the perturbation method to the spacing and heights of the antenna elements. Making use of the computer program developed for optimizing the Yagi antena, it was observed a sensible dependence of the directivity on the element rays. A series of experimental data is presented to be compared with the theoretical results.

MAMMOLI, M. *Correção do Efeito Doppler na Recepção de Sinais de Satélites Meteorológicos via Satélite.* São José dos Campos, INPE, Maio, 1975a.

Due to time variation of the cristal oscillator frequency and due to the presence of accidental noise in a meteorological satellite signal reception it is not possible to obtain perfect synchronism at the beginning of the scanning of the signal received with an *oscilloscope. The resulting effect from these pertubations appear in the form of picture distortion. Another undesired effect which also causes distortion is the Doppler effect. In this report a circuitry is proposed which eliminates the mentioned distortions, providing an excellent linearity at the beginning of the oscilloscope scanning with the received signal.*

MAMMOLI, M. *Correção do Efeito Doppler na Recepção APT Usando Phase Locked Loop com VCO a Cristal.* São José dos Campos, INPE, Dezembro, 1975b. (INPE-807-NTI/044).

This report presents method for eliminating the Doppler effect and noise distortion from APT images. The method makes use of a Phase Locked Loop with cristal VCO.

______ *Eliminação do Efeito Doppler em fotografias transmitidas por satélites meteorológicos.* São José dos Campos, INPE, Julho, 1976. (INPE-910-PE/031).

This a revised version of the previous report (Mammoli, 1975b). (Correção do Efeito Doppler na Recepção APT com VCO a Cristal).

MOURA, A.D. *Mapeamento de Pontos sobre a Terra para Imagens Obtidas por Radiometro de Varredura a Bordo de Satélites.* São José dos Campos, INPE, Julho, 1975. (INPE-697-NTI/021).

In this report an iterative method is presented which has been developed to map points over the earth which are given by their geographic coordinates for imagens obtained by the scanning radiometers on board meteorological satellites. In this method a circular orbit and spheric Earth are considered. The method is very simple and useful to map the land masses which are frequentely present in the satellite images. The method converges quickly and only 3 to 4 iterations reduce the longitude error to 10^{-6} *radians.*

NICOLLI, D.N. *Manual de Análise de Imagens Infravermelhas dos Satélites Meteorológicos.* São José dos Campos, INPE, Setembro, 1975. (INPE-748-NTE/027).

This is an infrared imagery manual. It was especially prepared for the intensive course on satellite imagery offered by INPE from September 15 to October 30, 1975. This manual presents: the elements of remote sensing with scanning radiometers, a discussion on the advantages of computer processing the infrared pictures and methods for utilizing UV images on an operational basis.

NUNES, H.M.T. *Manual de Interpretação de Imagens de Satélites Meteorológicos.* São José dos Campos, INPE, no prelo.

This a guide to satellite imagery interpretation dealing specifically with synoptic situations over South America. The main picture source for this work has been the INPE archives.

NUNES, H.M.T.; ARAGÃO, M.R.S.; SANTOS, R.P. *Normas para Processamento Operacional de Sinais Enviados por Satélites Meteorológicos.* São José dos Campos, INPE, Outubro, 1975. (INPE-777-NTI/038).

This publication presents a set of rules which is adopted at INPE for the operational processing and archiving of the meteorological satellite signals received by the APT ground Station.

NUNES, H.M.T.; CALHEIROS, R.V.; ISLVA, M.R.; ALDAZ, L. *Manual de Controle de Qualidade de Diapositivos, Negativos e Cópias em Papel, Provenientes do Processamento de Sinais Enviados por Satélites Meteorológicos.* São José dos Campos, INPE, Julho, 1973. (INPE-LAFE-389).

This is a gridding manual which describes, points out and furnishes examples of the imperfections that may occur as a result of the photographic processing of the signals transmitted by meteorological satellites. Also presented is a set of rules for the quality *control of positives, negatives and prints.*

OLIVEIRA, J.R.; ELIAS, M. *Estação Receptora de Satélites Meteorológicos com Radiometro de Muito Alta Resolução - Relatório Final.* São José dos Campos, INPE, Junho, 1977.

This document constitutes the Final Report of the project "Installation of the Very High Resolution Radiometer Signals Receiving Station" executed by the Instituto de Pesquisas Espaciais, with partial support of SUBIN (Secretaria de Cooperação Econômica e Técnica Internacional) during the period of January 1974 to December 1976. The main discussed aspects are: system definition equipments device and acquisition, technical description of the system, operation. evolution and data utilization.

OLIVEIRA, J.R.; MOURA, A.D.; CALHEIROS, R.V.; GARCIA, G. *Rotinas para Operação de uma Estação de Rastreio de Satélites Meteorológicos.* São José dos Campos, INPE, Dezembro, 1971. (INPE-LAFE/175).

This report presents the procedures to operate an APT/INPE ground station, covering the following aspects: photographic processing, oscilloscope and synchronism adjustment, clock adjustment and imagery gridding.

OLIVEIRA, J.R.; RODRIGUES, V. *Um Sistema de Aquisição e Processamento de Imagens de Alta Resolução Transmitidas por Satélites Meteorológicos.* São José dos Campos, INPE, Julho, 1976. (INPE-902-PE/023).

This is a technical report on the VHRR aquisition and processing system developped and assembled at INPE. The signal trasmitted by the satellite is received andits subcarrier recorded to be reproduced later on at a speed 4 times smaller. The FM demodulation is made by digital detection process. Each image line is digitized and stored in the memory of a minicomputer. The data are retrieved and sent to a high precision photographic recorder.

The photographic recorder drum generates pulses which command the lines output and its rotation is sinchronyzed with the video signal. A detailed prescrutration of the acquisition and processing system as well as of the images obtained in photographic paper is also included.

PONTES, MORAES E CIA LTDA. *Sistema de Recepção de Fotografias de Satélites Meteorológicos (APT) Modelo APT-102.* São José dos Campos, Abril, 1971.

This is the operation and maintenance mannual of the APT/INPE ground station manufactured by Pontes, Moraes e Cia. Ltda.

SANTANA, P.H.A.; OLIVEIRA, J.R.; MEIRA FILHO, L.G. *Gradeamento de Imagens Produzidas por Radiômetros de Varredura a Bordo de Satélites.* São José dos Campos, INPE, Outubro, 1974. (INPE-558-RI/251).

This publication presents the first computer program specifically developped at INPE to generate coordinate grids for imagens obtained by the scanning radiometer on board ITOS/NOAA meteorological satellites.

SCHWALB, A. *Modified Version of the Improved Tiros Operational Satellite: ITOS D-G.* Washington, D.C., NOAA, April, 1972, (NOAA TM NESS 35).

SOUZA, A.N. Filtro de Portadora com Cristal. In: ELIAS, M.; OLIVEIRA, J.R. *Manual do Usuário da Estação APT,* Seção 1, Apêndice A. São José dos Campos, INPE. No prelo.

This is on updated version of the report entitled "Correção do Efeito Doppler na Recepção em APT usando Phase Locked Hoop com VCO a Cristal" (Mammoli, 1975). The original project of the so called Doppler Correction Adapter to be used in the APT/INPE ground station had to be modified in order to substitute some of the imported components by national ones, to avoid importation problems.

TAKAKI, L.T. *Mapeamento Térmico da Superfície do Mar Utilizando Imagens Digitalizadas VHRR dos Satélites da Série NOAA.* Tese de Mestrado. São José dos Campos, INPE, Julho, 1977. (INPE-1072-TPT/059).

This is a M.S.Thesis on a method to derive the sea surface temperatures through the use of the digitized infrared VHRR/NOAA signals.

VIOLA, F.E.C. *Sistema de Aquisição de Dados VTPR.* São José dos Campos, INPE, Julho, 1977. (INPE-1069-NTE/091).

This technical report presents the computer program specifically developed for the VTPR real time data aquisition on the minicomputer HP-2116B.

——— *Sistema de Digitalização de Imagens VHRR.* São José dos Campos, INPE, Maio, 1976. (INPE-880-NTI/068).

This is a technical report that describes the computer program specially developped to digitize the VHRR signals in a minicomputer HP-2116B.

ZAMLUTTI, C.J. *Cálculo do azimute e de Elevação a partir de um Cruzamento com o Equador.* São José dos Campos, INPE, Agosto, 1974. (INPE-511-RI/217).

The revised version of the computer program to calculate the initial and subsequent position of a polar orbiting satellite and completely determines the antena position to track the spacecraft (Zamlutti, 1969).

——— *Previsão de Passagens para Satélites em orbitas Etilicas ou Circulares sem Perturbações.* São José dos Campos, INPE, Julho, 1969. (INPE-LAFE/089).

This is a report on the computer program developped to calculate the initial and subsequent position of a polar orbiting satellite for tracking purposes. Orbital perturbation is neglected.