FROM A REAL PENCIL TO A SYNTHETIC BROOM: THE PAST, PRESENT AND FUTURE OF HIRAD

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1. INTRODUCTION

The Hurricane Imaging Radiometer (HIRAD) is a new airborne sensor that is currently under development by NASA Marshall Spaceflight Center, the University of Central Florida, the NOAA Hurricane Research Division, and the University of Michigan. It will produce wide-swath images of ocean surface wind speed and near surface rain rate in hurricanes conditions. HIRAD will extend the scientific capabilities of the Stepped Frequency Microwave Radiometer (SFMR) airborne instrument by adding the imaging capabilities of a synthetic aperture spatial interferometer. The HIRAD program has required major development efforts in antenna technology, system engineering, radiative transfer forward modeling, and geophysical retrieval algorithms. A programmatic development history will be presented, with particular emphasis on the technology, engineering, modeling and algorithm work that has occurred, followed by a report on the current status and future plans for the program.

2. PENCIL BEAM AND PUSH BROOM PREDECESSORS

2.1. SFMR Pencil Beam

The Stepped Frequency Microwave Radiometer (SFMR) is a real aperture instrument that operates at a number of distinct frequencies covering roughly the full C-Band octave. It is deployed on NOAA Hurricane Research Division aircraft to provide simultaneous real time estimates of ocean surface wind speed and rain rate [1]. SFMR has a single nadir-pointing horn antenna and makes wind and rain estimates directly below the aircraft. It is able to retrieve rain rate and underlying ocean surface wind speed in severe, hurricane-strength, conditions.

2.2. Fourier Synthesis Push Brooms

The correlation between the electric field at two positions is given by

$$V(\vec{s}) = \left\langle A_1\{E(\vec{r},\Omega)\}^* A_2\{E(\vec{r}-\vec{s},\Omega)\}\right\rangle \tag{1}$$

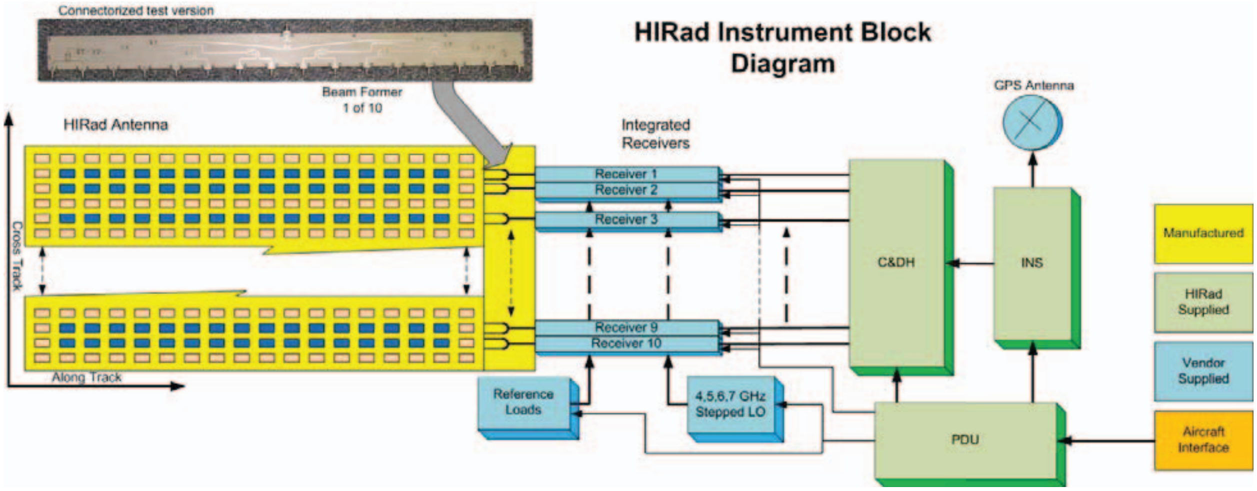

Figure 1. HIRAD functional block diagram. The multi-resonant planar antenna array is shown at left. Ten parallel phase-matched correlating receivers condition and downconvert the antenna and calibration signals, where they are digitized. A Command and Data Handling module performs self- and cross-correlations of all single channels and pairs of channels.

where $E(\vec{r},\Omega)$ is the electric field at position $\vec{r}$ arriving from angular direction Ω, $A_n\{\bullet\}$ denotes the angular reception sensitivity of antenna n ($n = 1, 2$) to the incident electric field, and $\vec{s}$ is the separation between the two versions of the electric field being correlated. This correlation statistic is referred to as the visibility of the brightness temperature distribution. The visibility is sampled over a suitable range of separations between antenna pairs. If the two antennas have a common angular reception sensitivity, then the Fourier transform of the visibility with respect to the separation, $\vec{s}$, is proportional to the angular dependence of the power density of the incident electric field received by the antennas. The power density is, in turn, proportional to the brightness temperature of the source of the electric field. Spatial Interferometers (also called Fourier Synthesis Imagers) are used to determine the angular dependence of the brightness temperature, $Tb(\Omega)$. The Fourier transform required to convert measured visibilities to a Tb image is performed in software as part of the data post-processing. Interferometers are used to image the Tb when its angular variation is to be resolved sufficiently fine resolution that a large antenna, capable of comparable spatial resolution, is impractical [2].

3. HIRAD SYSTEM DESCRIPTION

The HIRAD sensor has evolved by wedding the SFMR with Fourier synthesis imaging [3]. A functional block diagram of the HIRAD sensor is shown in Fig, 1. The key to HIRAD's improved performance is its ability to operate as a Fourier synthesis imager at discrete frequencies that cover the same C-Band octave as does SFMR. The HIRAD antenna array is comprised of linear arrays of multi-resonant stacked microstrip patch antennas. The

Table 1. Predicted performance of HIRAD aircraft and spacecraft sensors at 11 and 350 km altitude

	CHARACTERISTIC	AIRCRAFT (1m aperture)				SPACECRAFT (5m aperture)			
System Design	frequency (GHz)	**4**	**5**	**6**	**7**	**4**	**5**	**6**	**7**
	altitude (km)	11				350			
	# of STAR sub-arrays	10				25			
	# of synthesized baselines	36				208			
Receiver Design	bandwidth (MHz)	85	60	60	150	85	60	60	150
Spatial Resolution	Nadir(km)(geometric mean of principle plan	1.4	1.2	1.0	0.9	7.7	6.1	5.1	4.4
	30 deg cross track off-nadir (km)	1.9	1.5	1.3	1.1	10.0	8.0	6.6	5.7
	60 deg cross track off-nadir (km)	5.6	4.5	3.8	3.3	28.0	22.4	18.6	16.1
Brightness	NEDT (K) (assuming 290K scene brightness	0.19	0.25	0.27	0.18	0.90	1.27	1.53	1.09

linear arrays produce a real-aperture fan beam antenna pattern that defines the instantaneous field of view of the sensor. The fan beam antennas are themselves configured in a thinned linear array. A synthetic-aperture pencil beam antenna pattern is formed in software from the cross-correlation products of all pairs of fan beam antennas. The predicted performance of the HIRAD sensor is given in Table 1 for both the current aircraft version, with 1x1 m^2 effective synthesized aperture and a follow on notional spacecraft version with a 5x5 m^2 aperture.

11. REFERENCES

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