A DESCRIPTION OF A STANDARD SMALL SATELLITE GROUNDSTATION FOR USE BY WMO MEMBERS

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FOREWORD

This document has been prepared by the Commission for Basic Systems and forms the basis for a description of a standard small satellite groundstation. The major components of a standard small satellite groundstation are described in detail as well as the functionality expected from such a station. The intended audience for this document includes the Heads of the National Meteorological and Hydrological Services, those enterprises who manufacture satellite receiving equipment, agencies and organizations providing financial support for environmental projects (e.g. World Bank, UNDP), education and training facilities involved with satellite meteorology, satellite operators in order to provide a reference for standard data exchange interfaces, and most importantly the potential user of a small satellite groundstation. The document was developed by the CBS Working Group on Satellites Sub-group on Small Workstations with a majority of the effort accomplished by the Sub-group Chairman, Dr. Xu.

1. INTRODUCTION

1.1 On 19 June 1993, the forty-fifth session of the Executive Council (EC) transferred the responsibility of satellite matters to the Commission for Basic System (CBS) and the CBS Working Group on Satellite (CBSWGSAT) was established. Earlier, at the tenth session of CBS, the following items were decided to be included in the terms of reference for CBSWGSAT:

- To assess the observation, collection, and analysis systems relating to the use of satellites in activities of interest to all WMO Members and to suggest ways and means for improving system capabilities, particularly to Members in developing countries [(a) in the terms of reference];

- To make recommendations concerning standardization of satellite services and related ground receiving systems [(e) in the terms of reference].

1.2 A work plan was developed by the Chairman of the CBSWGSAT and later agreed through correspondence with other working group members. In the work plan, "satellite workstations" was identified as a topic to be dealt with and a sub-group was assigned to this topic. Based on the work plan, the tasks for the Sub-group on "Satellite Workstations " were developed and include:

- Develop guidelines (minimum performance specifications) for reception and display of satellite ground receiving stations;

- Develop a project plan for low cost, and long-life satellite receiving stations; and,

- Develop and prepare a publication implementation report on satellite ground receiving equipment in WMO Regions.

1.3 The Chairman of the CBSWGSAT requested the Sub-group Chairmen and Rapporteurs to prepare documentations before the first CBSWGSAT meeting, 7-11 March 1994, so that the working group could meaningfully discuss topics and arrive at recommendations. A paper containing the essentials of this document was drafted for the above purpose.

1.4 During discussions in the first CBSWGSAT meeting, the working group felt that it was necessary to use the nomenclature "small ground stations" since "workstation" did not imply to most potential users a satellite data reception and utilization station.

1.5 Considering the outstanding requirements from users, the first session of the CBSWGSAT meeting requested the sub-group to supplement the draft report with materials describing the desirable characteristics of a small ground station for environmental satellite data reception and analysis. It was suggested that such materials should focus on applications which would be available within the station and that it would be beneficial in developing minimum performance specifications and to identify standard processing package for the station.

1.6 The first CBSWGSAT meeting also noted that a training, installation and maintenance programme was needed. The meeting requested the sub-group to draft such a plan for consideration by the CBSWGSAT.

1.7 After the first CBSWGSAT meeting, the draft report was revised and supplemented based on advice and comments made at the first CBSWGSAT meeting. The draft report was then guided by the following considerations:

(i) The strategic goal of the small ground station sub-group is to systematically improve the use of satellite data over the next 10-15 years by spreading work station availability in the member countries. To support this goal, there is a requirement to continue data direct broadcast service and to develop low cost satellite receiving stations. In section 2, the direct broadcast service is briefly described as well as the necessity to continue the direct broadcast service.

(ii) The configuration of a small satellite ground work station is characterized in Section 3. This section is for administrators and meteorologists to understand easily the conception of satellite ground stations and their components.

(iii) In sections 4-7, functional requirements, performance specifications (minimum and full), reliability considerations and training requirements are proposed.

(iv) Finally, the Commission requested the CBSWGSAT to develop a proposal for more sophisticated data structures and standardized advanced data exchange interfaces. This subject is discussed in Section 8.

2. DIRECT BROADCAST SERVICE BRIEFING

2.1 *History of Direct Broadcast Service*

2.1.1 Direct broadcast service is a broadcast service provided by some operational environmental observation satellites that transmit satellite sensor data and products in real-time and near real-time for reception by ground stations within receiving range of the satellite. The direct broadcast service was first initiated by the USA satellites. In December 1963, TIROS-8 included a vidicon TV camera for Automatic Picture Transmission (APT). The APT system permitted direct real-time transmission of analogue cloud pictures covering a 1,600 to 3,200 km radius to APT ground stations around the world. The APT service has been available ever since. There are now more than 1,000 user stations in at least 123 countries. The analogue cloud image transmission evolved into digital data transmission in 1977 with the ITOS-D satellite (NOAA-2). The digital transmission was formalized as the High Resolution Picture Transmission (HRPT) from the Advanced Very High Resolution Radiometer (AVHRR) in 1978 by TIROS-N satellites. HRPT service has also been provided on a continuous basis ever since. Now, there are more than 130 user stations in 44 countries. The Direct Sounder Broadcast (DSB) has also been providing TIROS Operation Vertical Sounder (TOVS) data since 1977.

2.1.2 In 1974, the SMS-1 satellite started the Weather Facsimile (WEFAX) service from geostationary meteorological satellites. The WEFAX service provided processed satellite imagery through an analog signal compatible with the APT signal of the polar orbiting satellites. High resolution digital image data from the Visible and Infrared Spin-Scan Radiometer (VISSR) that is stretched (S-VISSR) has been available since 1973 when the SMS-1 satellite first started its broadcast. Although originally for internal use by NOAA, S-VISSR was made available for all users and has become a major type of direct broadcast service. GOES satellites, replacing SMS in 1975, now have over 127 S-VISSR user stations. The GOES series of geostationary satellites introduced the joint functionality of multi-spectral imaging and dwell sounding data provided by the VISSR Atmospheric Sounder (VAS). Similar direct broadcast services have been provided by most of the satellite operators and most of these services have been continued up until the present. In December 1971, the meteorological satellites of the former USSR initiated APT service. The European Meteosat-1 started high resolution digital image and WEFAX services in 1977. The Japanese GMS-1 satellites have provided stretched-VISSR (earlier HR-FAX) and WEFAX services since 1977. The Chinese FY-1 satellites provided HRPT and APT services IN 1988 and 1990-1991. In 1990, the European Meteosat 4, 5 and 6 started the MDD (Meteorological Data Distribution) service. This service broadcasts meteorological data through geostationary meteorological satellites in support of the GTS.

2.2 ***Action and benefits from Direct Broadcast Service***

2.2.1 The direct broadcast service is used to distribute a myriad of digital, WEFAX and APT data to users in real-time or near real-time. This limited processing makes the service very reliable. Most of the satellite operators successfully achieve 98 percent availability or more. The data are transmitted to the users almost at the same time as the observation and is appropriately called "real-time". The reliability and real-time transmission aspects of the direct broadcast service greatly attract users. Now, most meteorological satellite data users get their satellite data through the direct broadcast service. The direct broadcast service also plays a positive role in spreading meteorological satellite data application, prompting improvement of product derivation algorithms and in bringing about global data collection. With the direct broadcast service, ground stations spread across many locations can obtain satellite imagery and remote sensed data. Meteorological satellite data applications have greatly proliferated. Such applications are mostly in the fields of natural disaster prediction and public service and thus are for the benefit of all humankind. With the direct broadcast service more scientists over the world are involved in research for meteorological satellite product derivation algorithms and application methodologies. This in turn has a positive feedback to the promotion of product accuracy and application level. With the direct broadcast service, meteorological satellite data are collected and archived at many locations. It helps to improve the availability of global data.

2.2.2 Considering the reliance of the current meteorological network on the direct broadcast service and the potential benefits to humankind, it is necessary to continue this service in the future and to broadcast directly meteorological satellite data. It should be noted that WMO has established the direct broadcast service as one of its satellite service requirements.

2.3 ***Actions for encouraging the continuity of direct broadcast service in the future***

2.3.1 The value of the direct broadcast service of satellite data to WMO Members is well recognized. The Forty Fourth WMO Executive Council noted and endorsed the conclusion that direct readout services from meteorological satellite are essential and that satellite operators were urged to continue these services. Until now, agencies operating satellites provide satellite imagery, data and products to WMO Members free and unrestricted. At present WMO is reviewing its policy and remains committed to broadening and enhancing the free and unrestricted international exchange of meteorological and related data and products.

3. CONCEPTIONAL CONFIGURATION OF A SMALL SATELLITE GROUND STATION

The operational meteorological satellites, both polar-orbiting and geostationary, have different forms of direct data-dissemination facilities on the same satellite.

There are two of these direct data dissemination services provided on some of the polar-orbiting satellites. The most widely used is the Automatic Picture Transmission (APT) service. APT is a VHF analogue transmission in which visible and infrared pictures are transmitted on one of two frequencies (137.1 or 137.9125 MHz) with a transmission power of 5W. Low-cost ground receiving equipment consisting of a computer and appropriate radio equipment is capable of receiving, displaying and manipulating APT transmissions. Data provided on the APT transmissions have a medium spatial resolution (4 km) and are presented in pictorial form. There are at present over 1,000 APT receiving stations throughout the world. It is anticipated that the APT service will change from analogue to digital at the end of this decade.

The second data-dissemination is the high resolution picture transmission. This is a transmission at any one of three S-band frequencies - 1,698.0, 1,707.0 or 1,702.5 MHz (the latter frequency is only used when the 1,698 and 1,707 transmitters have failed). Data are transmitted at 665.4 kbit/s. Included in this transmission are the full resolution 1 km data for all channels of the scanning radiometer (one visible, one near infrared and either two or three infrared spectral intervals) and all the digital data contained in the beacon transmission.

The geostationary spacecraft also provide two direct data dissemination services. The first of these is a full resolution digital transmission from which the user can obtain all the image data available from the spacecraft. Receiving equipment required for this service is more complex and expensive than that required for the second direct data-dissemination service, weather facsimile (WEFAX). By informal agreement among the international satellite operators, the WEFAX service of the various geostationary satellites transmits signals with identical characteristics. These signal characteristics, except for transmission frequency, are the same as for the APT service from the polar-orbiting satellites. Thus, by the addition of an S-band antenna and a down-converter, an APT station can be equipped to receive WEFAX as well. The service is provided at 1,691 MHz and the same receiving station can operate with any of the geostationary spacecraft. Data transmitted on the WEFAX service are at a reduced resolution and the transmissions consist of a series of sectors extracted from the full disk picture, transmitted serially. In general, WEFAX services provide a set of sectors from a full disk image, with a repetition at least every three hours. Both visible and infrared images of WEFAX are provided in analogue form while high-resolution transmissions are in digital format. The transmission characteristics of the high-resolution broadcasts are unique to each of the satellite operators. Japan's Geostationary Meteorological Satellite GMS broadcasts Stretched VISSR (S-VISSR) transmissions. These are obtained by a Visual and Infra Red Spin Scan Radiometer mounted directly on the spinning geostationary satellite. This radiometer scans the Earth from west to east as the satellite rotates; a slowly moving mirror provides the north/south component of the scan. Because Earth subtends only 17 degrees of arc at the geostationary orbit the high rate raw VISSR signal is "stretched" by the Satellite Control and Data Acquisition Station in Japan and retransmitted during the remaining 343 degrees of the satellite's rotation. This transmission, at a data rate of 660 kbit/s is known as the S-VISSR signal. GMS S-VISSR transmissions are transmitted at a frequency of 1687 MHz. China's planned Feng Yun-2 satellite will transmit a S-VISSR signal in a similar format to that of GMS. Details of other transmission characteristics are given in later parts of this publication.

A small satellite ground station capable of receiving any of the above data transmission schemes should consist of two major parts: data receiving and data processing. In the following section we first describe transmission characteristics and then explain the conceptional configuration of the data receiving and data processing parts.

3.1 *Transmission Characteristics*

3.1.1 Modulation

3.1.1.1 Satellite sensors produce signals of direct current with fluctuations. The frequency of such signal may be very low depending on the object remotely sensed. It is impossible to transmit the signal with such a low frequency from a spacecraft to ground since low frequency electro-magnetic waves are attenuated while they are transmitted. Thus, a high frequency wave called the carrier is combined with the original signal (baseband) to form a modulated signal which can be transmitted for a long distance. This process is called modulation. In a small satellite ground station, the baseband signal should be recovered from the "modulated signal" received from the satellite. This process is called demodulation.

3.1.1.2 The carrier can be expressed as:

$$A \sin (2 \pi ft + Ø)$$

In the expression, A is the amplitude of the carrier; f the frequency; and Ø the phase. From this expression, we can see that there are three possible modes to modulate a baseband signal: Amplitude Modulation (AM), Frequency Modulation (FM) and Phase Modulation (PM). AM, FM and PM shift the amplitude, frequency or phase respectively to describe the baseband signal. FM has better transmission characteristics than AM when considering level change and interference. PM is more appropriate than AM or FM for high speed digital data transmission because interference usually changes the amplitude and to a lesser extent the frequency. However, interference has little effect on phase. In phase modulation, amplitude and frequency of a carrier do not contain useful information. In practise, dual modulation is used.

3.1.1.3 For APT and WEFAX, the sensor output with a frequency range of 0-1600 Hz is amplitude modulated to form a sub-carrier with a central frequency of 2400 Hz. The sub-carrier is then frequency modulated by a main carrier at a higher frequency (136.5-138 MHz) to form a modulated signal for transmission. This mode of modulation is called AM/FM.

3.1.1.4 For HRPT, the sensor output is firstly digitized to form a pulse code. This process is called Pulse Code Modulation (PCM). In PCM, a continuous signal is quantized into numeric pulse signals and then the pulse code signal is phase modulated for transmission. This process is called Phase Shift Keying (PSK). Thus the HRPT modulation mode is called PCM/PSK.

3.1.2 Coding

3.1.2.1 The output signal from a sensor is an electrical current with continuous variation. In analog transmissions, the signal is transmitted directly. Noise or random fluctuations in electrical energy due to the atomicity of matter is inevitably introduced into the signal during the processes of modulation, transmission and reception. Analogue signals are particularly affected by noise, consequently an analogue transmission system is unable to accurately reproduce the signal levels obtained by the satellite sensor. This greatly limits the application of meteorological satellite data.

3.1.2.2 In digital transmission, the sensor output is quantized (i.e. converted from analogue to digital form) on the spacecraft and then transmitted to ground as a sequence of "1"s or "0"s. Digital transmission rejects errors (such as those introduced by noise in analogue signals) in the transmission process. Therefore, through the use of digital transmission the quality of the signal received by the ground station is significantly improved. The quantized data bits or character must be encoded into an electrical signal for transmission. This process is called coding. The common codes include None Return to Zero (NRZ) and Biphase, (Bi-Ø). NRZ coding keeps the signal level of the last bit unchanged until the next bit arrives. Biphase coding uses phase 0 degree and phase 180 degree to represent 1 and 0 respectively (or alternatively biphase coding always has a transition in the middle of the bitcell where a 0 to 1 transition would be a logical 0, etc.).

3.1.2.3 In digital transmissions, a "bit" is a basic information unit. Any form of information, such as character, command, graphic and image, can be expressed as a sequence of bits. To correctly recognise the encoded bit sequence, the receiver must be synchronised with the transmitter so that both transmitter and receiver share the same timing. To achieve this a synchronisation pulse or "clock" is added to the coded electrical signal. This clock is used by the receiver for bit synchronisation.

3.1.2.4 Data are assembled on the satellite into blocks called a frame for transmission. Each frame is of a fixed length. It is headed with a few fixed synchronization words (i.e, frame synchronization signal) and ended with a few fixed words. The action of the synchronization words is to let the receiving system correctly recognize the start and the end of a data block so as to correctly recognize the contents of the data block.

3.1.3 Electrical Signal Characteristics

3.1.3.1 The signal strength transmitted by the satellite is measured by its Effective Isotropic Radiated Power (EIRP). This is an important characteristic which must be taken into account in designing a ground station to receive data from the satellite. Other factors include the distance between the satellite and the ground station and the frequency and bandwidth of the transmitted signal. A particularly important feature of the receiving ground station is its figure of merit as defined by its "G/T ratio" expressed in decibels (dB). "G" is the gain of the satellite ground station in dB relative to that of an isotropic (omnidirectional) antenna; "T" is the station noise temperature in degrees Kelvin (also expressed in dB).

3.1.3.2 Ideal rectangular waves of a serial bit stream at baseband after coding have infinite bandwidth. In practice, the bandwidth is limited by a filter in the spacecraft. This has the effect of increasing the rise time of the edge of baseband signal such that the received waveforms are not truly rectangular, but the likelihood of interference from adjacent channel radio links is reduced. The bandwidth of the modulated carrier depends on the type of modulation. To allow the signal to be transmitted appropriately with a limited error probability, it is necessary to have the bandwidth above some specified value. This bandwidth value is linearly proportional to the transmission speed (bit rate).

3.1.3.3 Polarization is also an important characteristic which defines the varying rule of direction and amplitude of an electrical field with time. The antenna polarization of a ground stations must correspond with the antenna polarization of the satellite. Otherwise, the strength of receiving signal is decreased.

3.1.4 Data Format

3.1.4.1 Useful information contained in the direct broadcast includes:

- Satellite operator identification;
- Spacecraft and sensor identification;
- Observation time and serial count;
- Orbit and attitude, or grid information for mapping,
- Calibration information;
- Observation data;
- Other information satellite operator want to include.

3.1.4.2 These data are assembled in a specific way called the data format to enable users to extract them. The data format is issued by the satellite operators.

3.1.5 Summary of Transmission Characteristics

3.1.5.1 In summary, important transmission characteristics include:

- Frequency:
  carrier frequency and stability,
  maximum frequency deviation,
  subcarrier frequency (analogue).
- Modulation mode and index
- Transmission speed:
  bit per second (digital),
  line per minute (analogue and digital).
- Data volume:
  number of bits in a line (digital),
  number of lines in a sectorized image (analogue).
- Transmission power:
  power of transmitter EIRP.
- Polarization
- Bandwidth
- Data coding
- Data format

3.1.5.2 The characteristics listed in 3.1.5.1 are issued by the satellite operators.

3.2 *Components description and functional analysis for the data receiving part of a small satellite ground station*

The data receiving part of a small satellite ground station consists of the following components: antenna, antenna control unit (for polar orbiting satellite), receiver, synchronizer (for high resolution ground station) or A/D converter (for low resolution ground station) and ingestor. The receiving range of a ground station is about 3100 km for polar orbiting satellites, and 70 degree latitude/longitude for geostationary satellites respectively.

3.2.1 Antenna and Front End

3.2.1.1 The antenna intercepts and concentrates the radiated energy transmitted by the satellite in a preferred direction. When the antenna points at the satellite, the received signal transmitted by the satellite reaches a maximum. The increase in power flux density at a receiving antenna is called gain G. $G \propto (D/\lambda)^2$, where D is the diameter of the antenna reflector and λ is the wavelength of the radiation. The larger the diameter, the higher the gain of the antenna. When the satellite deviates from antenna boresight, the signal level received is reduced. The angle at which the signal level received is reduced to the half of the peak level is called the beamwidth. The larger the diameter, the narrower the beamwidth of the antenna. That is, while the antenna diameter increases, the gain of antenna increases, but the beamwidth decreases.

3.2.1.2 In order to achieve hemispherical coverage of the sky, the antenna must be mounted on two axes of rotation. There are two kinds of antenna mounting: elevation-azimuth mounting and X-Y mounting. X-Y mounting is better than elevation-azimuth mounting for tracking overhead satellite passes. However, X-Y mounting is more complex than elevation-azimuth mounting.

3.2.1.3 The concentrated signal is intercepted by a primary feed at the focus of the antenna. The intercepted signal is very weak, and is contaminated with noise as in any communication links. It must be amplified by a low noise amplifier. For ease in transmitting the high frequency signal to a receiver, a frequency down converter is added after the low noise amplifier. The assembly of primary feed, low noise amplifier and frequency down converter is called the front end.

3.2.2 Antenna Control Unit (for polar orbiting satellite)

3.2.2.1 To ensure that the satellite is always within the beamwidth of the small satellite ground station antenna, it is necessary to track the satellite accurately from horizon to horizon. There are two tracking modes, programme tracking and autotracking. In programme tracking, satellite orbit prediction is fed into a computer in the antenna control unit which tracks the satellite with the antenna. The success of programme tracking depends on the accurate knowledge of the satellite orbit elements. Autotracking searches for the strongest signal and the antenna follows it automatically. Autotracking has the advantage of overcoming any uncertainties in the orbital elements. However, if the signal is lost for any reason, the autotrack system will not recover acquisition of the satellite. The best arrangement is a combination of programme track and autotrack. The programme track presets the antenna to the start position before a satellite pass. When the signal commences, the antenna works in the autotrack mode. If the autotrack loses the satellite, then the programme track mode automatically takes over.

3.2.3 Receiver

3.2.3.1 The outdoor front end sends an intermediate frequency signal to the receiver. The major tasks of the receiver are:

- To amplify the signal,
- To convert the frequency of the signal,

- To demodulate the intermediate signal to a baseband signal, and

- To set the tracking error signals for the antenna control unit.

3.2.3.2 When specifying a receiver, the following factors must be considered:

- Input frequency and bandwidth of the signal. The receiver bandwidth should cover the bandwidth of modulation, the frequency shift of the satellite transmitter, the doppler shift of frequency and the frequency instability of the receiver's local oscillator.

- Demodulation mode

- Bit rate and bit error rate

- Provision of an output proportional to signal strength for autotrack

3.2.4 Bit synchronizer and frame synchronizer (for high resolution ground stations)

3.2.4.1 The output of the receiver is a somewhat noisy baseband signal corresponding to the original encoded serial bit stream. The function of the bit synchronizer is to examine each bit cell as it is received and decide whether it contains a "0" or "1" with the greatest possible discrimination against noise. It extracts the clock pulses, regenerates the bit stream against noise, and makes code conversion from biphase to NRZ if necessary. The clock pulse and the reconstituted serial bit stream are passed to the frame synchronizer.

3.2.4.2 Before the received data can be manipulated by the data processing system, the beginning of every frame (every scan line of sensor) must be detected and the serial bit stream from the bit synchronizer must be sliced into meaningful words. This job is done by the frame synchronizer. The frame synchroniser continuously examines the received bit stream for the presence of the line synchronisation sequence. Once line synchronisation is found the data sector boundaries which delineate infra red or visible signals within the data line can be determined and the raw data extracted. This data stream, together with recovered clock and synchronisation signals is passed to the data ingestor.

3.2.5 A/D converter (for low resolution ground station)

The output from receiver of a low resolution ground station is an analogue signal. It must be converted to digital data and then input into the computer.

3.2.6 Data ingestor

3.2.6.1 The data ingestor is an interface between the frame synchroniser (or analogue/digital converter) and the data processing computer. The ingestor performs the task of converting the data stream into a computer disk file or files. Typically an ingestor will buffer the data stream to minimise excessive loading on the computer central processing unit.

3.2.6.2 In the data receiving part, a signal from the satellite is received by the antenna, amplified and demodulated by the receiver, decoded by the synchronizer and ingested into the computer.

3.3 *Components, description and functional analysis for data processing part of a small ground station*

The data processing part of a small ground station extracts and displays useful information. The following section describes the data processing part of a small ground station capable of processing high resolution data but the section is equally applicable for low resolution data with the following differences:

- The data rate of high resolution data is much higher than that of low resolution data. It is necessary that the computer speed for processing high resolution data be higher than that for processing low resolution data.

- The data volume of high resolution data is much larger than that of low resolution data. Therefore the size of memory and disk for high resolution data must be larger than that for low resolution data.

- Since the resolution of high resolution data is many times higher than that of low resolution data, the resolution of the image processing card and the image monitor for displaying the high resolution data must be higher than that for the low resolution data.

- Generally speaking, low resolution data is useful in the field of general meteorology while high resolution data is not only useful for general meteorology but also for environment monitoring. The available channels of data from the radiometer for high resolution data is more than that of low resolution data. Finally, application software packages for high resolution data are more abundant and more complex than that for low resolution data.

3.3.1 Hardware of a data processing system

3.3.1.1 The hardware for a data processing system can be a personal computer (PC) or a small scale computer system with some peripherals. A typical configuration for a data processing system consists of a:

- Central processing unit
- Memory
- Coprocessor
- System console
- Hard disk drivers
- Floppy disk drivers
- Keyboard
- Printer
- Digital tape unit for data storage
- Image processing and displaying unit
- Colour monitor
- Facsimile with interface card for image hard copy output

3.3.2 Software of a data processing system

The software for a data processing system should have the following functions.

3.3.2.1 Satellite Orbit Prediction

For a small satellite ground station for polar orbiting satellite data, the software must include the function of satellite orbit prediction based on the orbital elements in order to calculate the start time and the azimuth and elevation for the antenna to obtain the desired satellite passes. It is important that the antenna system be controlled by a precision clock, to ensure proper synchronization with the satellite.

3.3.2.2 Data ingest and file pick up

The data ingest software takes the satellite data from the frame synchronizer or A/D converter into the computer. This was described in paragraphs 3.2.4 through 3.2.6. Data ingest software should be carefully timed to ensure that the data are written to the ingest buffer, transferred from the ingest buffer to the computer memory, and written to the hard disk of the computer. In the data ingestor, no data rearrangement is made and the data ingested is in the order the satellite transmitted. File pick up software picks up the expected files, such as document files and observation files, and transforms them into a convenient format for later processing.

3.3.2.3 Calibration and location

The data transmitted from the satellite is an electric signal level sensed by the instrument. Calibration software converts the electric signal level into an appropriate radiation value. While basic information for calibration is supplied by the satellite operators, other calibration information is contained in the document files or in the data stream. Location software calculates longitude, latitude and solar altitude angles for individual ground points viewed by the satellite. After the files are picked up, calibrated and located, radiance quantities at given position are determined. This part of data processing is called data preprocessing. Preprocessing is the preparation work for parameter extraction and image processing.

3.3.2.4 Meteorological parameter extraction

Based on the preprocessed data, meteorological parameters, such as cloud detection, vertical profiles of temperature and humidity, sea surface temperature, ice information, vegetation index etc., can be derived. Due to the limited ability of calculation, a data processing part of a small ground station can normally only perform a few of them. Although not mandatory, it is desirable that the receiving system have a direct interface to the Global Telecommunications System (GTS) to obtain other standard meterological data, e.g. SYNOPS, NWP fields, etc.) necessary in the calculation of meteorological parameters.

3.3.2.5 Image processing

Image processing eliminates irrelevant information while enhancing required information. These functions make information gained from the satellite easier to be understood and used.

3.3.2.6 File management

In data processing process, a variety of data files are produced. File management software administers these data files and makes them easy to access. Normally, a catalog file is formed which contains the necessary information for sorting. File management software also has functions for data archiving, display and output.

3.4 *Block diagram of a typical small ground station*

3.4.1 The block diagram of a typical small ground station is shown in Fig. 1. For a small geostationary ground station, the antenna control unit is not needed.

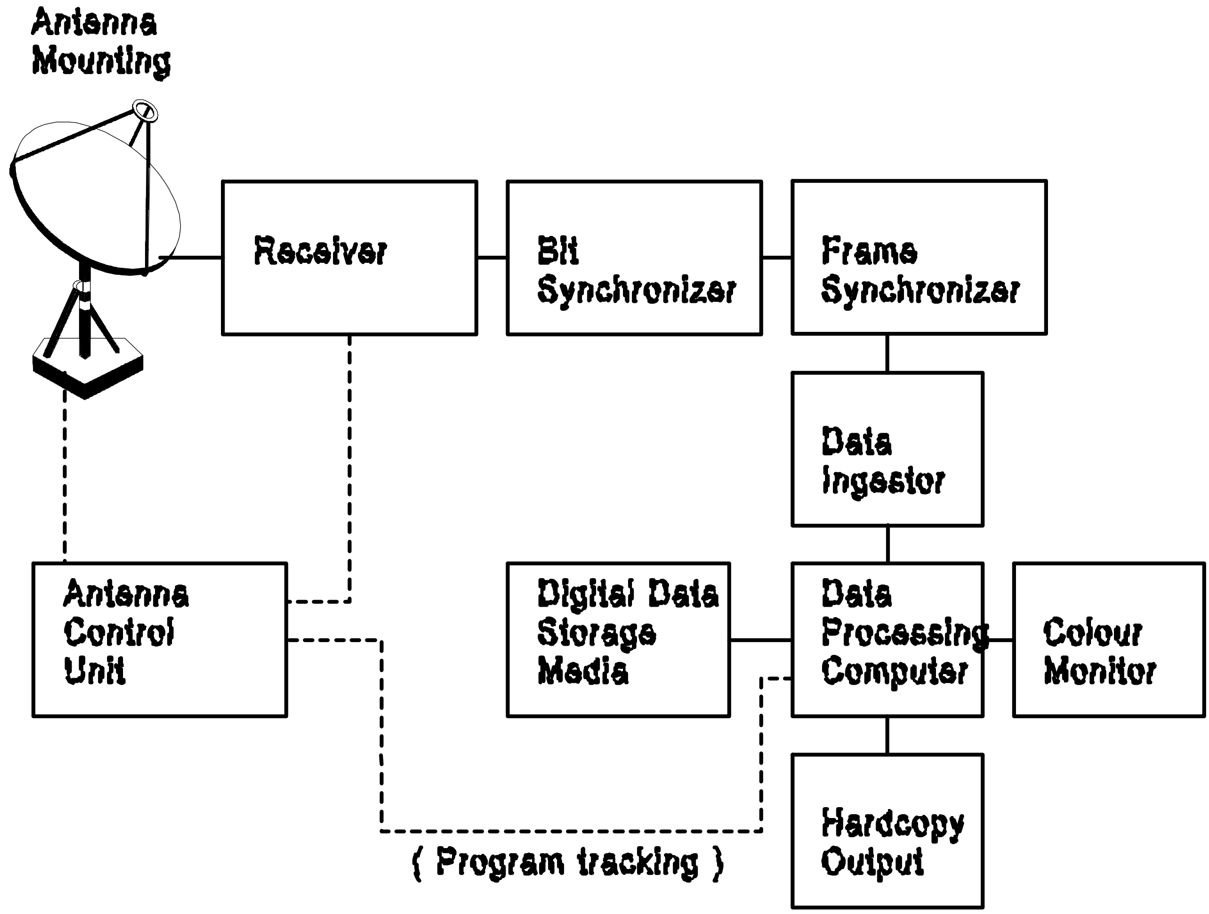

Fig.1 Block Diagram of a small satellite ground station

4. FUNCTIONAL REQUIREMENTS

The functions of a small satellite ground station as shown in Figure 1 are described in paragraphs 4.1 and 4.2. It will be noted that some items are marked with an **asterisk " * "**. These should be considered as desirable options. Therefore, those functions not marked with an asterisk constitute the minimum performance specifications for a low resolution ground station (paragraph 4.1) and for a high-resolution ground station (paragraph 4.2). WMO Members could use the minimum performance specifications as a guide in evaluating the suitability of commercially available systems.

4.1 *Functional requirements for low resolution ground stations*

A low resolution ground station should receive processed APT data from polar-orbiting satellites (NOAA, Meteor, etc.) and WEFAX data from geostationary satellite (GOES, Meteosat, GMS, GOMS and FY-2).

4.1.1 A WEFAX station should be capable of the following functions :

4.1.1.1 Receive WEFAX data from GOES, Meteosat, GMS, GOMS and FY-2 satellites,

4.1.1.2 Ingest WEFAX data into computer,

4.1.1.3 Display WEFAX image on computer monitor screen in real-time and by playback,

4.1.1.4 Process WEFAX data as follows:

4.1.1.4.1 Image enhancement (gamma enhancement),

4.1.1.4.2 Pseudo colour display,

4.1.1.4.3 Enlargement (zoom),

4.1.1.4.4 Image animation (film loop),

4.1.1.4.5 Split screen display,

4.1.1.4.6 Filtering (mending of bad image line),

4.1.1.4.7 Annotation,

4.1.1.4.8 Image re-projection,

4.1.1.4.9 Brightness temperature or albedo display.

4.1.1.4.10 Roam (data migration).

4.1.1.5 Store image data,

4.1.1.6* Receive Meteorological Data Distribution (MDD) or similar missions.

4.1.2 **An APT station should be capable of the following functions :**

4.1.2.1 Receive APT data from NOAA and Meteor Satellite,

4.1.2.2 Ingest APT data into computer,
4.1.2.3 Display APT image on computer monitor screen in real -time and by playback,

4.1.2.4 Predict satellite pass according to orbital message from GTS,

4.1.2.5 Process APT data as follows:

4.1.2.5.1 Image gridding (latitude, longitude and coastlines),

4.1.2.5.2 Image enhancement (gamma enhancement),

4.1.2.5.3 Pseudo colour display,

4.1.2.5.4 Enlargement (zoom),

4.1.2.5.5 Split screen display,

4.1.2.5.6 Filtering (mending of bad image line),

4.1.2.5.7 Annotation,

4.1.2.5.8 Brightness temperature or albedo display,

4.1.2.5.9 Statistics,

4.1.2.5.10 Contouring.

4.1.2.5.11 Roam (data migration).

4.1.2.6 Store image data

4.1.2.7* Receive Meteorological Data Distribution (MDD) or similar missions.

4.2 ***Functional requirements for high resolution ground stations***

A high resolution ground station should receive and process HRPT data from NOAA polar orbiting satellites or high resolution digital stretched VISSR data from one of five geostationary meteorological satellites (GOES, Meteosat, GMS, FY-2 and GOMS).

4.2.1 **A high resolution station for geostationary meteorological satellites should be capable of the following functions:**

4.2.1.1 Receive high resolution data from one of the five geostationary meteorological satellites (GOES, Meteosat, GMS,FY-2 and GOMS);

4.2.1.2 Ingest high resolution data into computer and to store it into hard disks;

4.2.1.3 Display high resolution image on colour monitor screen in real-time or by playback in various selectable resolutions and scales;

4.2.1.4 Process high resolution data.

4.2.1.4.1 Preprocessing: to generate parameter file, to check the qualities of parameter file, to generate image data file including essential calibration values, and to create geographic grids files,

4.2.1.4.2 Image process and display: enhancement, zoom, split screen display, temperature contours, filter, histogram, loop display, annotation, roam,

4.2.1.4.3 Navigation: draw geographic grid, coastal lines, boundaries and rivers; display geographic co-ordinate of image pixel; image navigation using landmark; image re-projection,

4.2.1.4.4* Conventional data processing and display: weather report and grid data input, display of observation, sounding profile and contour,

4.2.1.4.5* Overlap of satellite image and conventional data including observation and contour,

4.2.1.4.6* Application package: cloud top/surface temperature or albedo; cloud top height and cold cloud size; typhoon location, path, velocity, moving direction,

4.2.1.4.7 File management and archives.

4.2.2 **A high resolution station for HRPT data of NOAA satellites should be capable of the following functions:**

4.2.2.1 Receive HRPT data from NOAA satellite,

4.2.2.2 Ingest HRPT data into computer and store it into hard disk,

4.2.2.3 Display AVHRR image on colour monitor screen in real-time and by play back in various selectable resolutions,

4.2.2.4 Process HRPT data as follows:

4.2.2.4.1 Satellite pass prediction and programme tracking,

4.2.2.4.2 AVHRR/HRPT data preprocessing, to separate TIP data and to create AVHRR 1A.5 and 1.B data set,

4.2.2.4.3 AVHRR data playback, overlap with geographic grid, coastlines, boundaries and rivers and landmark navigation.

4.2.2.4.4 Image processing: zoom, image enhancement,split screen display, and histogram statistics,noise smoothing, contouring, pseudo-colour display, colour composition of three channel data, profile annotation, arithmetic calculation, area calculation,

4.2.2.4.5 Quantitative processing: cloud-top and surface Tbb, SST, vegetation index,

4.2.2.4.6* Application Package: snow cover, sea ice cover, forest fire detection, flood monitor, river mouth silt monitor,

4.2.2.4.7* Conventional meteorological data processing: weather report and grid data input, display of observation and countering,

4.2.2.4.8 System test function demonstration and operation management

4.2.2.5* Process TOVS data as follows:

4.2.2.5.1* TOVS data quality control and 1.B data set generating,
4.2.2.5.2* TOVS data preprocessing,

4.2.2.5.3* Atmospheric parameter retrieval (temperature and moisture profiles),

4.2.2.5.4* Radiosonde data collection,

4.2.2.5.5* Matchups of soundings with radiosondes,

4.2.2.5.6* TOVS image data processing,

4.2.2.5.7* Product analysis and display.

5. SPECIFICATION REQUIREMENTS

5.1 *Specification requirements for low resolution ground stations*

The station should be reliable and easy to operate. The block diagram of low resolution station is shown in Fig.2.

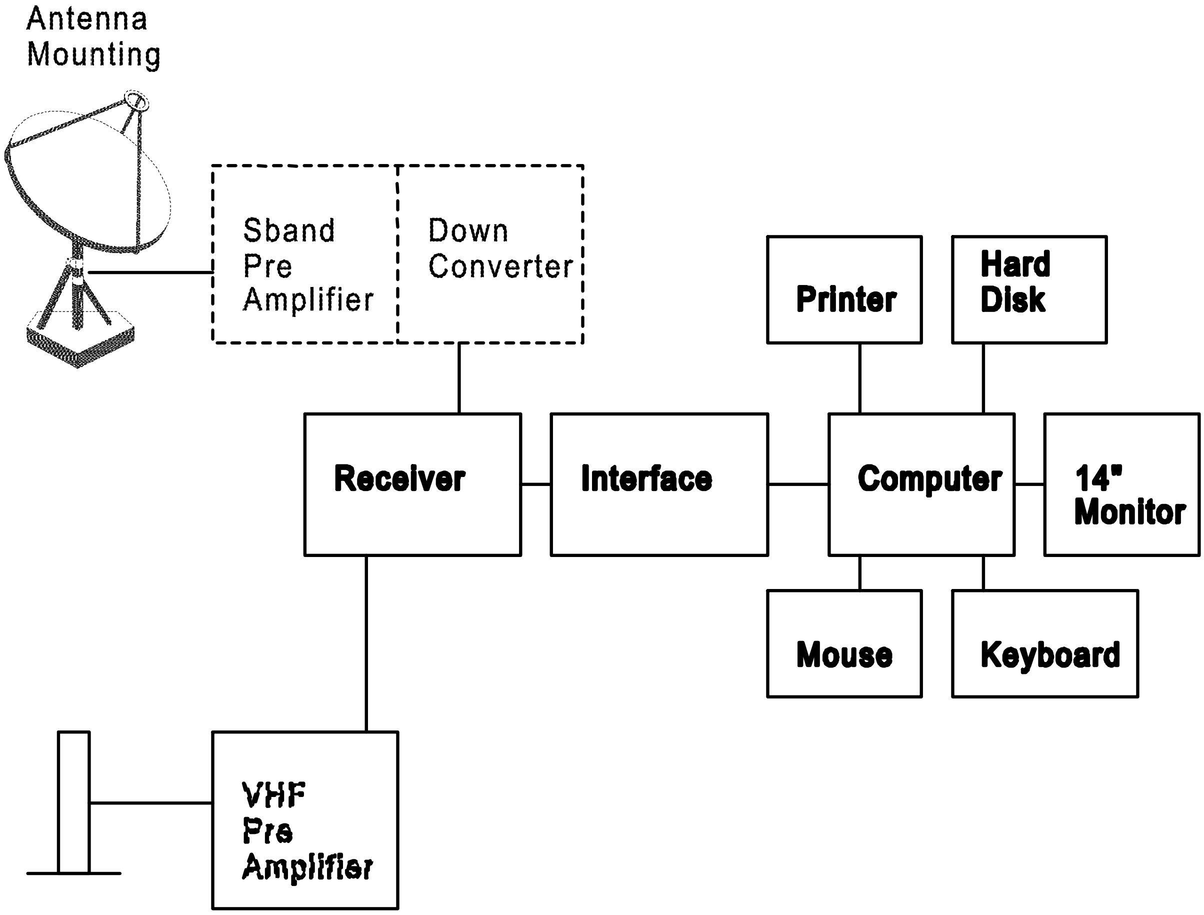

Fig.2 APT/WEFAX Receiving and Processing Station

5.1.1 S-band parabolic antenna

5.1.1.1	Diameter of antenna:	: 1.5 m
5.1.1.2	Gain	: 26.0 db
5.1.1.3	Beamwidth	: 8.1°
5.1.1.4	Frequency	: 1691.0 MHz
5.1.1.5	Polarization	: linear
5.1.1.6	Mount	:fixed, variable adjust, elevation 90°, azimuth (20° - 70°)
5.1.1.7	VSWR	: 1.5
5.1.1.8	Impedance	: 50 Ω

5.1.2 S-band preamplifier and down converter

5.1.2.1	RF input	: 1691.0 MHz
5.1.2.2	IF output	: 137.5 MHz or other
5.1.2.3	Band width	: 6 MHz
5.1.2.4	IF/RF gain	: 30 db
5.1.2.5	Noise figure	: 1.5 db
5.1.2.6	Stability	: 5×10^{-6}
5.1.2.7	Impedance	: 50 Ω
5.1.2.8	Cable length	: 60 m

5.1.3 VHF antenna

To reduce the price and for ease of maintenance, an OMNI directional non-tracking antenna is recommended. An OMNI directional non-tracking antenna must be able to receive data above an elevation of 5°. This requirement will reduce interference while maximizing the possibility for coverage of synoptic scale meteorological phenomena.

<u>OMNI directional antenna</u>

5.1.3.1	Frequency	: 137.5 MHz
5.1.3.2	Polarization	: right hand circular
5.1.3.3	Impedance	: 50 Ω
5.1.3.4	VSWR	: 2.1 max
5.1.3.5	Gain	: 3 dbi
5.1.3.6	Beamwidth	: 180°

Depending on the user's situation and requirements, an omni-directional antenna may not be sufficient for proper APT reception. Under these circumstances, the use of a directional antenna, such as a crossed Yagi, would provide higher performance and greater coverage. Note that use of program tracking and other antenna pointing methods would be required. The following information describes an alternative to the OMNI directional antenna described in sections 5.1.3.1 through 5.1.3.6.

<u>Directional antenna (Yagi)</u>

5.1.3.7	Centre frequency	: 137.5 MHz
5.1.3.8	Polarization	: right hand circular
5.1.3.9	VSWR	: 2.0 max
5.1.3.10	Gain	: 20 dBi or greater
5.1.3.11	Beamwidth	: 20 degrees at 20 dBi
5.1.3.12	Mount	: Elevation over azimuth
5.1.3.13	Program track	: Program track

5.1.4 VHF Preamplifier

5.1.4.1	Centre frequency	: 137.5 MHz
5.1.4.2	Gain	: 30 db
5.1.4.3	Noise figure	: 2 db
5.1.4.4	Installation	: in antenna base

5.1.5 Receiver

5.1.5.1	Type	: FM phase lock loop
5.1.5.2	Input frequency	:Switch selectable crystals for reception of APT and WEFAX
5.1.5.3	IF bandwidth	:50 KHz and 30 KHz --switch selectable
5.1.5.4	Noise figure	: 5 db

5.1.6 Computer

5.1.6.1	486 computer with TVGA card (1024 x 768 resolution)	
5.1.6.2	Colour monitor	:14"
5.1.6.3	Hard disk	: 120 MB
5.1.6.4	Memory	: 4 MB
5.1.6.5	Clock : 33 MHz	
5.1.6.6	Keyboard	
5.1.6.7	Mouse	
5.1.6.8*	Printer (optional)	

5.1.7 Outdoor environment

5.1.7.1	Temperature	: -40° C - +50° C
5.1.7.2	Humidity	: 98%
5.1.7.3	Wind	: operational 20 m/s, survival 35 m/s

5.1.8 Power

5.1.8.1	110v/220v +- 10%
5.1.8.2	50Hz/60Hz

5.2 ***Specification requirement, for high resolution ground station***

The stations should be reliable and easy to operate. The block diagram of the high resolution ground station is shown in Fig.3. If the station receives geostationary satellite data, it should be equipped with a fixed antenna. If the station receives polar orbiting satellite data then it must be equipped with a tracking antenna and antenna control unit.

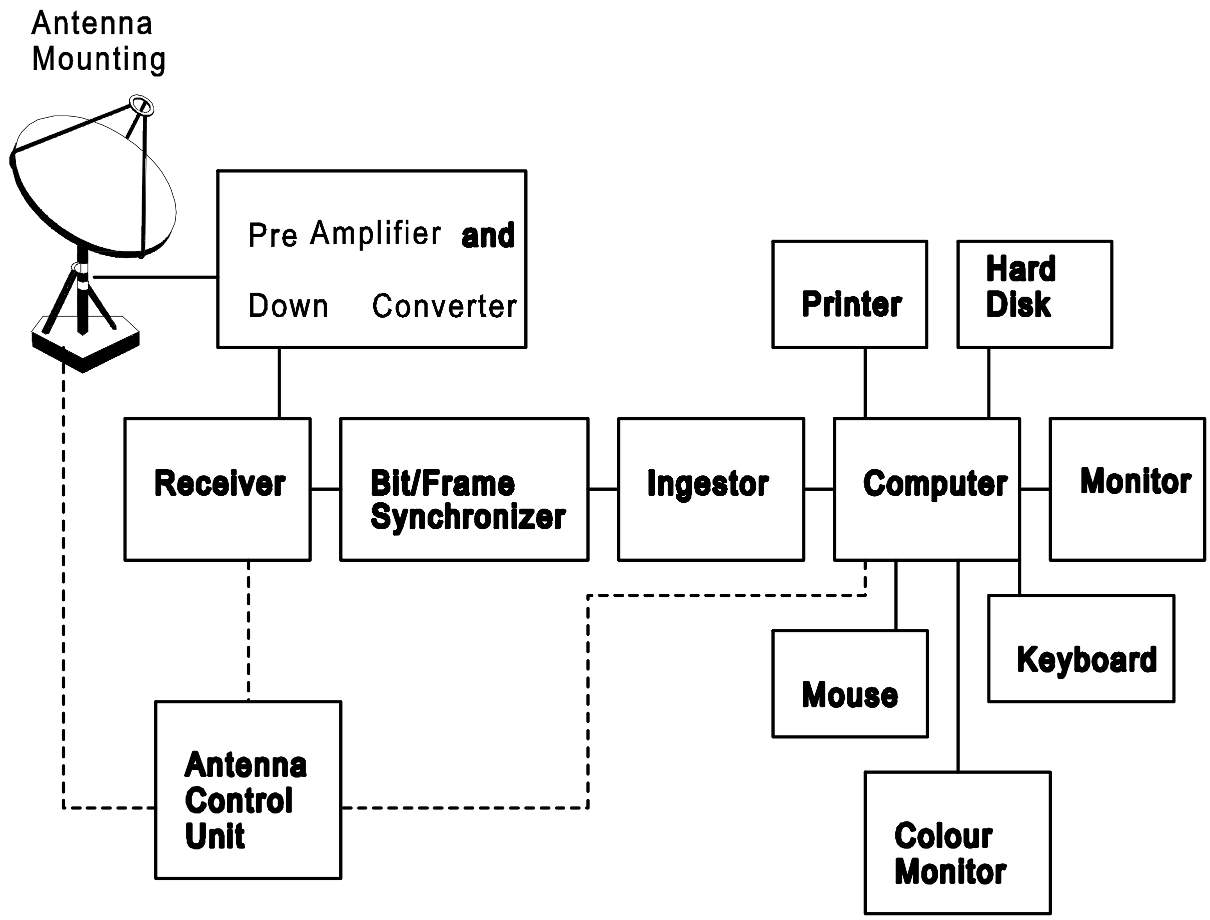

Fig.3 High Resolution Data Receiving and Processing Station

5.2.1 **S-band tracking antenna and antenna control unit for receiving HRPT data**

5.2.1.1	G/T merit of antenna system	:>6 db/K bit error rate is better than $1x10^{-6}$ at 5 degree elevation
5.2.1.2	Frequency	:1670~1710 MHz
5.2.1.3	Polarization	: RH, LH
5.2.1.4	Impedance	: 50/75 Ω
5.2.1.5	VSWR	: 1.5
5.2.1.6	Antenna mounting	: azimuth-elevation
5.2.1.7	Tracking coverage	: full geometric coverage including overhead passes (Z-pass), good performance of Z-pass tracking

5.2.2 **S-band fixed antenna for receiving geostationary satellite**

5.2.2.1	G/T merit of antenna system	:G/T depending on which satellite to be received, G/T must guarantee that bit error rate is less then 10^{-6} in the worst case
5.2.2.2	Frequency	: 1670~1710 MHz
5.2.2.3	Polarization	: linear
5.2.2.4	Mounting	: fixed, variable adjust elevation 90, azimuth 20° ~70°
5.2.2.5	VSWR	: 1.5
5.2.2.6	Impedance	: 50/75 Ω

5.2.3 Preamplifier and down converter

5.2.3.1	RF input	: 1670~1710 MHz
5.2.3.2	IF output	: 137 MHz/70 MHz
5.2.3.3	IF/RF gain	: >30 db
5.2.3.4	VSWR	: 1.5
5.2.3.5	Noise figure	: 1.5 db
5.2.3.6	Stability of local oscillator	: 5 X 10^{-6}
5.2.3.7	Impedance	: 50/75 Ω
5.2.3.8	Connector	: type N
5.2.3.9	Cable length	: 60 m

5.2.4 Receiver

5.2.4.1	Demodulator type	: PSK-PLL demodulator
5.2.4.2	Input frequency	: 137 MHz/70 MHz band (switchable crystal or frequency synthesizer to select input frequency)
5.2.4.3	Noise figure	: 5 db
5.2.4.4	Image rejection	: 60 db
5.2.4.5	Input impedance	: 50/75 Ω
5.2.4.6	Output impedance	: 50/75 Ω
5.2.4.7	I.F bandwidth	: selectable, depending on which satellite to be received

5.2.5 Bit/Frame Synchronizer

The bit synchronizer provides the following functions:

5.2.5.1 Input signal conditioning
5.2.5.2 Bit synchronization
5.2.5.3 Clock extraction

The frame synchronizer provides the following functions:

5.2.5.4 detect the frame sync signal of the data stream
5.2.5.5 decommutate the data
5.2.5.6 convert serial data to parallel data

5.2.6 Ingestor

Ingestor is a data buffer which can ingest digital data from frame synchronizer to computer (interface).

5.2.7 Microcomputer system

5.2.7.1 Main frame: 80486, main memory >8 MB, 400 MB hard disk, coprocessor, mouse, keyboard, printer and monitor (Note: If the optional applications shown with an * are desired, then a more powerful workstation, e.g. RISC of Alpha technology, may be more appropriate)

5.2.7.2 Image processing card, 512 X 512 X 8 bit X 4 or 1024 X 1024 X 8bit X 4

5.2.7.3 Image colour monitor

5.2.8 Outdoor environment

5.2.8.1	Temperature	: -40°C~+50°C
5.2.8.2	Humidity	: 98%
5.2.8.3	Wind (sites with normal conditions)	: Operational 20 m/s, Survival 35 m/s
5.2.8.4	Wind (sites with squally wind conditions)	: Operational 35 m/s, Survival 50 m/s

5.2.8.5 Corossion (adequate protection against corossion should be provided for those sites with adverse conditions of high humidity and salt spray such as found in coastal areas)

5.2.9 Power

5.2.9.1 110V/220 V +- 10%
5.2.9.2 50 Hz/60 Hz

6. CONSIDERATION IN RELIABILITY

To make ground stations with good performance, reliability is extremely important especially for ground stations operating at remote sites without good technical and spare parts support. To make a ground station reliable, the following points should be considered:

6.1 *Environmental condition analysis at the site where the ground station will operate*

Carefully examine the environmental conditions at the site where the ground station may operate. Environmental conditions outside the design environment of the ground station will normally result in equipment failure. Important environmental conditions include:

- Power supply. A stable power supply and ground connection are necessary for normal functioning of a system. In the case of many or large power supply fluctuations, power stabilizing equipment is needed. A good connection to ground should also be checked and confirmed before system installation.

- Strong mechanical mounting for the outdoor antenna. The antenna should be able to withstand strong winds while it is functioning , or at least not be damaged in extremely strong wind cases.

- Temperature and humidity. Ground stations should be designed to work properly within the temperature and humidity range it may encounter. The outdoor portions should fit a broader range of temperature and humidity.

- Waterproof. The sealed components of some outdoor equipment should be waterproof to avoid damage by rain.

- Electromagnetic interference. At the site, electromagnetic interference, such as microwave telecommunication interference, should be within acceptable limits. It may be necessary to perform a noise survey at the site to determine the actual level of interference.

- Antenna location. For optimum signal strength, avoid tall structures in the antenna's line-of-sight especially for directional antennas.

6.2 *Reliability design*

A ground station should be designed to fit the environmental condition it may meet. Component aging should be anticipated.

6.3 *Redundancy*

Redundancy should be provided for unexpected failures, for expansion, and for performance improvement after years of use.

6.4 ***Quality control in production process***

Good skill should be used. Quality control must be performed during all phases in the process of production.

6.5 ***System test***

Hardware needs to be tested under expected mechanical stress and in appropriate temperature and humidity conditions. Software testing is also required to make sure that all software paths and included functions work properly.

7. TRAINING FOR LOCAL MAINTENANCE STAFF AND INSTALLATION

7.1 Local maintenance and operating personnel should be trained to allow them be able to solve minor problems and to use the system properly. This is very important for the long life of the ground station

7.2 ***Trainees***

It is suggested that trainees have some electronic engineering or computer science background.

7.3 ***Training content***

The content of training should include:

7.3.1 General concept of meteorological satellites (radiometer, satellite orbit .... etc.) and general principles of remote sensing

7.3.2 Principles of meteorological satellite data receiving and processing

7.3.3 Station layout

7.3.4 Station installation

7.3.5 Operation

7.3.6 Maintenance

7.3.7 Data applications - This item should receive high priority during the training phase and include as many practical exercises as possible.

For the training, practice will be the highest priority and theory will be secondary.

7.4 ***Duration of training***

Training should take 2-3 weeks for low resolution stations and 3-4 weeks for high resolution stations
.

7.5 ***Installation***

The high resolution station installation should be done by the manufacturers and not by the users.

The low resolution installation can be done by the users themselves who have received training. The installation will include:

- site selection (radio environment test, view field, North-South direction test)
- Antenna installation (antenna base)
- System integration
- Equipment test
- Operation

8. UNIFICATION OF STANDARDIZED DATA EXCHANGE INTERFACES

8.1 *Advantages and Difficulties*

8.1.1 At the tenth session of CBS, the following item was included in the terms of reference for CBSWGSAT:

"To make recommendations concerning standardization of satellite services...."

8.1.2 The standardization of satellite services, such as data transmission characteristics, has apparent advantages. The small satellite ground station configuration described in section 3 was based on specific data transmission characteristics. Differences in data transmission characteristics and data formats make configuration of workstations different in both hardware and software. Considering the convenience to the users, satellite operators tend to adopt compatible transmission characteristics and data format.

8.1.3 It should be noted that it is difficult for satellite operators to change existing data transmission schemes. Equipment has already been designed and tested before being installed on the satellite. Any change of equipment in the spacecraft may cause unexpected results. During the development of new generation equipment by satellite operators, detailed specifications are normally not uniform.

8.2 *Actions of CEOS and CGMS*

8.2.1 The Committee of Earth Observations Satellites (CEOS) and the Co-ordination Group for Meteorological Satellite (CGMS) are fora for space activity co-ordination. Members of CEOS include all space agencies responsible for civil spaceborne earth observation programmes with WMO being an Affiliate Member. Members of CGMS are operators of meteorological satellites and WMO. One major objective of both groups is to develop compatible data products and formats. It is considered appropriate that WMO requests the two organizations to co-ordinate and develop compatible future data transmission standards.

8.3 *Ground stations face to all meteorological satellites with direct broadcast service*

8.3.1 As described in section 3, the different configurations of satellite ground stations are fundamentally similar. Thus, it is easy to design a ground station to receive the direct broadcast service available in any region.

References:

[1] P.E. Baylis, Guide to the design and specification of a primary user receiving station for meteorological and oceanographic satellite data. Page 81-96, Remote Sensing in Meteorology, Oceanography and Hydrology, Editor A.P. Cracknell etc, Ellis Horwood Limited, 1981.

[2] Weather Satellites: System, Data, and Environmental Applications, Edited by P.K. Rao, S.J. Holmes, P.K. Anderson, J.S. Winston, P.E. Lehr, American Meteorological Society, 1990

[3] Satellite Meteorological Center of State Meteorological Administration of China, Course of the WMO Workshop on Satellite Meteorology, 1991.

[4] CGMS Consolidated Report 1989

[5] CEOS Consolidated Report 1992