RUDAK - THE PACKET RADIO EXPERIMENT ON-BOARD OSCAR P3C

Hanspeter Kuhlen DK1YQ
AMSAT-DL
Program Manager AMSAT-RUDAK Project

Finkenstrasse 11
D-8011 Aschheim nr. Munich
West- Germany
Tel.: 49 89 - 90 33 90 5 (home)
49 89 - 6000 - 3542 (qrl)

Abstract

Nearly two years ago, AMSAT-DL initially published the outcome of its first RUDAK system design meeting at the 4th ARRL Conference in San Francisco [1]. At this time we wish to present the current status of the flight ready hardware and the completed and tested ground station equipment.

This paper will briefly present the objectives of the RUDAK experiment and the performance achieved by the RUDAK transponder on-board OSCAR Phase 3 C. It will also include a description of a recommended user terminal which can be utilized for all satellite operating modes via OSCAR Phase 3 C, FUJI OSCAR 12, as well as for terrestrial packet radio.

Introduction

Early in 1985 when the packet radio revolution began spreading around the world, following acceptance of the AX.25 as an international amateur radio protocol for link control, the first system design meetings took place, where the payload capabilities of the new AMSAT OSCAR satellite were discussed.

The experiment was named RUDAK which is the accronym for " Regenerativer Umsetzer für Digitale Amateurfunk Kommunikation " which is translated into English " Regenerating Transponder for Digital Amateur Communications ".

Objectives of the RUDAK experiment

These are:

* Real-time digital communications facility with ALOHA (i.e. uncoordinated) type of time division multiple access and continuous time division multiplex (i.e. permanent) on the downlink. Due to the long visibility of the spacecraft because of its elliptical orbit, a mailbox or any other store-and-forward facility was not considered necessary.

* Operational use of binary shift keying (BPSK) with differential coding for the purpose of individual communication, education and experimentation.

* General information broadcast in AX.25 (UI-frames) or AMSAT format.

* Computer controlled mode switching (autonomous operation)

*Provide in-orbit facility using a fully programmable computer with intelligent hardware interfaces in order to provide a testbed for communications experiments such as testing alternative access procedures, different bitrates and so forth.

* Keep size and complexity of ground user equipment as low as possible to motivate home-brewing of station equipment.

* Information system through a ROBOT mode to RUDAK processor. In this mode, connects from individual stations to RUDAK will be responded with a particular message e.g. Keplerians and then disconnected. So at least a positive confirmation of a contact will be provided.

The RUDAK space segment

The RUDAK mode will be in operation on mode L only. Due to the fact that the RUDAK transponder is basicly independent from the normal passband it will be operative even when the mode L passband is switched off. The uplink frequency will be 1269.725 MHz and the downlink 435.725 MHz, however the exact frequency plan will be published after final calibration of all transponders.

A block diagram of the digital RUDAK transponder is given in figure 1.

The transmissions from the ground stations will be short packets or bursts to allow time sharing of the frequency among several users simultaneously. A specially developed burst demodulator on-board the satellite scans around the center frequency to cope with uncertainties of the uplink signals in terms of frequency accuracy, doppler shifts and so on. A range of +- 7.5kHz is scanned at 120msec/scan.

The measured performance of the flight unit is about 100 msec for the acquisition i.e. the time span from detection of an input signal to its demodulation. The demodulated signal then is the recovered data and clock for further processing in the RUDAK computer.

This unavoidable overhead time of 100msec has to be considered in setting the appropriate TNC parameter. For instance the AXDELAY in TNC 1s so, that a sufficient number of flags (#7E) are being transmitted prior to each packet thus allowing the demodulator to lock on the signal. The optimum values will be communicated in the broadcast beacons, however according to our present experience they will probably be almost the same as used for the standard FM MODEMs in the TNCs .

Due to the inherent collision problem for the uplink packets, the maximum theoretically achievable throughput is limited to 18%. In other words, even under optimum channel conditions, only 18% of the packets offered to the channel will survive. This effect is also to be observed when a mountain top packet radio digipeater is within reach of many local stations, where on the other side the local stations cannot hear each other. In this case the carrier sensing mechanism (CSMA), which normally avoids collisions by inhibiting transmissions on an engaged frequency, is useless. Therefore 2400bps has been selected for the uplink bitrate resulting in 400bps for the downlink.

As an option there is a 1200bps mode, where NRZI coding is used so as to be fully compatible with the FUJI OSCAR 12 downlink.

Mode L has been designated to be the dominating mode throughout the entire mission of Phase 3C. For the digital experiment, the RF modules will be independent of the normal passband of mode L.

RUDAK User Terminals

For the user, probably the most interesting part of the experiment is the design and installation of his/her own satellite user terminal.

As defined in the objectives, one of the main goals of the experiment is to enable reasonably skilled individual operators to test the modem modes of digital communications. This has been considered not only in the selection of moderate bitrates, but also in the design and development of an extremely versatile easily built user terminal.

During the last couple of months, all necessary modules (PCBs) for the RF and digital unit have been designed and tested. Wherever possible, we took off-the-shelf designs in order to avoid re-inventing the wheel. The PCBs are now available and have been beta-tested by several amateurs.

Now its time to bring it all together in such a way as to be easily and reliably reproduced. The design of the terminal consists of two separate cabinets, called ‘RF-Unit” and “Digital Unit”.

The features can be summarized as follows:

* Operates in ALL satellite modes: CW, SSB, PSK through passband and of course RUDAK modes.

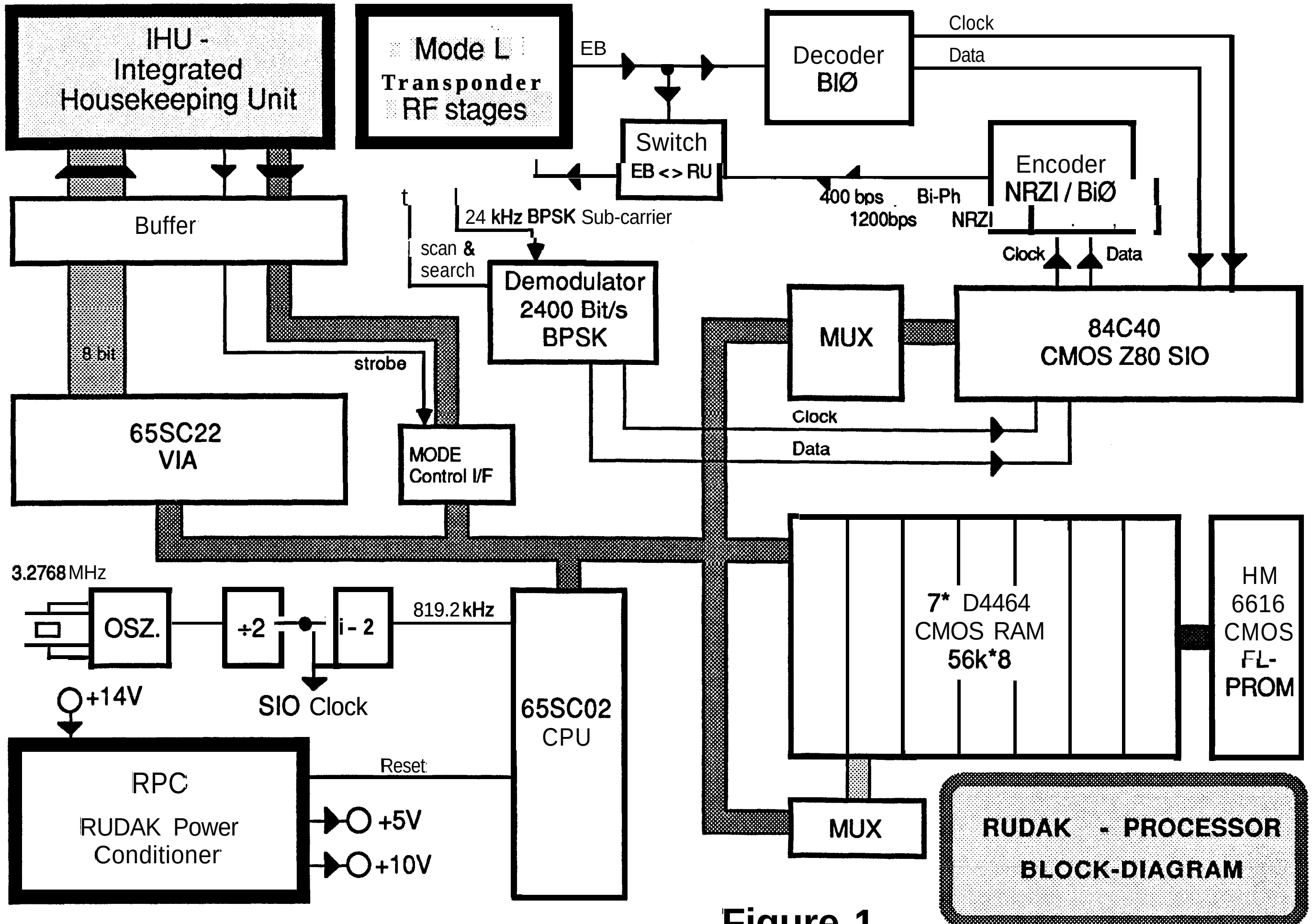
* The RF-unit can also be used as general purpose power amplifier for terrestrial 23cm use, etc.

* The power amplifier provides 20W CW output power on 24cm with hybrid PA module.

* Converts 2m into 24cm; built-in attenuator to accept 1 W of driving power.

* Modulator for 2400bps

* BPSK demodulators for 400bps and 1200bps with Bi-phase and NRZI coding respectively.



IHU - Integrated Housekeeping Unit
Mode L Transponder RF stages
EB
Decoder BIØ
Clock
Data
Switch EB <> RU
Encoder NRZI / BiØ
400 bps Bi-Ph
1200bps NRZI
Clock
Data
Buffer
24 kHz BPSK Sub-carrier
scan & search
Demodulator 2400 Bit/s BPSK
MUX
84C40 CMOS Z80 SIO
8 bit
strobe
Clock
Data
65SC22 VIA
MODE Control I/F
7* D4464 CMOS RAM 56k*8
HM 6616 CMOS FL-PROM
3.2768 MHz
OSZ.
÷2
÷2
819.2 kHz
+14V
SIO Clock
65SC02 CPU
RPC
RUDAK Power Conditioner
Reset
+5V
+10V
MUX
RUDAK - PROCESSOR BLOCK-DIAGRAM

Figure 1

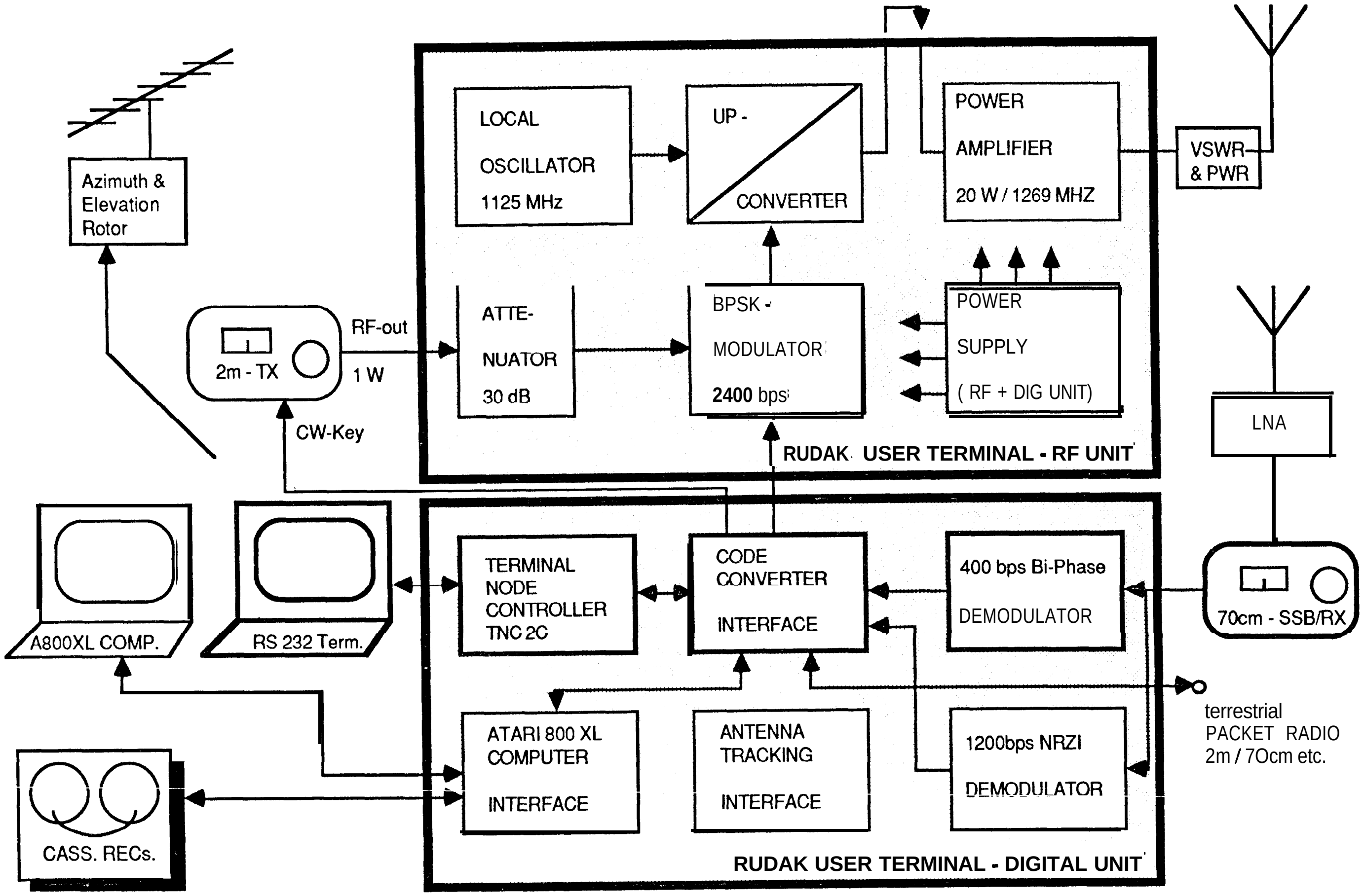


Figure 2

RWDAK USER TERMINAL
® AMSAT RUDAK GROUP 4.87

* Compatibility with FUJI OSCAR 12 formats.
* Built-in Terminal Node Controller (TNC)
* Internal switching for space- or terrestrial packet radio operations.
* AMSAT interface to general purpose computer (ATARI 800XL) for satellite tracking with automated antenna azimuth and elevation control, satellite telemetry decoding with display of measured parameters in engineering units, visibility prediction, data communications in AMSAT block format similar to telemetry blocks of OSCAR10, etc.

To the best of our knowledge, the ATARI 800XL is available in almost any country in the world. This computer has been selected for OSCAR 10 satellite control purposes because of its extremely low price and even more importantly (sometimes) because of its very effective RF-shielding. As soon as another computer is operated close to the sensitive satellite RX, this shielding is appreciated even more.

* Common power supply in the RF-unit.

For the digital unit, we selected a so-called modular design, so that commencing from a common baseline version, the station can be expanded on a step-by-step basis with additional functions, if desired ("matched to the achievable PFD - pecuniary flux density .hi !)

The whole set-up is shown in figure 2. This block diagram shows the required equipments in addition to the user terminal.

Before getting nervous on the very complex configuration shown in that diagram it must be emphasized that it shows the ultimate super dupe version of an amateur satellite home terminal. The minimum required hardware beside the receiver and an RS232 monitor are the 400bps demodulator, the code converter interface and the TNC. This will allow monitoring of RUDAK activities as a looker-on. Doing so and reading hopefully a lot of exotic call signs passing by will definitely motivate to do one more step and participate with active transmissions.

RUDAK Field Test Installation

Since the RUDAK experiment utilizes several newly developed items, in both the hardware and software areas, a comprehensive field test for all components was therefore determined to be mandatory.

The equipment has been installed on top of a 45m high water tower in the city of Ismaning near Munich providing RUDAK experimentation and testing to several amateurs in the Munich region. The block diagram of the installations is given in figure 3.

From here RUDAK is operated exactly the same way as hopefully soon from OSCAR XX in-orbit.

This includes also the testing of the IHU interfaces and the internal communications among the two computers on-board.The equipment configuration of the field test is kept exactly the same as the equipment on-board the satellite so that the achieved performance improvements and hardware changes can also be introduced into the flight hardware.

The RUDAK Software System

The basic operational software (S/W) is available and has been tested. However, it is the software which will hopefully provide a caleidoscope of new features during the in-orbit life time of the experiment.

For the sake of communications among the members of the RUDAK group, the AMSAT control stations and, last but not least, interested experimenters, we defined the S/W in modular way:

The entire S/W system is composed of the subsystems Flight S/W, Ground Support S/W and Test & Simulation S/W.

The subsystem Flight S/W breaks down into so-called tasks such as:

The Task 1.0: ROM operating system (ROS), Task 1 .1: the IPS kernel, Task 1.2 : the AX.25-server, Task 1.3 : the beacon service, Task 1.4 : the traffic control and Task 1.5 : Utilities

The subsystem Ground Support S/W breaks down into:

Task 2.1 : RUDAK+IHU Command S/W, Task 2.2 : Integrated S/W package (public domain S/W for ATARI 800XL), Task 2.3 : TNC S/W (i.e. modifications and changes for RUDAK operation of various TNC- S/Ws)

The subsystem Test & Simulation breaks down into:

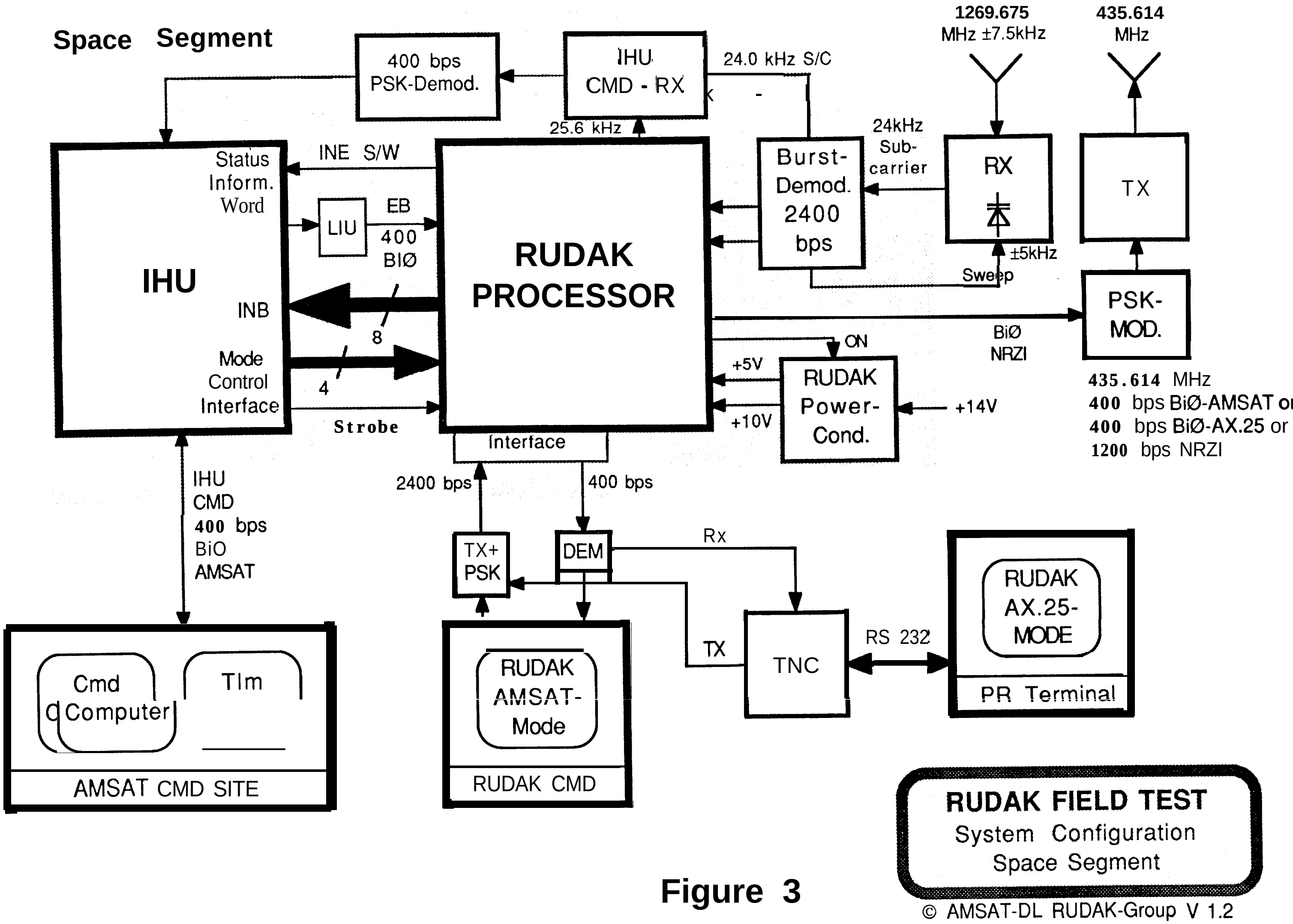

Space Segment
400 bps PSK-Demod.
IHU CMD - RX
24.0 kHz S/C
1269.675 MHz ±7.5kHz
435.614 MHz
25.6 kHz
24kHz Sub-carrier
IHU
Status Inform. Word
INE S/W
LIU
EB
400 BIØ
INB
8
Mode Control Interface
4
Strobe
RUDAK PROCESSOR
Burst-Demod. 2400 bps
RX
±5kHz
Sweep
TX
PSK-MOD.
BiØ NRZI
ON
+5V
+10V
RUDAK Power-Cond.
+14V
435.614 MHz
400 bps BiØ-AMSAT or
400 bps BiØ-AX.25 or
1200 bps NRZI
Interface
2400 bps
400 bps
IHU CMD 400 bps BiO AMSAT
TX+ PSK
DEM
Rx
TX
TNC
RS 232
RUDAK AX.25-MODE
PR Terminal
Cmd Computer
Tlm
AMSAT CMD SITE
RUDAK AMSAT-Mode
RUDAK CMD
RUDAK FIELD TEST
System Configuration
Space Segment
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Figure 3

Task 3.1 Field Test S/W, Task 3.2 In-Orbit Test S/W (Engineering mode)

The RUDAK User Manual

Great care and attention has been devoted to the objective of keeping the user station reasonably easy to built. Therefore the design of the proposed user terminal is such that no special tools or machinery will be necessary to built it. Several components, in particular those of the RF unit have been built and evaluated in many different design approaches testing their suitability for amateur construction.

The results of these investigations have been compiled in the RUDAK User Manual. This manual provides all necessary back ground information on all aspects of the experiment as well as a detailed description of how to built your own terminal.

At the time of writing this article we are in the final compilation and editing phase of the manual. The official release for the complete handbook is presently scheduled for the end of this year, right in time to get prepared for the launch of OSCAR P3C.

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References

[1] Dr.K.Meinzer DJ4ZC, H.Kuhlen DK1 YQ
" Formal definition meeting of the AMSAT RUDAK experiment "
Proceedings of the 4th ARRL Computer & Networking
Conference , San Francisco, USA 1985

[2] K.Brenndörfer DF8CA, G.E. Tucker,WA5NVI
" RUDAK: A status report "
AMSAT QEX 59, Jan. 1987

[3] H.Kuhlen DK1YQ, D.Moe KE6MN/DJ0HC
" The RUDAK Experiment "
73 Magazin, August 1986