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LOW LOSS, FLEXIBLE, LIGHTWEIGHT CORPORATE RF FEED SYSTEM FOR SAR ANTENNA APPLICATION

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SUMMARY

Mechanical and electrical efficiency constraints imposed by the SEASAT-A Synthetic Aperture Radar (SAR) Antenna posed difficult design problems. After consideration of available standard cable and waveguide systems, it was determined that an optimum design could be obtained from a suspended substrate [1] RF feed system. Size and mechanical flexibility constraints forced the design of a flexible, suspended substrate section capable of 180-degree flexure. Original design goal for insertion loss over power division was 1 dB; measured results indicated 0.6 dB maximum across the band. Multipactor testing of system components indicated system breakdown capability in excess of 4 kW compared to a specification input maximum of 1500 W.

1.0 SEASAT SAR STRUCTURE

The basic SEASAT SAR structure is depicted in Figure 1 in an exploded view showing the essential elements. The expandable support structure provides a locking truss capable of holding the eight, 2.16m x 1.34m, lightweight, honeycomb, microstrip antenna panels flat to within 0.63cm (0.25 inch) over the entire 10.75m length. When folded, the panels are separated by 3.43cm (1.35 inches) to provide an overall package volume of 2.16m x 1.34m x 25.4cm exclusive of the tripod structure. To fit the confines of the closed package, the RF feed system lines were constrained to 1.4cm (0.55 inch) in height to allow for thermal blanketing. When the SAR is folded, the connecting RF lines between panels must be capable of 180-degree flexure without any performance degradation for at least 10 cycles. Actual tests provided confidence in performance by flexing over 200 cycles without degradation.

1.1 MICROWAVE FEED SYSTEM FORMATS

During the initial stages of fabrication, approaches using commercial components were considered and tradeoff estimations compared. The tradeoff comparison given in Table 1 was used as the basis for deciding to design a suspended substrate. Four

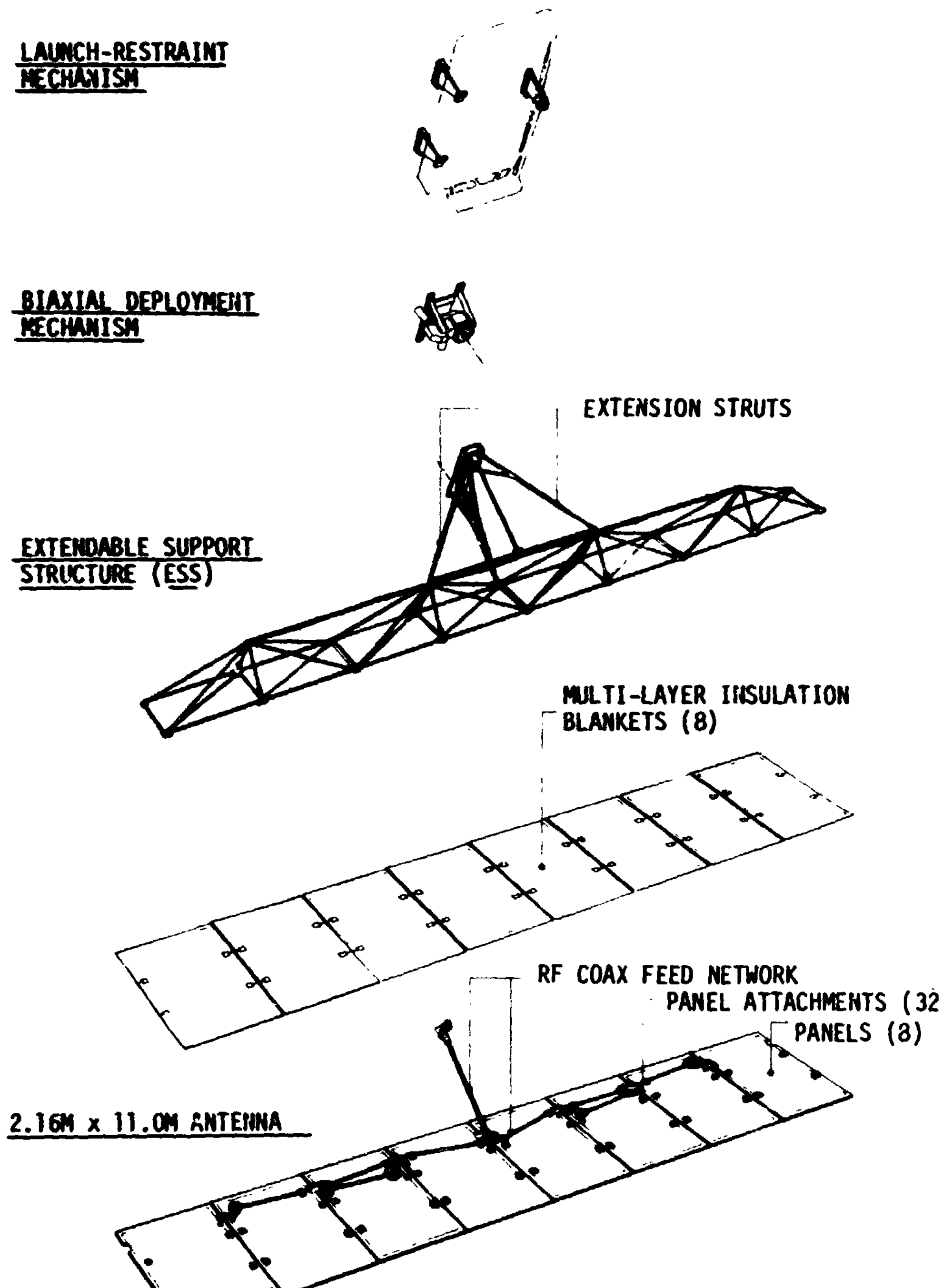

FIGURE 1

BASIC SEASAT LAYOUT

TABLE 1

MICROWAVE FEED SYSTEM TRADEOFFS

	COAX SYSTEMS						
	2,2,2 CORPORATE	2,4 BI-PUS	8 OCTOPUS	W/ROTARY JOINT	UNSHIELDED MICROSTRIP	SUSPENDED SUBSTRATE	REDUCED HEIGHT WAVEGUIDE
ELECTRICAL							
Loss Budget	1.15	1.10	.95	.85	1.70	.55	.90
Phase Sensitivity (PPM/°C)	Good	Good	Good	Good	Good	Good	Good
Phase Stability	Fair	Fair	Poor	Good	Good	Good	Good
Multipactor Spacing	Poor	Poor	Poor		Excellent	Excellent	Excellent
Phase Length Trimability	Fair	Fair	Fair	Fair	Good	Good	Good
Temp. Insertion Loss Sens.	Poor	Poor	Fair	Good	Excellent	Excellent	Excellent
Transition Loss Level	Poor	Fair	Good	Good	Excellent	Excellent	Excellent
MECHANICAL							
Complexity	Poor	Poor	Poor	Fair	Good	Good	Poor
Hinge Torque	Poor	Poor	Fair	Good	Good	Good	Fair
Packaging & ESS Compatibility	Poor	Poor	Fair	Fair	Excellent	Good	Fair
Weight (lb)	25	25	20	20	5	8	8
Thermal Expansion Loading	Poor	Poor	Poor	Fair	Excellent	Good	Good
Vibration Loading	Poor	Poor	Poor	Fair	Excellent	Good	Good
Vacuum Venting	Fair	Fair	Fair	Fair	Excellent	Excellent	Excellent
Mechanical Assembly							
THERMAL							
Power Dissipation	Poor	Poor	Poor	Fair	Good	Good	Excellent
Thermal Cycling Distortion	Poor	Poor	Poor	Fair	Good	Good	Excellent
Predicted RFM Temp. Profile	Poor	Poor	Fair	Good	Good	Good	Good
PROGRAM							
Mechanical Design Risk	Fair	Fair	Poor	Fair	Good	Good	Fair
Electrical Design Risk	Poor	Fair	Good	Good	Good	Excellent	Excellent
Material Availability	Poor	Poor	Poor	Poor	Excellent	Good	Good
Impact on Mechanical Layout	Poor	Poor	Poor	Poor	Excellent	Good	Fair
Impact on Thermal Layout	Good	Fair	Poor	Good	Excellent	Good	Fair

variations of coaxial feed systems were considered with different power split configurations (i.e., 2,2,2 giving 3 levels of 3 dB power splits) along with a microstrip feed system on the panel, and a reduced height waveguide. Within the mechanical, electrical and thermal constraints derived, the suspended substrate system appeared to be the optimal solution.

1.2 FEED SYSTEM REQUIREMENTS

Analysis of system requirements imposed stringent insertion loss and phase error requirements along with difficult mechanical specifications. The required low bellows torque to minimize expandable support system stress was met with considerable margin. Comparison of measured performance with required minimum specification, predicted performance, and measured results shows good agreement (Table 2). The power division tolerance was exceeded during test but not corrected because analysis of effect on antenna performance was shown negligible even with ± 2 dB amplitude deviation. Power balance within original specification could be achieved by balancing the output terminal mismatches with tunable output connectors.

1.3 FEED SYSTEM LAYOUT

The system layout is shown (Figure 2) with the power divider sections, bellows interconnection points (both valley and apex positions), and the 0.95cm (3/8 inch) air-articulated coaxial cables feeding the microstrip panels. The flexible input section ends in a TNC female connector interface specified by the customer; the outputs are TNC male.

Coaxial cable output lines were chosen to allow bending underneath the truss members to avoid mechanical interference when the SAR is folded.

1.4 MULTIPACTOR CONSIDERATIONS AND TEST RESULTS

Multipactor in high vacuum between electrodes with an RF potential between is a function of the peak field potential, the electrode spacing, and the transit time of the free electrons affected by the RF potential. The sinusoidally varying electric field accelerates the free electrons between electrodes in response to the field to cause collision with the electrodes and subsequent secondary emission. Since the phenomena is transit time induced, regions of multipactor occur dependent on the RF field period and electrode spacing. Thus, very high fields with small spacing relative to a half cycle may not lead to sustained multipactor. The best general rule for design use

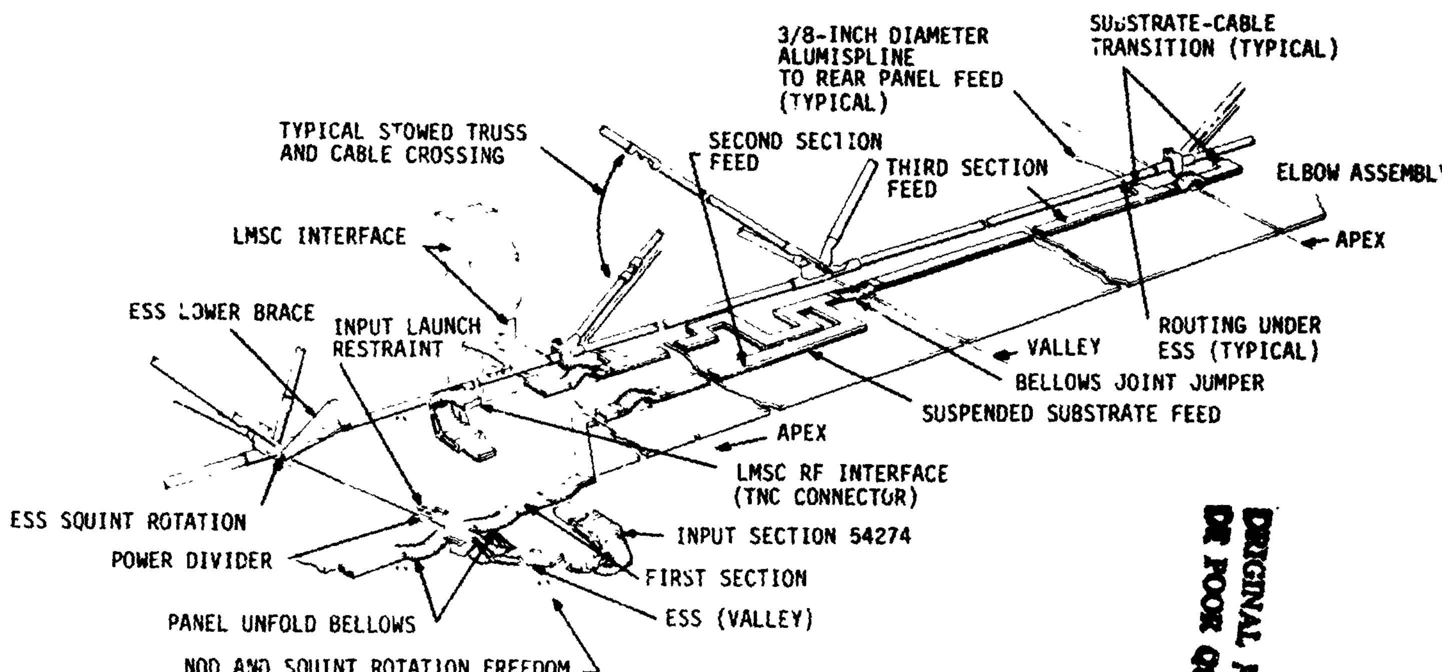

FIGURE 2

SEASAT FEED SYSTEM LAYOUT

TABLE 2

SUSPENDED SUBSYSTEM FEED SYSTEM - FUNCTIONAL REQUIREMENTS

PARAMETER	REQUIREMENT	EXPECTED PERF.	MEASURED PERF.
Insertion Loss—Input Port to Center of Panel	0.9 dB	0.84 dB	.60 dB
Input VSWR Rel. 50Ω			
With Panels Installed	1.5:1	1.5:1	1.5:1
With Ports @ 50Ω	1.3:1	1.2:1	1.2:1
Power Division to Ports	-9 ± 0.5 dB	-9 ± 0.5 dB	-9 ± 1.0 dB
Bandwidth (Basis for all Elect. Perf.)	±11 MHz	±11 MHz	±11 MHz
Center Frequency	1275 MHz	1275 MHz	1275 MHz
Input Power - Peak @ D.S. = .045	1500 W	OK	OK
Average	90 W		
Phase Error (Between Panel Ports)	±5°	±5°	±4°
Weight	15 lbs	12 lbs	
Input Connector Type	TNC Female Recep.	OK	OK
Panel Termination	3/8" Dia. Alumspline Coax	OK	OK
Temperature Range			
Storage	-30 to +140°F	--	OK
Stowed	-40 to +100°F	--	
Operating	-40 to + 80°F	--	
Test-Stowed-Qual	-66 to +176°F	OK	OK
Test-Operating-S/S Acceptance	-40 to + 80°F	OK	OK
Envelope-Rel. to 1/4" thick Panels			
Back-to-Back Panel Spacing-Stowed	1 3/8" Max	OK	OK
Front-to-Front Panel Spacing-Stowed	1/8" Max	OK	OK
Protrusion Beyond Panel Edges	1" Max	OK	OK
Flex Joint Torque - Per Hinge (Max)	1 ft-lb	1/2 ft-lb	1/30 ft-lb

a.plies a criteria based on the lowest power-spacing combination required to initiate multipactor. This is a function of the geometry used and is illustrated in curves of multipactor regions for air-loaded coax lines and parallel plate configurations [2]. Multipactor can be cured by interposing high quality dielectric provided that care is used in filling the void. This is the case where coax cable is used on spacecraft at levels above the critical multipactor level. Other ionization phenomena can occur if partial gas entrapment occurs in the RF structure; caution should be exercised if dielectric or foam-filled RF systems are employed.

The most useful general formula found for design was provided by Lockheed Aerospace and is given below:

$$P_{BRK} = 6.124 \cdot 10^4 \cdot \frac{Fo^2 \cdot S^2}{Zo} \qquad (1)$$

Fo = operating frequency (GHz)

S = electrode spacing (cm) -3.951•10^5 for S (IN)

Zo = RF structure characteristic impedance (ohm)

This equation has been used on previous multipactor test measurements made on earlier SEASAT-suspended substrate components and appears conservative. Test results are given in Table 3.

Testing is most easily performed by monitoring RF pulse reflected or transmitted power. Reflected power is slightly easier to monitor for breakdown than insertion loss variation but not significantly different. Where power division components are tested, multipactor in the output arms would be more evident in the insertion loss monitoring because of the masking effect of the power division.

2.0 REFERENCES

[1] Dennis L. Gish, "Characteristic Impedance and Phase Velocity of a Dielectric-Supported Air Strip Transmission Line with Sidewalls," IEEE Trans. Vol. MTT-18, No. 3, March 1970.

[2] R. Woo, "Final Report on RF Voltage Breakdown in Coaxial Transmission Lines," Tech. Report 32-1500, Jet Propulsion Laboratory, 1 October 1970.

TABLE 3

MULTIPACTOR TEST RESULTS - DEVELOPMENTAL COMPONENTS

Element	Matched Exp. Pk. Pwr.	Spacing Zo	Lockheed Form Multipactor	JPL (Par Plate) Multipactor	Pwr. Level Applied
Antenna (2 x 2)	1.46w	.250"/25Ω	~ 800w	~1000w	> 2-5w No Bkdwn.
High Power (.625")	750w	.3075"/50Ω	1214w	~2700w	>1500w No Bkdwn.
Hi Po Divider (.625")	750w	.3075"/50Ω	1214w	~2700w	>1200w No Bkdwn.

RF FEED PREDICTED BREAKDOWN LEVELS - BASELINE CONFIGURATION

Element	Matched Exp. Pk. Pwr.	Spacing Zo	Lockheed Form Multipactor	JPL (Par Plate) Multipactor	Pwr. Level Applied
Main Lines (.550")	750w	.270"/36Ω	1300w	~4500w	>4500w No Bkdwn.
Input Line (.625")	1500w	.3075"/36Ω	1687w	~4700w	>4500w No Bkdwn.
Panel Mtd. Bellows (.445")	750w	.220"/36Ω	863w	~4500w	>4500w No Bkdwn.
Input Bellows (.625")	1500w	.3075"/36Ω	1687w	~4700w	>4500w No Bkdwn.