AMSAT

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Amended Technical Proposal

Synchronous Amateur Radio Transponder (SYNCART)
Small Terminal Multiple Access User Experiment
for the ATS-G Applications Technology Satellite

Submitted to

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Communications and Navigation Programs Office
Office of Space Science and Applications
Washington, D. C. 20546

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Amended Technical Proposal

for an

ATS-G Synchronous Amateur Radio Transponder Experiment

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PREFACE

The SYNCART (Synchronous Amateur Radio Transponder) experiment employs a low-power linear repeater designed for operation aboard the NASA ATS-G Applications Technology Satellite with small amateur radio stations on the ground. The transponder will consume less than twenty watts of prime power from the spacecraft, and will weigh approximately 7.5 pounds. The package will be designed to operate within the presently allocated two meter and seventy centimeter amateur bands.

1. MISSION OBJECTIVES

The SYNCART experiment is designed to use stations in the amateur service to provide educational training, "bush" communication, emergency and other public service functions, and communications to medical centers in isolated areas. The repeater will also be used for multiple access experiments, a satellite-to-home voice broadcast experiment, and possibly a space-to-space amateur satellite relay experiment. All of these experiments will involve the use of small amateur radio stations as earth terminals, but will provide services to many outside the amateur community itself.

1.1 Educational Applications

It is expected that SYNCART will contribute to the advancement of education and training in satellite technology, both domestically and in other countries. Indeed, in some developing countries the establishment of a SYNCART amateur ground terminal may be the country's first encounter with satellite communication. Previous amateur satellites of the OSCAR (Orbiting Satellites Carrying Amateur Radio) series were used by schools for group and individual training. For example, at the Talcott Mountain Science Center for Student Involvement In Avon, Conn., over three hundred students were introduced to the concepts and methods of satellite tracking using real-time passes of Australis-OSCAR 5.[1] Student involvement took place on both an introductory and advanced level. Students were able to determine the passage times and directions of the satellite, and operated the tracking station themselves using an amateur station installed at the Science Center for this purpose. The Center is planning expanded activities of this type as a pilot program to encourage greater use of satellites by schools in the U.S. and abroad as an educational aid in the teaching of space science.[2]

1- Jan A. King and Perry I. Klein, "Radio Amateur Satellites for Education and Research," IEEE 1970 EASCON Convention record (copy attached).

2 - William I. Dunkerley, Jr., "Radio Amateur Satellites: A Means for Relating the Advances in the Space Program to the Public," presented at the Eighth Space Congress, Cocoa Beach, Fla., April 19-23, 1971 (copy attached).

1.2 Small-Terminal "Bush" Communications

The ATS-G mission is planned at a period of minimum solar activity in the eleven year sunspot cycle, a time during which long-distance ionospheric propagation is expected to be difficult on the higher frequency amateur bands. SYNCART is designed to provide long-distance VHF/UHF communication, especially needed during night-time periods or other times when long-distance ionospheric communication at HF is difficult.

"Bush" or "out-back" communication of a non-amateur variety, such as might be found in Alaska, northern Canada, Australia, Antarctica or developing regions, is analogous in many respects to amateur communication found anywhere in the world. Many amateurs regularly use small portable HF and VHF transmitters and receivers, including equipment installed in automobiles, and even hand- held portable units.

1.3 Emergency and Other Public Service Communications

Radio amateurs have, on numerous occasions, provided the only source of communication in time of emergency. The 1964 Alaskan earthquake and the June 1970 earthquake in Peru are but two noteworthy examples. Indeed, in setting forth the basis and purpose of the amateur service, the Federal Communications Commission cites "... the value of the amateur service to the public as a voluntary noncommercial communication service, particularly with respect to providing emergency communications.[3] It is expected that SYNCART will be used in support of such communications during and in preparation for any such emergencies, and particularly for warnings and alerts during the hurricane season.

1.4 Medical Data Transmission

Many cases have been documented in which amateur communication was used to locate needed drugs, diagnose a rare disease and prescribe treatment, or give medical instructions during surgery. SYNCART is designed to relay such communication, and tests will be arranged between medical centers and clinics or hospitals in isolated areas to exchange medical data. The National Institutes of Health Amateur Radio Club in Bethesda, Md., an AMSAT-affiliated club, has indicated an interest in participating in this aspect of the amateur satellite program.[4]

1.5 Multiple Access Experiments

In contrast to previous multiple access experiments which have generally been of limited scale, the amateur community provides a potential source of large numbers of simultaneous users. SYNCART will permit the evaluation of small-terminal multiple access techniques and operating procedures using large numbers of amateur stations. Of particular interest are the development of methods of accessing the repeater and self-monitoring for user power control. The cross-band (146/435 MHz) design of the SYNCART repeater will permit users to monitor their own downlink signals easily, and consequently, to adjust their power to compensate for changes in repeater loading or propagation effects. It is anticipated that self-monitoring and power balance can eventually be made automatic through closed-loop power control circuits that can be developed for the ground terminal equipment, in a method similar to conventional automatic gain control.

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3 - U.S. Federal Communications Commission Rules and Regulations, Paragraph 97.1(a).

4 - Arthur Griffiths, "Amateur Radio Satellites and Their Possible Use in Medical Communication," presented at the Fifth Annual Meeting of the Medical Amateur Radio Council, Ltd., Atlantic City, N.J., June 24, 1971.

A second method to be investigated is the transmission of short bursts of carrier by the user to permit monitoring the level of the burst over the downlink, taking advantage of the quarter-second round-trip propagation time of the satellite signal to switch the ground equipment from the transmit mode to the receive mode.

System performance under multiple access conditions will be evaluated by examining telemetered repeater AGC level and by observing the downlink passband spectrum to determine repeater loading, intermodulation, interference and efficiency, under a variety of operating conditions and modulation modes.

1.6 Satellite-to-home Voice and Slow-Scan Television Broadcasts

When operated in a full-power, single-access mode, SYNCART is expected to produce signal power flux density levels at the ground sufficient to permit useful reception with ordinary amateur receivers using low-gain receiving antennas. Different modulation techniques and program material will be employed over the SYNCART link to evaluate the usefulness of providing satellite-to-home voice and slow-scan television broadcasts directly to amateur receivers.

Emergency bulletins and alerts will use the broadcast mode. As regular program material, bulletins of the American Radio Relay League will be scheduled. Program material on radio/electronics in preparation for the Federal Communications Commission amateur radio examinations will also be transmitted, especially intended for use by the many amateur radio clubs affiliated with schools and universities. It is expected that slow-scan television transmissions of such program material will also be possible as part of the SYNCART program.

It is also anticipated that experiments with SYNCART will lead to the development, by amateurs, of increasingly simple ground terminal equipment for these satellite applications. Radio amateurs have a history for devising, at their own initiative, innovative methods of producing simple equipment at low cost, generally using readily available components.

1.7 Space-to-Space Amateur Satellite Relay Experiment

The AMSAT-OSCAR-B (A-O-B) amateur satellite, approved for launch by NASA, represents the first of what is hoped will be a series of similar, low-orbit amateur communications satellites having design lifetimes in excess of one year. The input and output frequencies of communications repeaters aboard these satellites is expected to permit a space-to-space relay experiment using the SYNCART link. The power output of the A-O-B and SYNCART repeaters is sufficient to relay narrowband teletype and telegraphy signals in both directions.

The presence of space-to-space relayed transmissions should he readily identifiable by observing Doppler shift, not otherwise expected over the SYNCART link. During the space-to-space relay experiment it will be of interest to determine whether the absence of ionospheric effects is identifiable and whether sea-reflected multipath effects are significant. These phenomena should be observable by measuring the fading rates and depths of the received signals.

2. SYNCART DESCRIPTION

SYNCART is a multi-channel, low power-consumption linear repeater designed for operation in the amateur radio service in the international portions of the amateur two meter and seventy centimeter bands. The repeater will be designed to interface with the ATS-G Applications Technology Satellite according to specifications to be developed jointly with the NASA ATS Project Office. One prototype and flight hardware will be furnished to NASA by AMSAT on a non-funded basis. The repeater will be designed to consume less than twenty watts of prime power from the ATS-G spacecraft, and is intended to be available for continuous operation by amateur users, except during eclipse or other such times when demands on the ATS-G power subsystem by other experiments may require it to be operated in a reduced-power mode or to be shut off temporarily.

The repeater will be designed to operate with input (uplink) signals between 145.75 and 145.95 MHz (i.e., with a 200 kHz bandwidth), and will retransmit these signals between 435.1 and 435.3 MHz with an RF power output of 20 watts PEP, 5 watts average. This repeater RF output power level will be maintained by an automatic gain control circuit which will be controllable from the ground to also provide a low-power mode.

The SYNCART repeater will be controlled by ground command through the regular ATS-G NASA command system. It is expected that no more than eight command functions and six telemetry functions will be required to control and monitor the SYNCART experiment.

The thirty-foot aperture of the parabolic reflector planned for ATS-G should prove nearly ideal for SYNCART, providing gains of approximately 18 dBi for both the up- and downlinks, and providing full earth disc coverage. The resultant EIRP should be in the neighborhood of 30 dBW (one kilowatt), yielding signal strengths on the ground comparable to those achieved with the VHF repeaters on the ATS-1 and ATS-3 Applications Technology Satellites.

The SYNCART linear repeater will employ the "envelope elimination and restoration" already developed for one of the AMSAT-OSCAR-B repeaters, to achieve linear operation at high efficiency with Class "C" amplifier stages. The repeater will be designed to operate with any method of modulation within its 200 kHz bandwidth, and to handle 20 to 50 simultaneous single-sideband, telegraphy or teletype users. A ground station EIRP of 1000 watts should produce full power output from the SYNCART repeater (30 dBW peak EIRP). This should result in a signal-to-noise ratio of 30 dB in a ground receiver, assuming a 4 dB noise figure, a 13 dBi antenna gain and a 2 kHz receiving bandwidth. Further details on the repeater design are furnished in Appendix A to this proposal.

The SYNCART package will include a low-power edge-of-band beacon which will be keyed in Morse code with messages stored by a "CODESTORE" message storage unit, also to be provided. The "CODESTORE" unit will be similar to hardware developed for AMSAT-OSCAR-B, and will permit bulletins and messages to be stored in the satellite for periodic retransmission in Morse code.

It is envisioned that the SYNCART repeater will be able to use antenna feeds planned for the ATS-G 136/148 MHz telemetry and command systems for receiving the 146 MHz uplink signals. A separate feed will be required for the 435 MHz SYNCART transmitting antenna, and it is expected that circularly polarized fourteen-inch crossed dipoles will be suitable for this purpose. These dipoles, when placed symmetrically about the focus of the ATS-G 30-foot reflector, should under-illuminate the reflector so as to produce an antenna gain of 18 dBi for full earth disc coverage.

3. PACKAGING AND SPACECRAFT INTERFACE

It is estimated that the SYNCART experiment package can be constructed by AMSAT in compliance with Goddard Space Flight Center Specification S-320-ATS-2B, and to properly fit within one 7" by 8" by 4.5" cavity in the primary equipment module. Based on experience with the repeaters developed for AMSAT-OSCAR-B, total weight is estimated to be approximately 7.5 pounds.

Efforts will he made to ensure that the SYNCART hardware, and particularly the antenna feeds, will have minimum affect on the ATS-G spacecraft and the other experiments. It is particularly desirable that RFI/EMC specifications be agreed upon early in the development of the hardware to assure that there will be no harmful interference to or from the other experiments and subsystems on the ATS-G spacecraft.

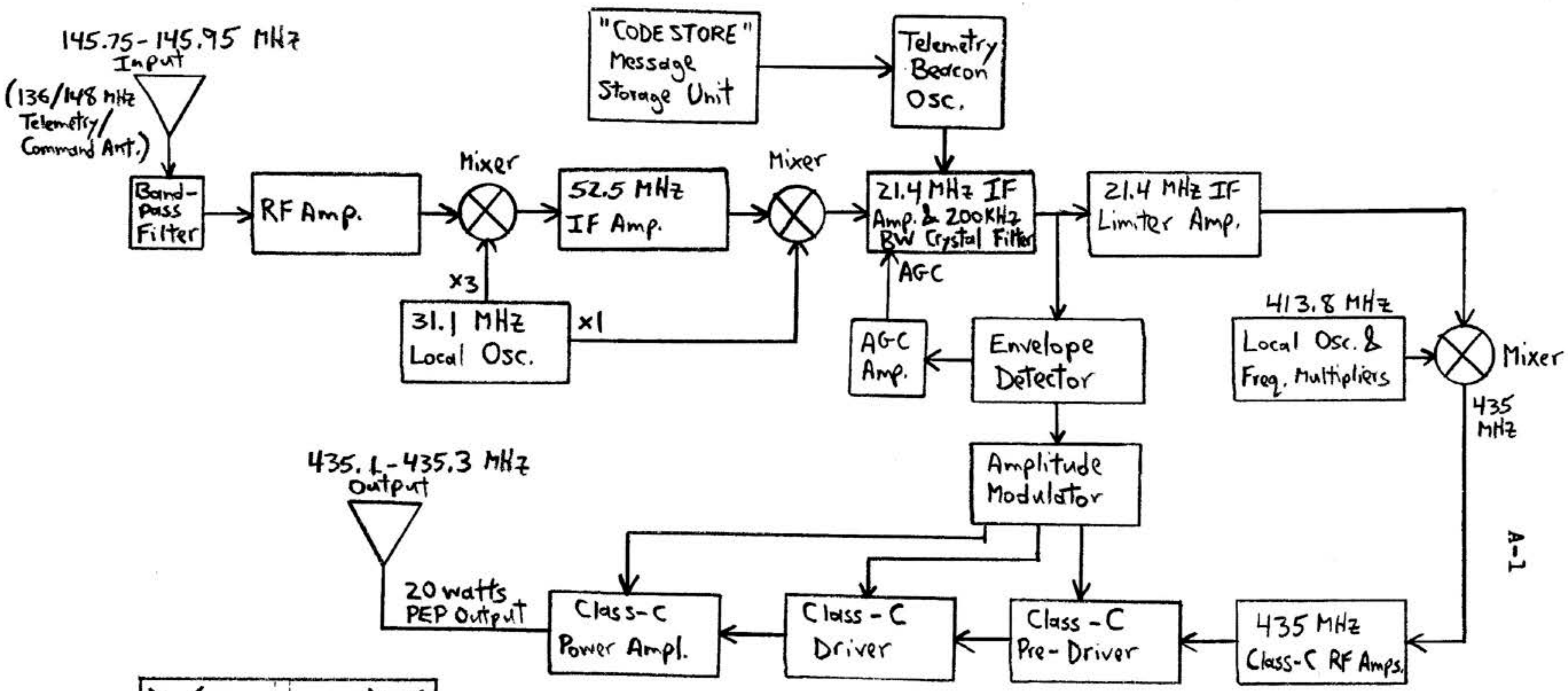
4. PROJECT MANAGEMENT TIME SCHEDULE, AND REPORTING

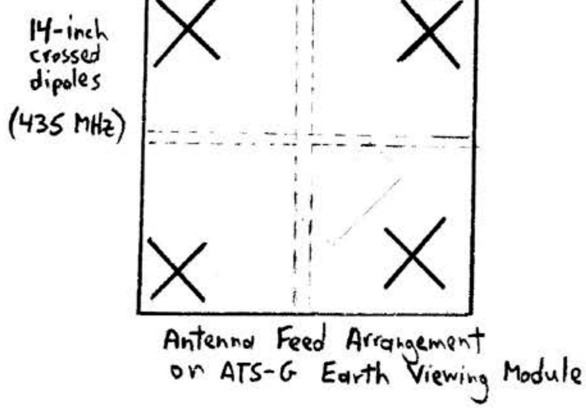
AMSAT will be responsible for furnishing NASA with the flight hardware on a non-funded basis, and will provide the fabrication, functional testing and post-launch data analysis. The project time schedule will be arranged jointly with a NASA technical monitor designated by the ATS Project Office. It is expected that the prototype hardware can be ready for environmental tests 18 months after go-ahead, and that the flight unit can he delivered one year later.

Upon completion of the SYNCART experiments, AMSAT will provide NASA with interim and final reports detailing the results achieved in the SYNCART program. These reports will be coordinated with NASA to ensure that the results are presented in a form of maximum usefulness to NASA and the scientific community. It is anticipated that the results will also be published In IEEE and other technical journals, as well as in the amateur literature.

APPENDIX A

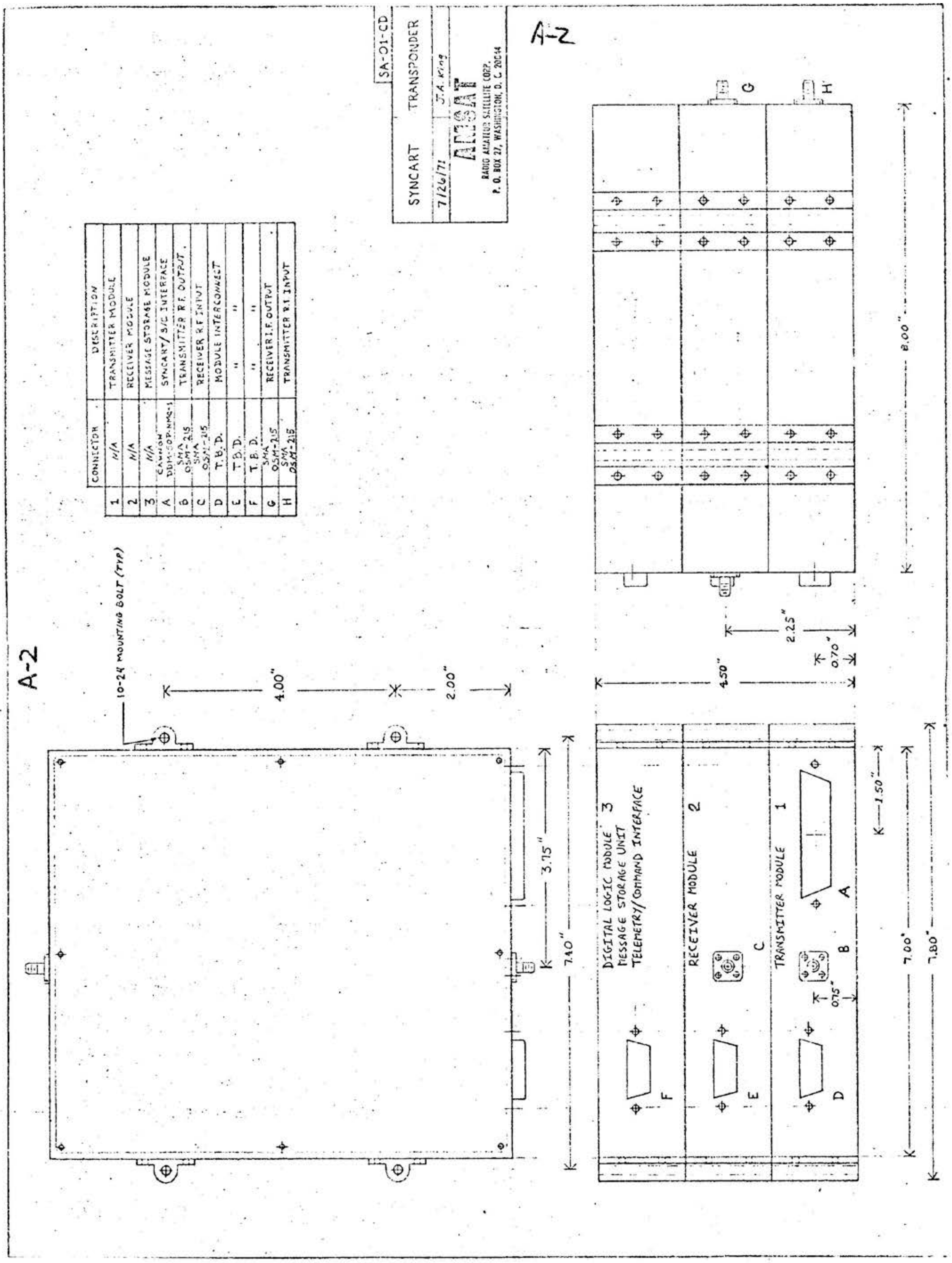
A-1





ATS-G SYNCART REPEATER BLOCK DIAGRAM

July 26, 1971


A-2
A-2
10-24 MOUNTING BOLT (TYP)
4.00"
2.00"
3.75"
7.40"
4.50"
2.25"
0.70"
0.75"
1.50"
7.00"
7.80"
8.00"
DIGITAL LOGIC MODULE 3
MESSAGE STORAGE UNIT
TELEMETRY/COMMAND INTERFACE
RECEIVER MODULE 2
TRANSMITTER MODULE 1
A
B
C
D
E
F
G
H
CONNECTOR | DESCRIPTION
1 N/A TRANSMITTER MODULE
2 N/A RECEIVER MODULE
3 N/A MESSAGE STORAGE MODULE
A CANNON DDM-50P-NMS-1 SYNCART/S/C INTERFACE
B SMA OSM-215 TRANSMITTER R.F. OUTPUT
C SMA OSM-215 RECEIVER R.F INPUT
D T.B.D. MODULE INTERCONNECT
E T.B.D. " "
F T.B.D. " "
G SMA OSM-215 RECEIVER I.F. OUTPUT
H SMA OSM-215 TRANSMITTER R.F. INPUT
SA-01-CD
SYNCART TRANSPONDER
7/26/71
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SYNCART PHYSICAL INTERFACE

- MOUNTING VIA FOUR 10-24 BOLTS
- T&C INTERFACE VIA SINGLE 50PIN CANNON (GOLDEN D) CONNECTOR
- R.F. INTERFACE VIA TWO SMA CONNECTORS
- THERMAL DISSIPATION ACHIEVED VIA FLAT MACHINED BOTTOM SURFACE OF TRANSMITTER MODULE. ADEQUATE THERMAL CONDUCTIVITY MUST BE ESTABLISHED.
- EXTERNAL SURFACES OF TRANSPONDER ANODIZED OR PAINTED BLACK.
- TRANSPONDER REQUIRES 252 CUBIC IN. VOLUME.
- ESTIMATED WEIGHT OF TRANSPONDER IS 7.5 LBS.

SYNCART POWER CONSUMPTION

- TRANSPONDER REQUIRES 20W AVERAGE POWER (UNDER MAX. USER LOADING) IN HIGH POWER MODE.
- TRANSPONDER REQUIRES 5W AVERAGE POWER (UNDER MAX. USER LOADING) IN LOW POWER MODE.
- 20W PEP R.F. OUTPUT – 5W AVERAGE IN HIGH POWER MODE.
- 5W PEP R.F. OUTPUT – 1.25W AVERAGE IN LOW POWER MODE.
- POWER FLUCTUATIONS WILL BE LESS THAN ±3W IN HIGH POWER MODE (USING ENERGY STORAGE TECHNIQUES).
- NOT MORE THAN 10.0W OF POWER WILL BE DISSIPATED HEAT.
- IDLING POWER WILL BE LESS THAN 5 WATTS (NO UPLINK SIGNALS).

SYNCART TELEMETRY PARAMETERS

TELEMETRY LIST

1. P.A. Temperature
2. High power Modulator Temperature
3. Transponder Current Drain
4. P.A. #1 Power Output
5. P.A. #2 Power Output
6. Receiver AGC Voltage

MINOR FRAME PARAMETERS

(1/3 SEC.)

1. Receiver AGC Voltage
2. Transponder Current Drain

MAJOR FRAME PARAMETERS

(1/48 SEC.)

1. P.A. Temperature
2. Modulator Temperature
3. P.A. #1 Power Output
4. P.A. #2 Power Output

SYNCART COMMAND LIST

1. (reserved)
2. (reserved)
3. SYNCART Transponder to High Power Mode
4. SYNCART Transponder to Low Power Mode
5. Enable P.A. #1 / Disable P.A. #2
6. Enable P.A. #2 / Disable P.A. #1
7. Message Storage Unit to PROGRAM Mode

SYNCART ANTENNA REQUIREMENTS

UPLINK:

- MAXIMUM GAIN OF REFLECTOR AT UPLINK FREQ. (12 dBi)
- CIRCULARLY POLARIZED P.F.F. PREFERRED
- MINIMUM FEED GAIN OF -2dB (dipole) AT 145.95 MHz
  (±1.0 dB OVER 200 kHz PASSBAND).
- 3 dB FILTER OR DIPLEXER LOSS (MAXIMUM) IS ACCEPTABLE

DOWNLINK:

- CIRCULARLY POLARIZED P.F.F.
- MINIMUM BEAMWIDTH OF 15 DEGREES (21 dBi GAIN)
  (Suggest that this be accomplished by under-illuminating the reflector).
- MAXIMUM BEAMWIDTH OF 28 DEGREES (15 dBi GAIN)

TRANSPONDER OUTPUT SPURIOUS EMISSIONS

- SECOND HARMONIC OF TRANSPONDER PASSBAND >-50 dB*
- THIRD HARMONIC OF TRANSPONDER PASSBAND >-60 dB*
- HIGHER HARMONICS OF TRANSPONDER PASSBAND >-60 dB*
- L.O.s AND OTHER SPURIOUS >-60 dB*

* Relative to 20 Watts

TRANSPONDER INPUT FILTER CHARACTERISTICS