A DEPLOYABLE .015 INCH DIAMETER WIRE ANTENNA

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ABSTRACT

This mechanism has been developed to dispense a small diameter wire which serves as a receiving antenna for electric field measurements on an Earth orbiting satellite. The antenna is deployed radially from a spinning satellite. A brushless DC motor drives a storage spool to dispense the wire at a controlled rate. Centrifugal force, acting on a mass attached to the end of the wire, keeps the wire in the radial position. The mechanism design, testing and performance characteristics are discussed. Finally, operational data of the mechanism while in orbit is presented.

INTRODUCTION

The International Sun Earth Explorer (ISEE)-A is a spin stabilized satellite in a 22 Earth radii apogee by 278 KM perigee Earth orbit. One of its missions is to study the characteristics of the electric fields in this region of space. On board are two Deployable Wire Antennas, positioned 180° apart, which function as receiving antennas for these electric field measurements.

Approximately one week after launch, both antennas were successfully deployed to their full length. Each antenna is a beryllium-copper stranded wire conductor measuring 106.7 meters (350 feet) in length. The outboard 36 meters is bare wire while the remaining 70.7 meters has an insulation coating of Stilan*. The mechanism is both extendible and retractable and is driven by a brushless DC motor using Hall effect commutation. The mechanism weight is 2.5 Kg (5.5 pounds) and occupies an envelope of 25 cm x 14 cm x 18.5 cm (9.88 in. x 5.5 in. x 7.3 in.).

Because the antennas are deployed radially, they act as a despin system. Therefore, the mechanism must be capable of intermittent starts and stops so that the satellite can be spun-up when required. In addition, in order to deploy the long wire (106.7 meters)

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at the desired rate of 3 cm per second (.1 feet per second) the motor had to be capable of long running times in a vacuum. The total deployment time is approximately one hour.

DESIGN REQUIREMENTS

In order to gather meaningful low frequency data from the electric fields in space it is necessary to deploy a system of receiving antennas at a great distance from the spacecraft to preclude interference from on-board equipment. The following requirements were imposed by either experimental needs or spacecraft capabilities.

MECHANICAL

- Extendible and retractable
- No extension under vibration
- Positive stop at full extension
- Self-lubricating bearings
- 25 cycle life capability
- Non-magnetic materials wherever possible

ELECTRICAL

- 14 watts peak power
- Cutoff switches at full extension and retraction
- Deployed length indicator
- Motor life cycle of 100 continuous hours' operation between -15° C and +40° C

ANTENNA CHARACTERISTICS

- 106.7 meters (350 ft) long
- 30pf to case ground deployed over 100 Hz to 200KHz
- Non-magnetic wire
- 150 ohms resistance
- Insulation on inboard 70.7 meters (235 ft)

MECHANISM DESCRIPTION

The mechanism consists of two fiberglass side plates separated by aluminum posts. These side plates also support aluminum shafts to which are mounted the mechanism drive components. In the extend mode a motor, through a gear train, drives a spool containing the wire antenna element. As the wire is unwound from the spool it passes around a drive roller, under a backup roller and through an exit guide assembly. Centrifugal force acting on a tip mass attached to the end of the wire, maintains tension on where to keep it straight. The drive roller is also driven by the gear train but an integral slip clutch allows it to be driven at a slightly faster rate. This arrangement maintains a slight tension on the wire between the drive roller and the storage spool. This prevents any slack in the wire which could result in backwrapping, mistracking or looping of loose wire. The moving wire drives the backup rollers which is geared to a potentiometer to give an electrical readout of deployed length. At full extension, a microswitch is tripped which cuts power to the motor. In the event of switch failure, a positive mechanical stop is incorporated. In the retract mode, the spool is again driven to pull in the wire. The drive roller is on a one-way clutch and in this mode it is free-running. The centrifugal force acting on the wire provides the tension required to ensure even wrapping on the storage spool. At full retraction, microswitches again cut power to the motor.

To meet the weight requirements, all large gears were drilled out; alternate gears were dry-lubed using Electrofilm #2306. Aluminum was used wherever possible for weight considerations and to keep the unit magnetically clean. The bearings used were beryllium-copper with self-lubricating retainers. (A drag brake was designed into the system to prevent deployment of the antenna during vibration.)

The motor is a 28-volt DC brushless motor using the Hall effect electronics for commutation; it has an integral gearhead with a 17.76:1 reduction ratio. The motor/gearhead housing was machined steel for magnetic cleanliness purposes. The motor/gearhead was required to operate, under load, for 100 continuous hours under a thermal vacuum environment of 10^{-6} torr between -15° C and +40° C while being cycled in the forward and reverse direction without any failure or abnormal operating parameters.

The antenna element is a conductor of seven strands of wire. For magnetic cleanliness, the conductor material chosen was beryllium-copper. The base conductor is .015 inches in diameter and .019 inches in diameter over the insulation. The breaking strength of the wire is 23 pounds, which is more than three times the maximum flight induced loads. The full length of 106.7 meters (350 ft) is partially base (outboard 35 meters) and partially insulated. The insulation is Stilan, a product of Raychem Corporation.

TEST RESULTS

A thorough qualification and acceptance test program was completed on the protoflight and flight models, respectively. The life cycle test on the protoflight model was performed to verify the ability of all components to withstand repeated operation without failure. At the conclusion of the tests, the unit was disassembled and all parts checked for damage or signs of excessive wear. The only parts that showed wear although not excessive were the gear on the drive motor, a gear which drives the spool and the one-way clutch housings. Reviews of the parts and the amount of wear were initialed. Results were that the wear, after 25 cycles, was not significant enough to warrant design changes since the flight units would only get about 5 cycles at most prior to flight.

The qualification of the motor was one of the most successful tests of the program. The 100 continuous hours cycle test showed no dropoff in performance. The disassembly after resulted in no refurbishment of any part. The motor was reassembled and installed in the protoflight mechanism. This same motor went through all tests of the protoflight without any problems and is still operating without specifications. The total running time on this motor is now in excess of 175 hours.

Another test result which was well within specifications is the power required for the mechanism. The allotted power was 14 watts. Test result proved that the actual power required was 7 watts maximum with only about 4.5 watts nominal. Under both ambient and thermal vacuum conditions the motor case showed only a 10° F rise in temperature during an operational time of approximately one hour. This allowed the elimination of the motor heat sink in future mechanisms. (Test results and corresponding specifications are presented in Table 1.)

PROBLEM AREAS

There were a few problem areas which became evident during testing. The first concerned the drag brake setting. Under initial vibration the brake was set to provide no drag on the mechanism. During vibration the wire self-deployed approximately 1/2 inch. The brake was then adjusted until no deployment was noted. At this setting the motor current was observed and this was the criteria used for each mechanism. Further testing verified that this was a feasible method to set the drag. It did, however, put a small additional current drain but the power required was still well within specification. In addition, as the mechanism runs, the drag surface wears and current drain is reduced.

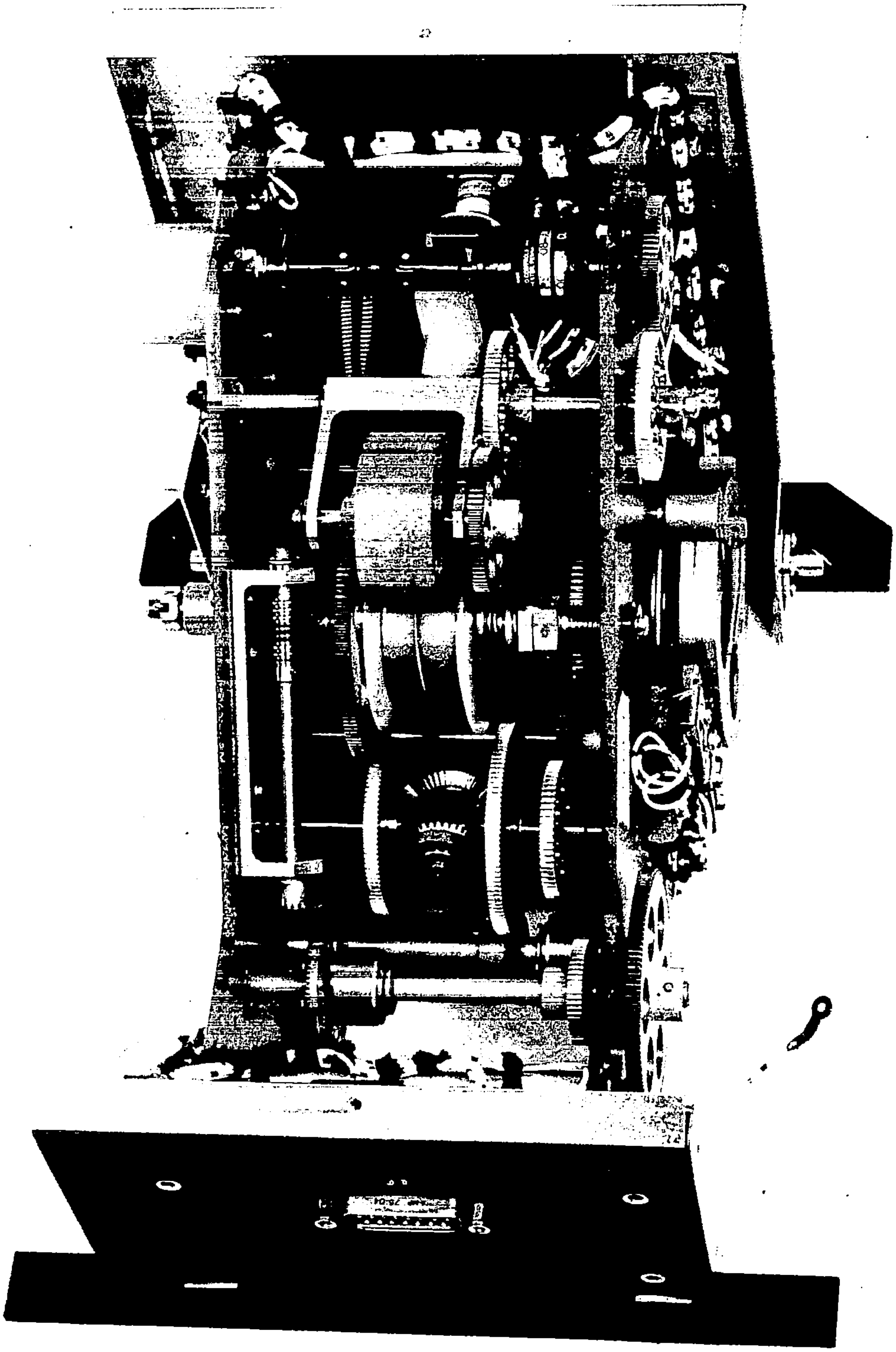
The second problem arose during the thermal vacuum testing of the first flight unit. One requirement during all tests is to monitor continuity of the antenna. This was accomplished by applying a voltage to the wire. During operation, a loop formed on the spool and as the spool was turning the loop of wire touched a shaft and shorted causing the wire to burn through. Although the failure occurred during thermal vacuum testing, it was evident that the problem was not associated with this environment. Continuity was then checked by means of an ohm-meter and no further problems arose. The looping was caused by random wrapping of wire on the spool whereby a large loop could form. It was then decided to level wind on each retraction when possible to avoid this problem.

The third failure also occurred under thermal vacuum but again the environment was not at fault. This was evident by a complete loss of power to the mechanism. Upon opening the chamber, investigation revealed a loose piece of solder in the test harness connector which, under the right conditions, could short out the power supply. This was then corrected and testing completed.

The last problem occurred during deployment in orbit. The potentiometer output indicated full deployment but the motor did not cut off. The deployment was stopped and an investigation begun into probable causes. The antenna was sending data. The spacecraft spin rate indicated that the wire was not fully deployed. It was finally determined that the telemetry supply voltage from the spacecraft was unregulated and was probably supplying 12.45 to 12.6 volts rather than the 12.0 volts used for calibration. The mechanisms were restarted and allowed to run to automatic cutoff. When this was done both mechanisms cut off within 1/2 meter of the recalculated values.

TABLE 1

TEST		DATA	UNITS	ENVIRONMENT
Operational		Actual - (Spec)		Ambient
a) Rate	Ext	1.8-2.7 (1.5-427)	cm/sec	
	Ret	2.4-3.0 (1.5-4.27)		
b) Motor Power	Ext	6.9-7.8 (14.0)	Watts	
	Ret	4.2-4.5 (14.0)		
c) Pot. Output	Ext	Per pre-calibration		
	Ret	Per pre-calibration		
d) Continuity	Ext	Yes		
	Ret	Yes		
e) Auto Shutoff	Ext	Yes		
	Ret	Yes (Manual Actuation due to test fixture)		
Vibration		All axis passed		Ambient
Spin		Extent 2 meters @ 60 RPM Retract 2 meters @ 60 RPM		
Thermal Vacuum				
a) Rate	Ext	2.4	cm/sec	-20° C
	Ret	2.4		-20° C
	Ext	2.4		+20° C
	Ret	2.4		+20° C
	Ext	2.1		+40° C
	Ret	3.4		+40° C
b) Power	Ext	8.0	Watts	-20° C
	Ret	5.0		-20° C
	Ext	8.0		+20° C
	Ret	4.8	+20° C	
	Ext	7.0		+40° C
	Ret	4.8		+40° C



Antenna deployment mechanism.