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**Fast, Space qualified 3000V Modulator for a Cloud Profiling Radar  
IVEC 2005**



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A NASA EARTH SYSTEM SCIENCE PATHFINDER MISSION

Cloud Profiling Radar

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## Fast, Space Qualified Modulator

April 20-22, 2005

By

Inam U. Haque, et. al.

**The research described in this (publication or paper) was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.**

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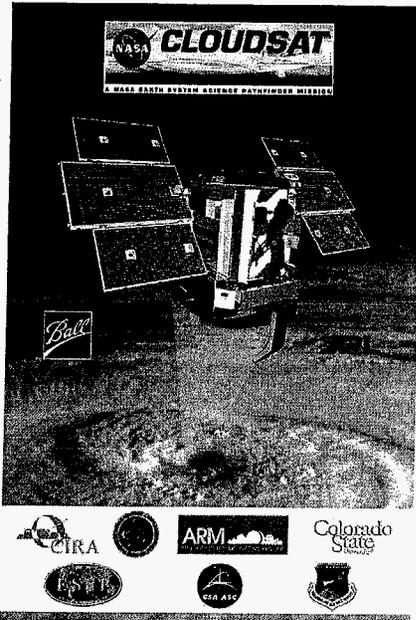


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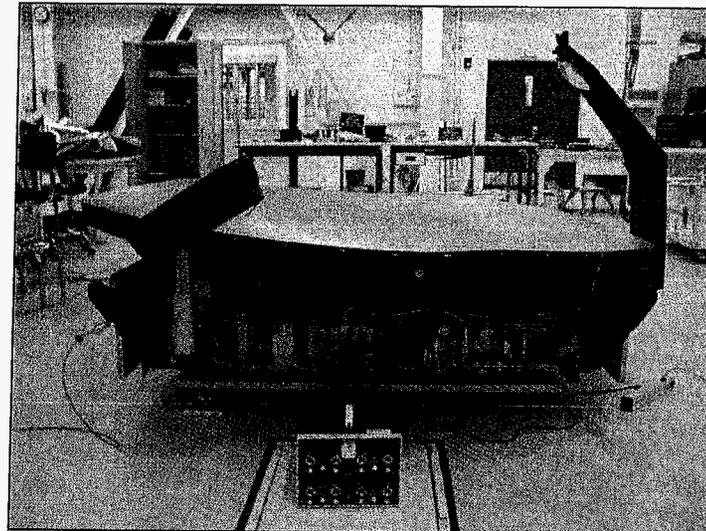
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Launch date June 2005

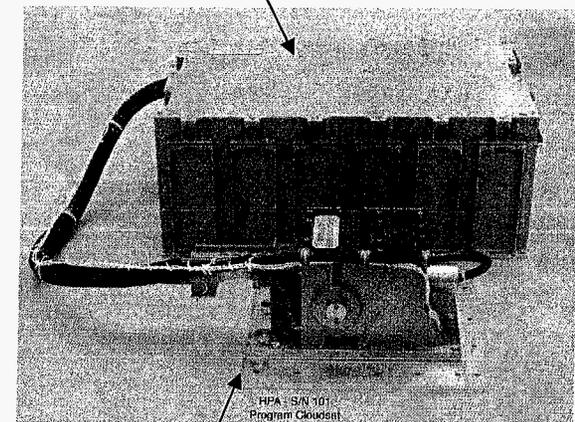


Cloud Profiling Radar  
CPR



HPA

HVPS



EIK

Cloudsat's Cloud Profiling Radar (CPR) delivers a 2 kW, 94GHz RF pulse using an a High Power Amplifier (HPA) consisting of a high voltage power supply (HVPS) and an Extended Interaction Klystron EIK.

Within the HVPS is a Focus Electrode Modulator (FEM) swinging 3000Vwith respect to EIK's Cathode at a slew rate of 15 kV/microsecond.

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**Focus Electrode Modulator (FEM)**

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### **Key Design Drivers:**

- **Switching Speed of 200 nanosecond rise and fall time**
- **Pulse Transformer design for rise and fall times**
- **Voltage Containment (- 20 kV Maximum)**
- **Voltage sharing/Arc Protection**

**Base Design was four stage Push-Pull arrangement. Flight design had to be modified to a 10 stage configuration due to orbit-dictated radiation environment.**



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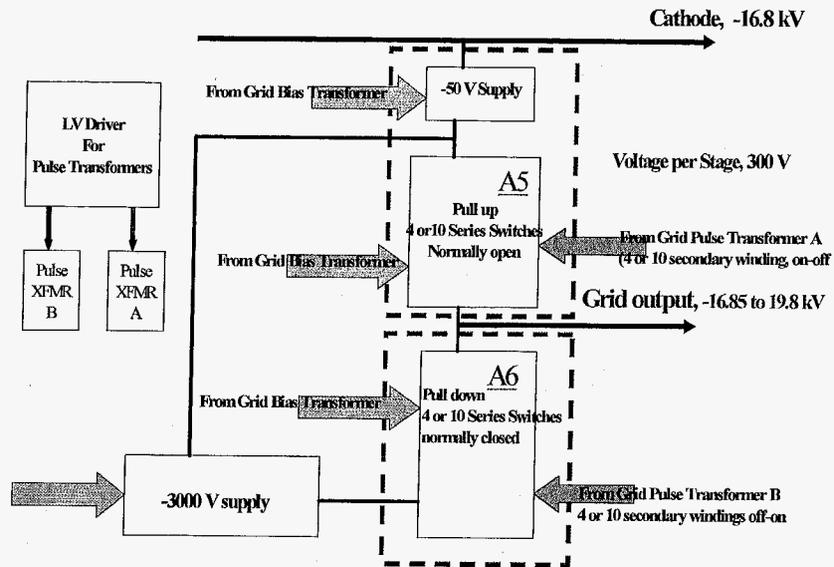
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**Block Diagram, Requirement and BB Data**

**Generic Block Diagram (4 or 10 Stages)**



**EM Test data ( 4 Stage per FEM)**

	Temperature, C	-20	25	55	70	Req.
Grid On	Volts	-53	-34.83	-35.1	-35.4	
Grid cutoff	volts	-2839	-2845	-2807	-2809	
Grid Delay	nano sec	500	525	552	544	
Grid Rise	nano sec	170	147	178	180	200
Grid Storage	nano sec	750	800	854	889	
Grid Fall	nano sec	50	73	72	41	200

**Basic Modulator Requirements :**

**Floats at Cathode voltage of :**

**Focus Electrode in Beam off mode:**

**Focus Electrode in Beam On mode:**

**Rise and fall time:**

**-16.3 kV**

**-3 kV with respect to Cathode**

**-45 V with respect to Cathode Grid**

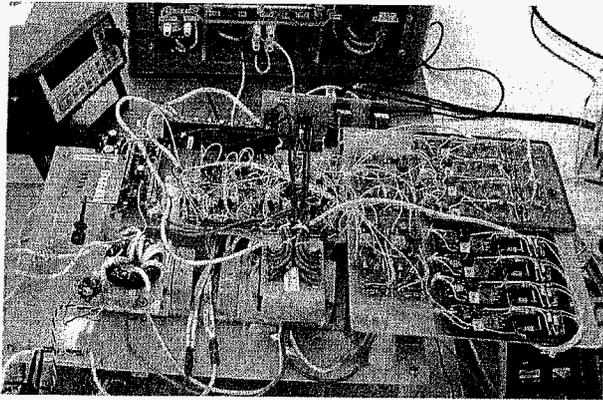
**≤ 200 nanosecond**



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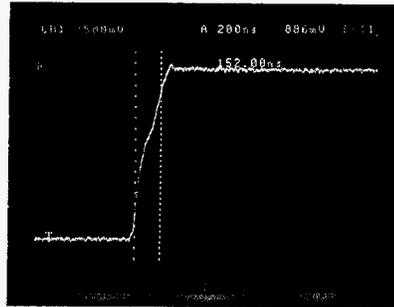
## Breadboard Performance Comparison

The design had to be modified to a 10 stage configuration due to orbit-dictated radiation environment

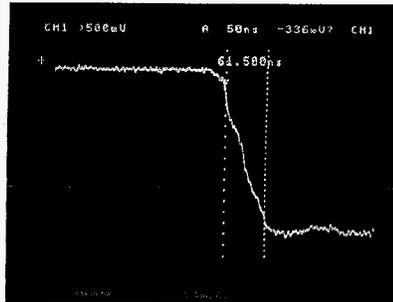


Photograph shows ten stage breadboard.

### Four Stage, BB

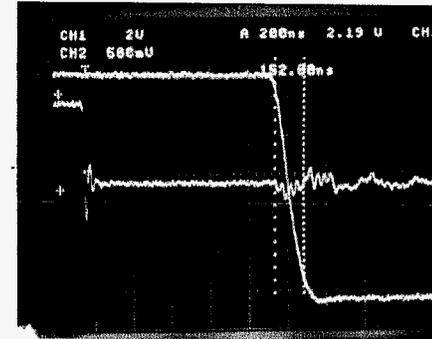
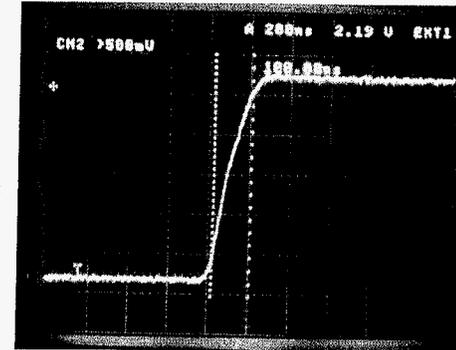


Rise time  
152 Vs 188nsec



Fall time  
66 Vs 152 nsec.

### Ten Stage, BB





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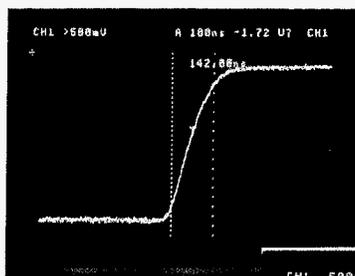


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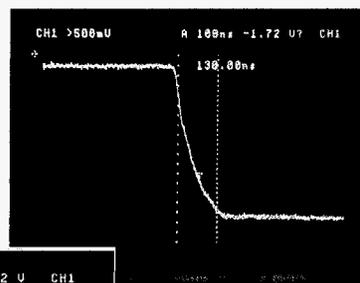
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### EM: FEM's Rise, fall and delay

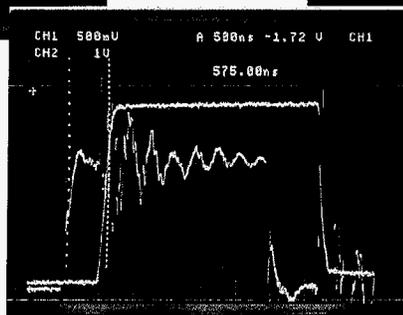


EM Grid Rise time



EM Grid fall time

Pulse width  
3.08 usec



Grid delay-Storage

Performance when mated to EIK

**Note: At JPL, Focus Electrode Modulator (FEM) is also referred to as Grid Modulator**

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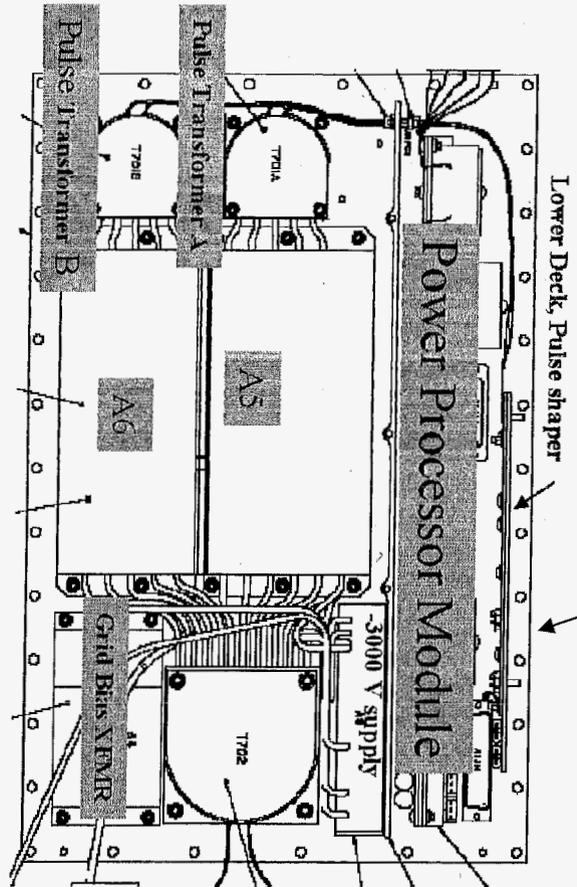


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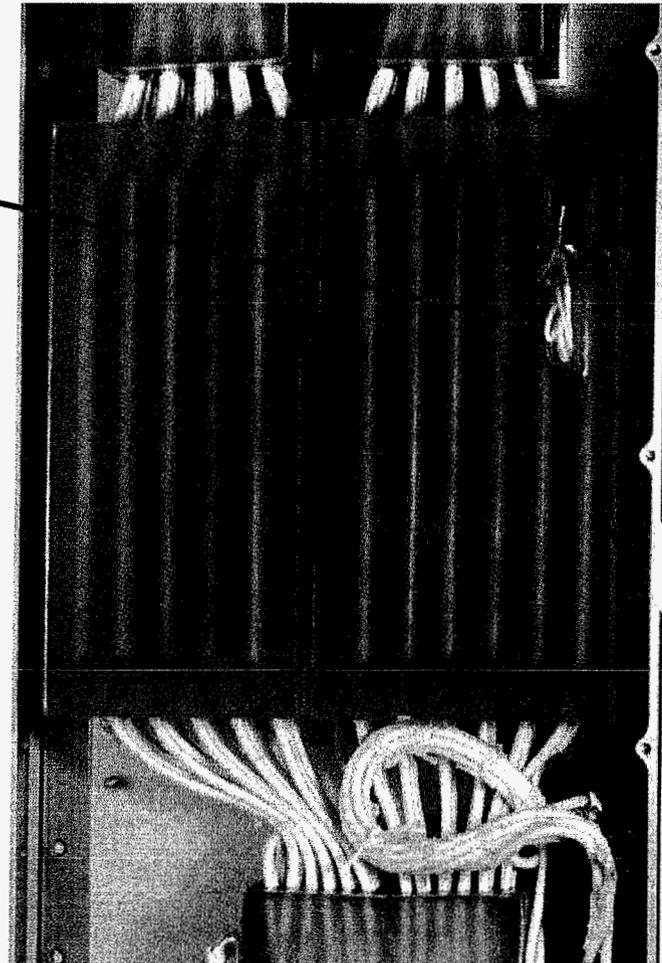
### Flight Configuration of FEM



Basic FEM layout for Flight Units

Select and Test for "On" Voltage  
Over potted after final selection

Mounting Surface



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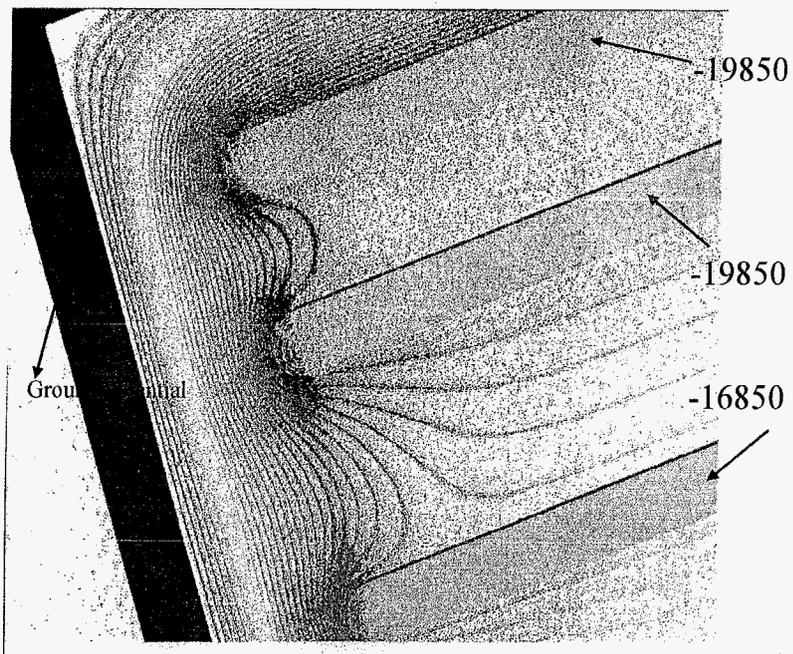
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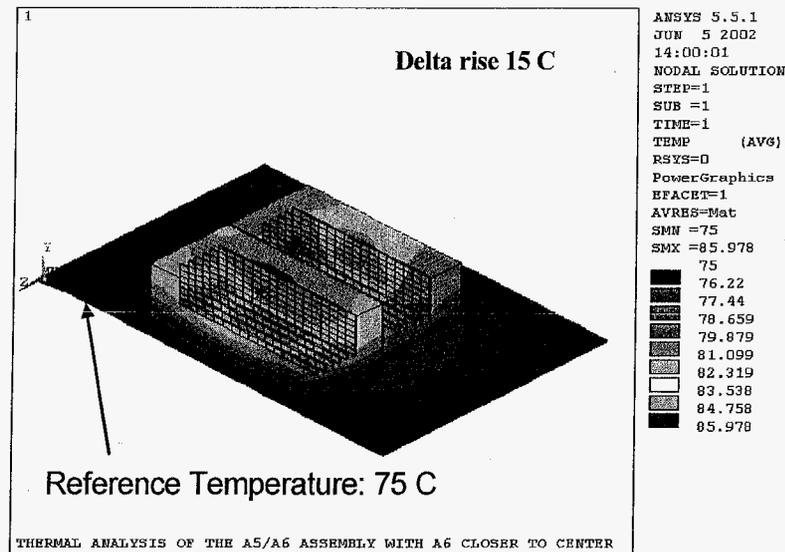
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### Electrical and Thermal fields for Flight

Voltage distribution across FEM



Modulator Temperature Distribution





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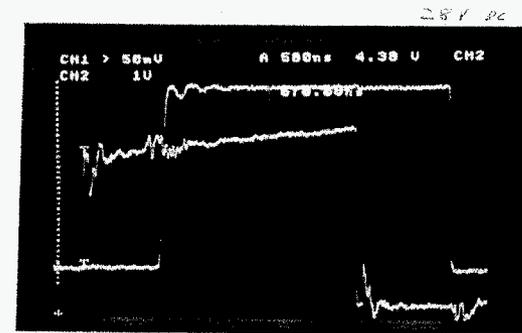
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### Flight, Thermal Vacuum Data

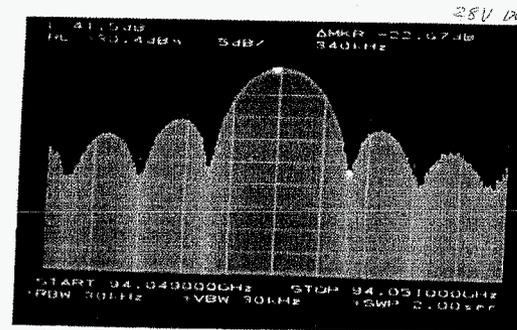
### Flight HPA 101, Rise/fall time (FEM data)

Temperature HVPS/EIK Deg C	RF Delay nana sec	RF Rise Nano sec.	RF Storage Microsec	RF Fall time Nano Sec.
33/50	928.0	62.0	1.050	18.0
25/35	980.0	57.0	1.080	22.0
0/20	922.0	50.0	1.020	28.0
-20/-15	910.0	49.0	0.950	14.0
-15/5	902.0	52.0	1.004	14.4
10/15	920.0	54.5	1.039	22.0
25/25	948.0	59.0	1.084	25.0
23/23	888.0	52.0	1.000	22.6

### FEM Command, RF output and Spectrum in TV



HPA 101 23/23°C 23:55 3/2/04



HPA 101 23/23°C 23:57 3/2/04



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## Conclusion

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EIK's requirement of 200 nanoseconds for rise time and fall times have been met over the specified environment. Data collected is within the CPR requirement and performance is very satisfactory and is ready to launch. When launched, it will be the first such instrument in orbit to delivering 2 kW of RF power at 94 GHz, with such a fast (15 kV/microsecond) Focus Electrode Modulator (FEM).

This approach to the design, is adaptable to any range of voltage swings (excursions) if attention is paid to the pulse transformer design, voltage containment and selection of base FET.