CGMS XXXIII NOAA-WP-19
Prepared by USA
Agenda Item: IV.2

DEVELOPMENT OF THE NOAA MULTI-CONSTELLATION USER TERMINAL (MCUT)

NOAA has developed a prototype Multi-Constellation User Terminal (MCUT) to help facilitate, explore and promote technology that could enable the commercial development of Direct Readout user stations that would receive and process signals from multiple satellite constellations. NOAA-WP-33 summarizes this effort including the advanced technologies employed by the prototype station.

The development effort is proceeding to further extend the MCUT capabilities. Additional meteorological services will be addressed. The ability to operate at higher data rates and to use other error correction decoding will be investigated to meet the requirements of future services such as METOP and the NPOESS LRD systems. Presently, the GOES GVAR service is the highest data rate service at L-band frequencies. This service, however, requires a larger aperture than other services. The existing antenna feed and receiver will be installed in a suitable reflector antenna to demonstrate the flexibility with which this prototype technology can be applied. Since a positioner capable of tracking polar satellites is not required for GOES GVAR reception, the implementation cost would actually be less than a design capable of tracking polar satellites. Other future high data rate services will be available at X-band. An examination will be made of technology for a similar architecture for these services. The existing high resolution geostationary services and these future X-band services require about the same aperture size. A dual frequency L- and X-band design would provide a higher resolution capability for polar satellites and a higher resolution refresh capability following the same design philosophy as the existing MCUT prototype. Antenna tracking requirements are more stringent with the narrower X-band antenna beamwidth; application of open loop antenna tracking techniques is being done as a lower cost alternative to the traditional closed loop tracking designs.

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1. Introduction

The number and capabilities of meteorological satellites is rapidly expanding on an international scale. An examination of individual satellite systems reveals that, while the systems employ a variety of data rates, modulation formats, and error correction techniques, there is a commonality of frequency range of operation and requirements for antenna aperture diameter for direct readout of the downlink data. The MCUT development was motivated by the belief that technology with the suitable flexibility to accommodate different modulation formats could be used to configure user terminals that can sequentially receive data from a variety of meteorological services. Not only can using a single user terminal in place of several dedicated terminals for different meteorological services reduce costs, but also the available technology, developed chiefly for wireless applications, offers the required flexibility at affordable prices. In operation, such a user terminal can receive data from polar satellites when in view and geosynchronous satellites at other times. Such operation affords meteorologists with the resolution capabilities of polar satellites and the rapid refresh of geostationary satellites to serve the majority of meteorologist's needs for satellite data in an affordable package.

2. Multi-Constellation User Terminal Development

2.1 Existing MCUT Prototype

A prototype user terminal was delivered to the NOAA location in Suitland MD in February 2004. This prototype has the capability to receive both the L-band downlink transmissions and S-band transmissions used by military meteorological satellites. A four foot diameter reflector antenna is used to provide design margin and two antenna feed designs were demonstrated, one having a wide bandwidth response and the other having a dual-band capability to cover the L- and S-band frequencies. Novel features are incorporated into the design to control the feed side-lobe and back-lobe levels to increase RF efficiency. An ASIC-based receiver has the capability to receive VHF, UHF, L- and S-band downlink services in a compact package. The digital technology used in the receiver includes an A/D, a tuner/demodulator chip set, and a Viterbi decoder. This technology affords the flexibility to receive existing and future satellite downlinks with a minor impact on implementation costs. An examination of the terminal hardware cost reveals that the most expensive component is an antenna positioner capable of tracking polar satellites. The MCUT development pursued a positioner design comprised of commercial components, e.g., motors, gear drives, encoders, bearings, etc. whose total cost was less than $3,000 US. This positioner was designed to allow operation with wind gusts up to 40 mph. A USB interface between the integrated antenna/receiver and a remotely located laptop computer is used. The laptop computer provides the commanding for the antenna positioner and receiver, image processing, and data storage.

This prototype has been used to receive and display data for the HRPT and CHRPT polar services meteorological services; additional effort is required to display the GOES LRIT service. Exclusive of local obscure limitations, the prototype terminal provides reliable horizon-to-horizon reception of these services.

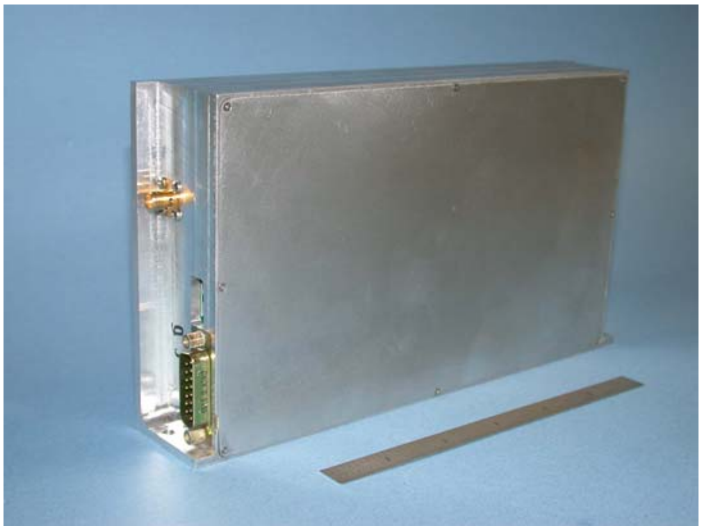
2.2 Current Development Activities

A final prototype version of the Multi-Constellation User Terminal (MCUT) has been developed for NOAA to demonstrate the feasibility of producing a relatively inexpensive terminal capable of receiving and displaying meteorological data and images from diverse polar orbiting and geostationary weather satellites. This latest version is known as MCUT-III. The MCUT-III terminal uses a single 6-ft aperture and an integrated multi-band receiver to receive, demodulate, and process transmitted signals at both L and S-band frequencies. Antenna control, data processing, image display and archival are all performed in a single laptop computer connected to the antenna system through a high speed USB 2.0 interface. The MCUT-I/II systems have been demonstrated to receive and display images from NOAA HRPT, Chinese Fengyun CHRPT, NPOESS/DMSP RDS and RTD, and NOAA GOES GVAR and LRIT services. The MCUT-III system has further been designed and programmed to receive data and images from ESA METOP HRPT and LRPT as well as GOES EMWIN-N when these systems become operational.

Multi-Constellation User Terminal

The MCUT-III antenna system employs a dual-band feed with the capability of electronically switching between circular and linear polarization. Linear polarization is required for reception of NOAA GOES products; all other services transmit with circular polarization. The feed design covers the 1670-1710 MHz and 2200-2300 MHz frequency bands used by meteorological satellites. Integral filtering is employed to minimize the effects of out-of-band interference. A separate port is provided in the base of the antenna to accept input from an external VHF/UHF antenna for reception of services transmitting at 137 MHz.
The MCUT-III terminal has a multi-band receiver integrated into the base of the unit. The ASIC based receiver accepts inputs at L, S, or VHF downlink frequencies and provides all of

the fine tuning, IF filtering, demodulation, and decoding functions required by the various services.

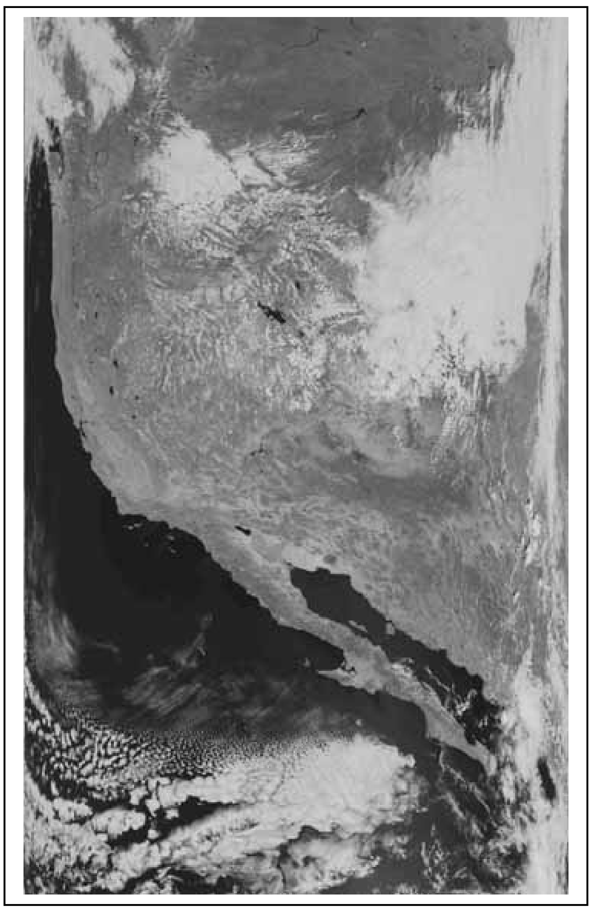


MCUT Multi-Band Receiver

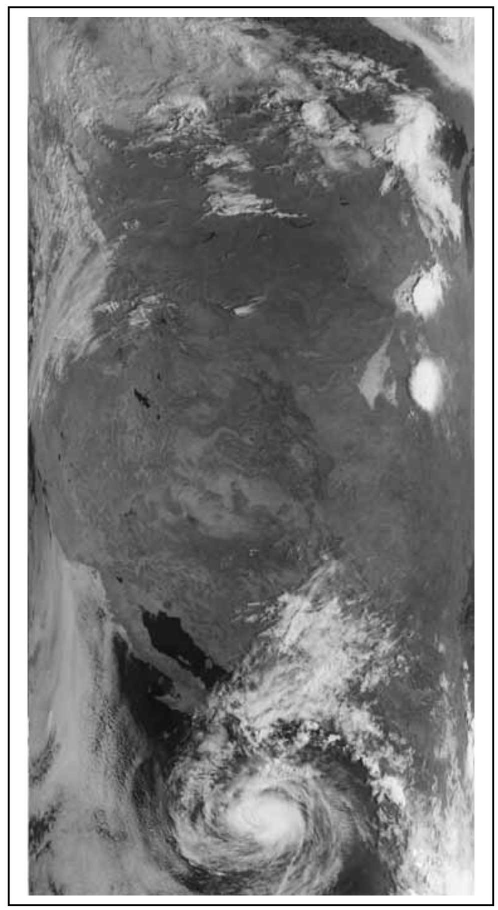
The receiver is based on the Intersil Digital Quadrature Tuner and Digital Costas Loop chip set to provide demodulation of the BPSK, QPSK, and OQPSK waveforms used by the meteorological satellite systems. The receiver has selectable IF bandwidths as well as a programmable FIR filter to optimize the demodulation process. An ASIC Viterbi decoder operating at either rate ½ or rate ¾ is available for those services employing convolutional error correction. A convolution de-interleaver is also built into the receiver for compatibility with METOP LRPT transmissions. Demodulated/decoded data is transferred to a host laptop computer over a high speed USB 2.0 interface.

The host laptop computer serves the dual role of antenna control and data processing and display. For polar tracking, two line orbital element sets are used to pre-calculate a set of pointing angles vs time. These values are then uploaded to a microprocessor in the antenna unit prior to satellite rise. At the appropriate time, the microprocessor servos the antenna to provide open loop tracking of the target satellite. As data is transferred from the antenna unit, the laptop computer provides the functions of data archival, frame sync, CCSDS packet decoding , de-randomization, error correction, data parsing, and real time image display as appropriate for the selected service.

GOES 10 GVAR Image



NOAA 17 HRPT



Fengyun 1D CHRPT

Sample MCUT-III Received Images

2.3 MCUT-III System Characteristics/Capabilities

Meteorological Services:

NOAA HRPT/ Fengyun CHRPT/ METOP HRPT/ METOP LRPT/GOES GVAR
GOES LRIT/GOES EMWIN-N/ NPOESS-DMSP RDS/ NPOES-DMSP RTD

Architecture:

Integrated Antenna, Receiver, Servo Control
Single Laptop Computer Interface
USB 2.0 and Cat5 Connectivity
Remote (150 ft) Operation

Antenna:

72 in Aperture	Gain/Beamwidth	27.6 dB/6.7 deg @ 1700 MHz 30 dB/5.2 deg @ 2222 MHz
Dual-Band Feed	1670 MHz-1710 MHz 2200 MHZ-2300 MHz Electrically selectable Linear/Circular Polarization Rolled edge design, integral filters for interference rejection	
Mount	Polar Tracking Capability 15 deg/sec each axis Helical gears for minimum backlash Microprocessor controlled open-loop tracking	
Construction	Powder Coated Aluminum Maintenance Access Panels	

Receiver:

Input	Multi-band	1675-1725 MHz 2187-2287 MHz 130-144 MHz 393-407 MHz
Tuning Step Size	.06 Hz All bands	
IF Bandwidth	Selectable: 2,4,8,13 MHz	
Doppler Tracking	± 65 KHz	
Data Filter	Selectable: Root Raised Cosine, Integrate and Dump Custom 256 Tap FIR	

Demodulator	Intersil HSP50110, HSP50210 Chipset Commandable: BPSK, QPSK, OQPSK
Decoder	NRZ-M, NRZ-S, NRZ-L, Manchester
Error Correction	Viterbi Rate ½, Rate ¾ Constraint length 7 Convolution deinterleaver (36,2048)
Host Interface	USB 2.0, USB->Cat5 Converter

Host Computer:

Hardware/ Operating System	Gateway M675-Intel Pentium 4, 3.4 GHz Windows XP/PRO
Software/ System Control	Ephemeris Generation Receiver Configuration Tracking Status Receiver Status
Software/ Data Processing	Frame sync CCSDS Packet Processing Derandomization Error Detection/Correction Channel Processing Real Time Image Display Post Processing Data Archival

2.4 Meteorological Satellite Transmission Characteristics

NOAA HRPT:

Symbol Rate	665,400 s/s
Data Rate	665,400 b/s
Modulation	BPSK Split Phase
Frequency	1698.0 MHz, 1707.0 MHz, 1702.5 MHz
Polarization	RCP
FEC	None
Ref:	"NOAA KLM Users Guide – Sep 2001"

Fengyun CHRPT:

Symbol Rate	1,330,800 s/s
Data Rate	1,330,800 b/s
Modulation	BPSK Split Phase
Frequency	1700.4 MHz, 1704.5 MHz
Polarization	RCP
FEC	None
Ref:	"The Chinese Meteorological Satellite Programs, National Meteorological Satellite Center, China Meteorological Administration"

METOP:

HRPT:	
Symbol Rate	2333.3335 ks/s
Data Rate	3500.000 kbit/s
Modulation	QPSK NRZ
Frequency	1701.3 MHz, 1707.0 MHz
Polarization	RCP
FEC	Rate ¾ K=7 Convolutional, (255,223) Reed-Solomon
LRPT:	
Symbol Rate	80.0 ks/s
Data Rate	72.0 kbit/s
Modulation	QPSK NRZ
Frequency	137.1 MHz, 137.9125 MHz
Polarization	RCP
FEC	Rate 1/2 K=7 Convolutional (36,2048) Convolutional Interleave, (255,223) Reed-Solomon
Ref:	"HRPT/LRPT Direct Broadcast Services Specification. MO-DS-ESA-SY-0048 1 Nov 2000"

NOAA GOES GVAR:

Symbol Rate	2,111,360 s/s

Data Rate	2,111,360 b/s
Modulation	BPSK NRZ-S
Frequency	1685.7 MHz
Polarization	Linear
FEC	None
Ref:	“NOAA/NESDIS DRL 504-02”

NOAA GOES LRIT:

Symbol Rate	293,000 s/s
Data Rate	128 kit/s
Modulation	BPSK NRZ-L
Frequency	1691.0 MHz
Polarization	Linear
FEC	Rate 1/2 K=7 Convolutional, (255,223) Reed-Solomon
Ref:	“NOAA LRIT Receiver Specification April 8, 2003”

NOAA GOES EMWIN-N:

Symbol Rate	22.080 ks/s
Data Rate	9.6 kb/s
Modulation	BPSK NRZ-L
Frequency	1692.7 MHz
Polarization	Linear
FEC	Rate 1/2 K=7 Convolutional, (255,223) Reed-Solomon
Ref:	“NOAA EMWIN Receive Station Specifications March 12, 2004”

DMSP:

RTD:

Symbol Rate	1.024 Ms/s
Data Rate	1.024 Mb/s
Modulation	BPSK NRZ-L
Frequency	2207.5 MHz, 2267.5 MHz
Polarization	RCP
FEC	None

RDS S-Band:

Symbol Rate	133.1 ks/s Through F15, 177.5 ks/s F16 and later
Data Rate	66.55 kb/s Through F15, 88.75 kb/s F16 and later
Modulation	BPSK NRZ-M
Frequency	2207.5 MHz, 2267.5 MHz Through F15, 2222.5 MHz F16

Polarization	RCP
FEC	Rate 1/2 K=7 Convolutional
Ref:	"DMSP Data Specifications IS-YD-821 28 April 1993"

3. References

1. J. T. Shaffer and R. B. Dybdal, "Dual Frequency Tactical Antenna," 1998 IEEE AP-S Symposium Digest, Atlanta GA, pp 58-61, June 21-26, 1998.
2. J. D. Michaelson and R. B. Dybdal, "Development/Demonstration of a Tactical RDS Terminal," 2003 MAXI Symposium.