IN-32
067286

NASA Technical Memorandum 113126

Ultra Small Aperture Terminal for Ka-Band SATCOM

Roberto Acosta, Richard Reinhart,
Richard Lee, and Rainee Simons
Lewis Research Center
Cleveland, Ohio

Prepared for the
Wireless & Microwave Technology '97 Conference and Exposition
sponsored by Wireless & Microwave Technology
Chantilly, Virginia, October 6–10, 1997

National Aeronautics and
Space Administration

ULTRA SMALL APERTURE TERMINAL FOR Ka-BAND SATCOM

Roberto Acosta, Richard Reinhart, Richard Lee and Rainee Simons

Space Communication Office
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135
e-mail: R.Acosta@lerc.nasa.gov

Introduction

An ultra small aperture terminal (USAT) at Ka-band frequency has been developed by Lewis Research Center (LeRC) for data rates up to 1.5 Mbps in the transmit mode and 40 Mbps in receive mode. The terminal consists of a 35 cm diameter offset-fed parabolic antenna which is attached to a solid state power amplifier and low noise amplifier. A single down converter is used to convert the Ka-band frequency to 70 MHz intermediate frequency (IF). A variable rate (9.6 Kbps to 10 Mbps) commercial modem with a standard RS-449 / RS-232 interface is used to provide point-to-point digital services. The terminal has been demonstrated numerous times using the Advanced Communications Technology Satellite (ACTS) and the 4.5 m Link Evaluation Terminal (LET) in Cleveland.

A conceptual design for an advanced terminal has also been developed. This advanced USAT utilizes Microwave Monolithic Integrated Circuit (MMIC) and flat plate array technologies. This terminal will be self contained in a single package which will include a 1 watt solid state amplifier (SSPA), low noise amplifier (LNA) and a modem card located behind the aperture of the array. The advanced USAT will be light weight, transportable, low cost and easy to point to the satellite. This paper will introduce designs for the reflector based and array based USAT's.

USAT

The objective of this work was to develop a Ka-band ground system which will achieve size reduction, low power consumption, portability, rugged construction and service enhancements of the ACTS terminals. The ACTS Ka-band USAT's were initially conceived to demonstrate feasibility of Supervisory Control and Data Acquisition (SCADA) applications using this ACTS channel. The overall block diagram depicted in **figure 1** shows the network components required to achieve a point-to-point digital transmission using ACTS. The network consists of several USAT's (same beam) and LET as the hub station. The USAT system uses the Microwave Switch Matrix or "bent pipe" mode of ACTS. They operate using the upper frequency portion of the 1 GHz bandwidth available.

A system block diagram for a USAT ground terminal is presented in **figure 2**. It consists of an antenna, RF transceiver (RFT), IF transceiver (IFT) and a satellite modem. All components are implemented using discrete integrated circuits. **Table I** summarizes the USAT specifications. The USAT EIRP and G/T performance parameters are 31.0 dBW and 7.0 dB/K, respectively. The antenna produces two orthogonally polarized beams, one at 30 GHz for transmit and another one at 20 GHz for receive. The transmit and receive antenna gains/half-power beamwidths are 38.5 dBi/2.4 degrees and 35 dBi/3.5 degrees, respectively. A picture of an installed USAT ground terminal is shown in **Figure 3**. The RFT directly interfaces with the antenna via the 30 GHz and 20 GHz ports of the orthomode transducer (OMT)for transmission of the 30 GHz uplink and reception of 20 GHz downlink. The IFT interfaces between the RFT, IF amplifier, master oscillator and DC/DC converters. The satellite modems can be any off-the-shelf commercial type implementing modulation schemes such as BPSK or QPSK.

Advanced USAT

Future Ka satellite communication will require small, portable and easily deployable ground terminals. Although the standard USAT is considered transportable and user friendly, further advancement in packaging technology will continue to reduce its size, and ultimately cost. The LeRC Space Communication Office has developed a conceptual design for a terminal that will utilize MMIC technology. The primary goals of the design are low cost construction and ease of operation. The terminal concept emphasis is on small, high efficiency flat plate array antennas, low power consumption modules, portability and rugged electronics. **Figure 4** shows the baseline terminal concept. It consists of 3 modules and a flat plate array antenna. One module will consist of 1 watt MMIC amplifier with an input at 70 MHz, the second module is a MMIC LNA with an output at 70 MHz and the third module consists of a modem card with standard RS 232 data input/outputs. All modules are packaged in one weather resistant enclosure.

Flat Plate Antenna

The standard USAT which is used to communicate with ACTS currently utilizes a parabolic reflector antenna. The advanced USAT will utilize a flat plate array antenna. The array is designed using either low loss printed circuit or sloted waveguide technologies. **Figure 5** shows a microstrip patch array antenna which radiates from a single rectangular aperture. The aperture consists of many single microstrip antennas combined in phase for maximum radiated power. Microstrip antennas can be constructed on printed circuit board material and thus have an extremely low profile and economical high volume construction cost. Taking into account the small thickness of the materials and in certain cases, their large dimensions, a mechanical support is sometimes necessary. This can be created by plating the antenna onto a rigid support structure. The combining network can be etched on the same substrate and multiple layers of substrate can be used to create dual polarization, wide frequency bands and other desirable antenna performance characteristics.

Microstrip antennas can be designed to be equal or more efficient than dish antennas of the same aperture size. When apertures become extremely large, however, patch arrays tend to become less efficient than reflector antennas. This is due to the line losses caused by an extensive combining network required for very high gain antennas. Depending on the type of substrate on which the antenna is etched, this loss can have a pronounced effect. To achieve high radiation efficiency, innovative feeding techniques must be utilized. The primary design objective for beam forming in to have low loss which can be achieved using low loss materials.

Several designs exist in the literature that are large and very lossy. They all utilize microstrip beam forming techniques. Waveguide feeds are easy to manufacture and also exibit low loss (a factor of 100 over microstrip). The primary design constraint in the flat plate antenna is to transmit and receive using a single aperture producing a high gain (> 38 dBi) antenna with low beam forming loss.

MMIC Transmit/Receive Modules

The transmit modules and receive modules are implemented by using the MMIC technology. The transmitter utilizes advanced InP HEMT MMIC power amplifier and the receiver front-end utilizes a pseudomorphic HEMT MMIC low noise amplifier. **Figure 6** shows the 30 GHz transmitter/high power upconverter (HPU) and **figure 7** shows the architecture of the 20 GHz receiver front-end/low noise downconverter (LND).

The 30 GHz MMIC power amplifier design will consist of a three stage circuit, microstrip lines & MIM capacitor for impedance matching, on-chip bypassing of power supplies, through substrate grounding vias and device model derived from measured and predicted data. The MMIC technology is necessary for modules to be efficient and compact. The input and output are at 70 MHz, although 140 MHz can be also considered.

In the future, most applications will use moderate data rates (< 1.5 Mbps) and the customized modem card can be compact and very low cost. With a modem card and MMIC ground station modules combined, the user will have the capability to utilize other application equipment like a TV camera, a personal computer or a telephone.

Conclusions

An operational Ka-band ultra small aperture terminal has been successfully demonstrated through multimedia video conferencing via the ACTS spacecraft for data rates up to 1.5 Mbps full duplex and up to 40 Mbps half duplex. Also, a conceptual design for a flat plate terminal (suitcase type) was presented. In the future, small Ka-band satellite communication terminals like the Advanced USAT will compare favorably with the current Ku-band receive only terminals.

References

1. Philip Y. Sohn and Richard C. Reinhart, "Ultra Small Aperture Terminal: System Design and Test Results", ACTS Results Conference, 1995.
2. Gene Fujikawa and James S. Svoboda, " Test Results of a 20 GHz, Low Noise Downconverter for USAT Applications", NASA TM–106892.
3. Daniel P. Siu, "Advanced MMIC 30/20 GHz transmitter/Receiver for Low Cost Ka-band Ground Terminals", NAS3–27658.

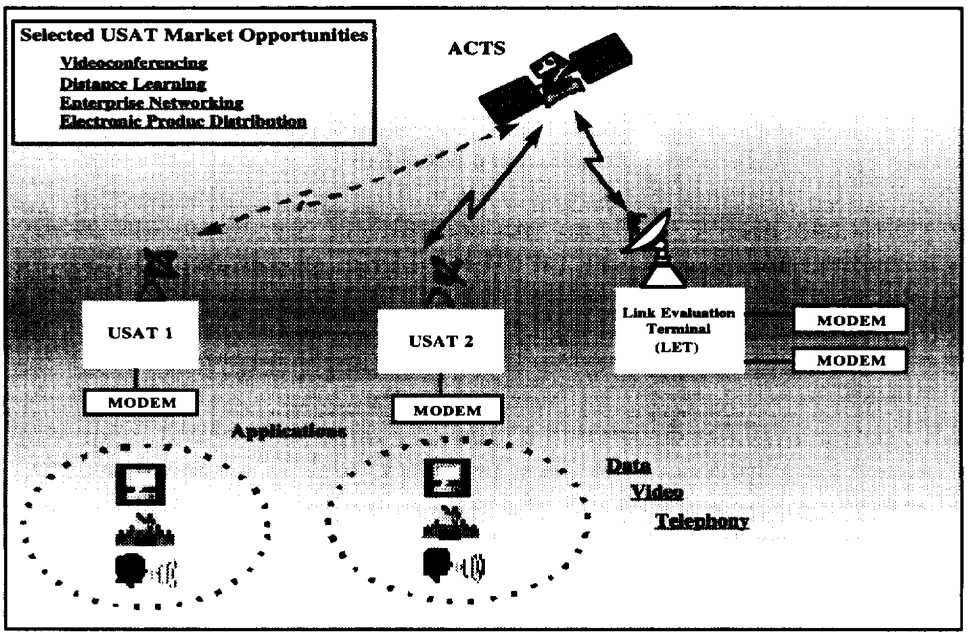

Figure 1 : USAT Network Block Diagram

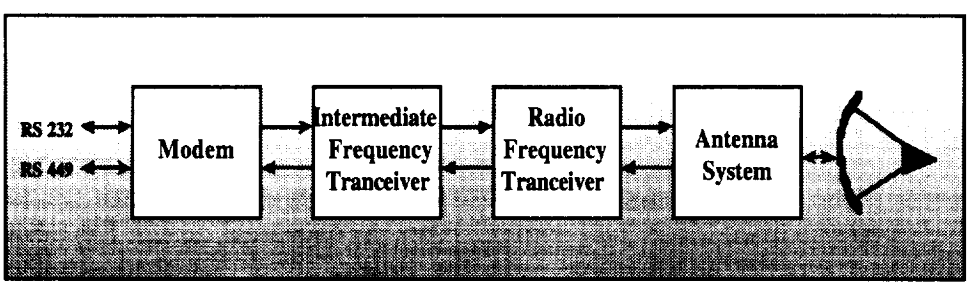

Figure 2 :USAT System Block Diagram

USAT Transceiver System Specifications	
Antenna	**35 cm Parabolic Dish with Offset Feed (F/D = .6)** **Antenna Gains: 38.5 dBi for TX** **35.0 dBi for RX**
RF Transceiver	**Tx Frequency Range : 29.4 to 29.8 GHz** **Tx Power: 23 dBm** **Rx Frequency Range: 19.7 to 20.0 GHz** **Noise Figure 4.5 dB** **Image Rejection : 18 dB**
IF Transceiver	**Tx Frequency Range: 770 Mhz to 910 Mhz** **Rx Frequency Range: 52 to 88 MHz**
Satellite Modem	**Modulation ; BPSK or QPSK** **Data Rates: Rx up to 30 Mbps;Tx up to 144 Kbps**

Table I : USAT System Level Specifications

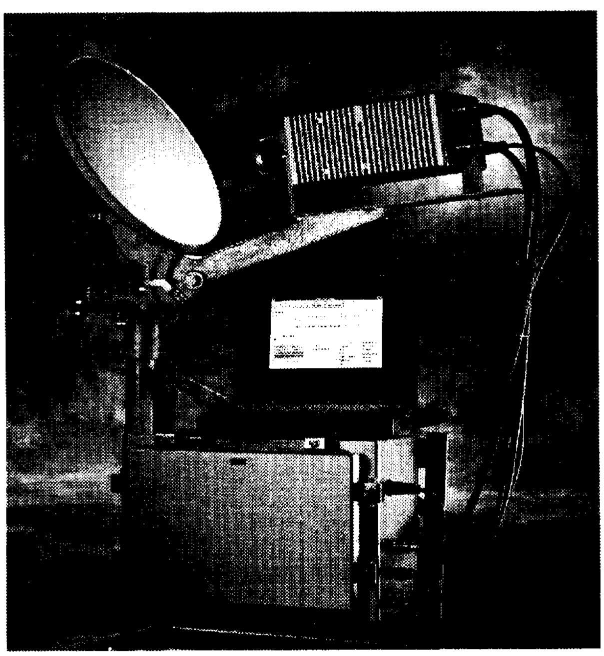

Figure 3. Ka Band Ultra Small Aperture Terminal

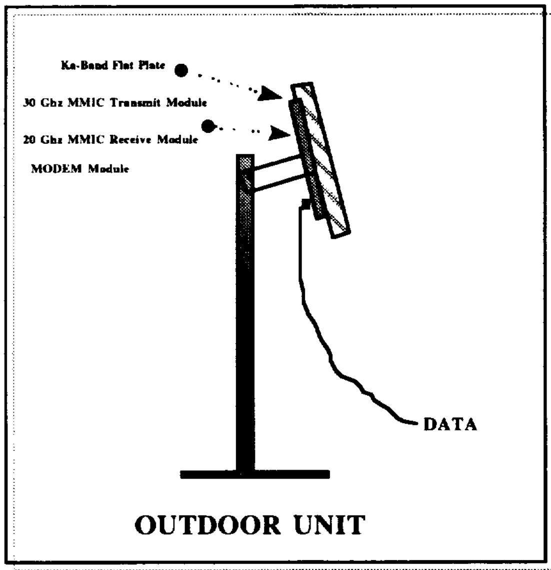

Figure 4 - Advanced USAT Architecture

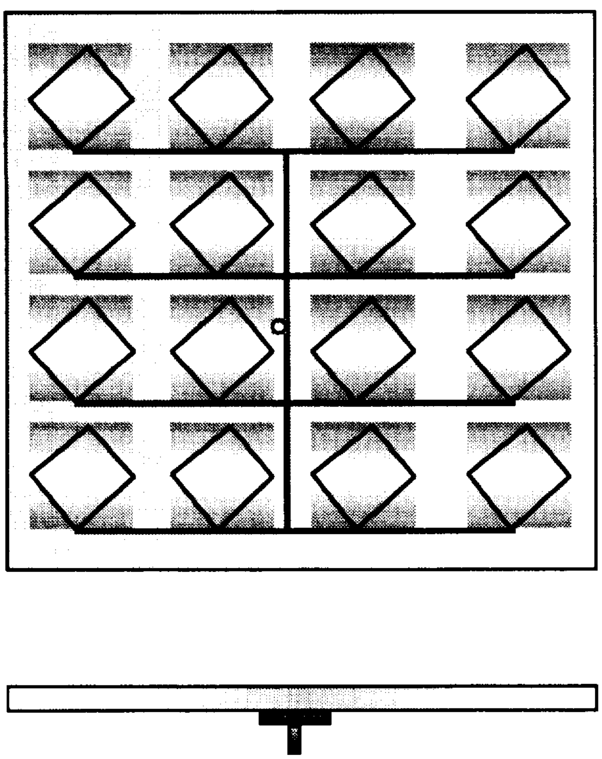

Figure 5. Outline of Flat Plate Antenna

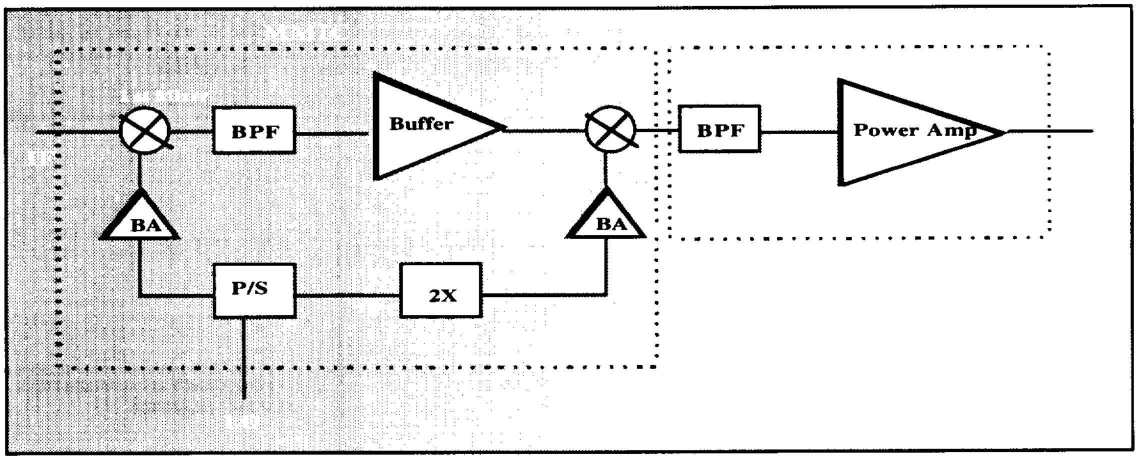

Figure 6 . Architecture of the 30 GHz Transmitter/High Power Upconverter (HPU)

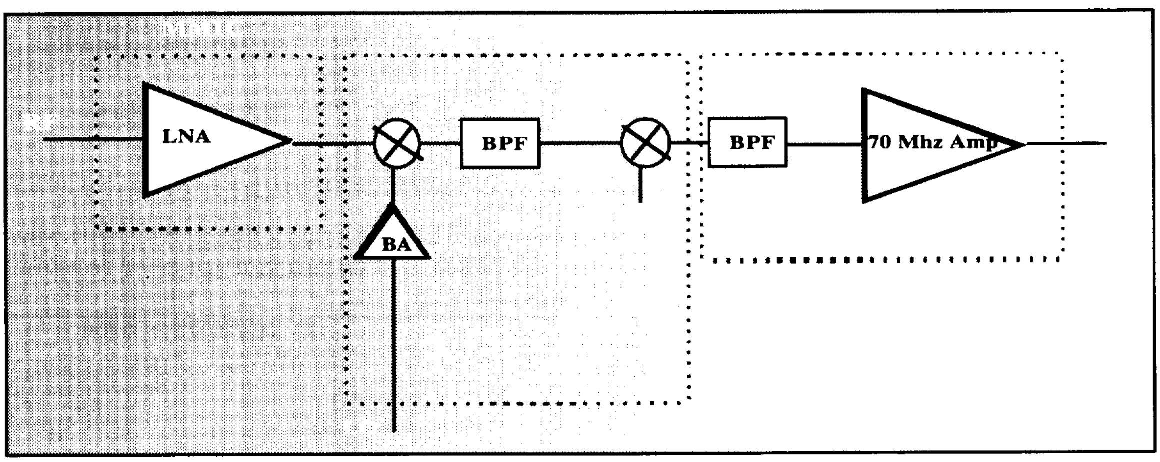

Figure 7. Architecture of the 20 GHz Receiver/ LNA Downconverter (LND)

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1997	Technical Memorandum

4. TITLE AND SUBTITLE

Ultra Small Aperture Terminal for Ka-Band SATCOM

5. FUNDING NUMBERS

WU–315–90–2C

6. AUTHOR(S)

Roberto Acosta, Richard Reinhart, Richard Lee, and Rainee Simons

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135–3191

8. PERFORMING ORGANIZATION REPORT NUMBER

E–10894

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

National Aeronautics and Space Administration
Washington, DC 20546–0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

NASA TM–113126

11. SUPPLEMENTARY NOTES

Prepared for the Wireless & Microwave Technology '97 Conference and Exposition sponsored by Wireless & Microwave Technology, Chantilly, Virginia, October 6–10, 1997. Responsible person, Roberto Acosta, organization code 6160, (216) 433–6640.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Unclassified - Unlimited
Subject Category 32

This publication is available from the NASA Center for AeroSpace Information, (301) 621–0390.

12b. DISTRIBUTION CODE

13. ABSTRACT ***(Maximum 200 words)***

An ultra small aperture terminal (USAT) at Ka-band frequency has been developed by Lewis Research Center (LeRC) for data rates up to 1.5 Mbps in the transmit mode and 40 Mbps in receive mode. The terminal consists of a 35 cm diameter offset-fed parabolic antenna which is attached to a solid state power amplifier and low noise amplifier. A single down converter is used to convert the Ka-band frequency to 70 MHz intermediate frequency (IF). A variable rate (9.6 Kbps to 10 Mbps) commercial modem with a standard RS-449 / RS-232 interface is used to provide point-to-point digital services. The terminal has been demonstrated numerous times using the Advanced Communications Technology Satellite (ACTS) and the 4.5 m Link Evaluation Terminal (LET) in Cleveland. A conceptual design for an advanced terminal has also been developed. This advanced USAT utilizes Microwave Monolithic Integrated Circuit (MMIC) and flat plate array technologies. This terminal will be self contained in a single package which will include a 1 watt solid state amplifier (SSPA), low noise amplifier (LNA) and a modem card located behind the aperture of the array. The advanced USAT will be light weight, transportable, low cost and easy to point to the satellite. This paper will introduce designs for the reflector based and array based USAT's.

14. SUBJECT TERMS

Ka-band satellites; Ground station

15. NUMBER OF PAGES

9

16. PRICE CODE

A02

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102