Westford FCC Form 442 Application Exhibit

1.0 Introduction

MIT Haystack Observatory has been contracted by NASA to support UHF satcom operations as a backup for missions served by the 18 meter NASA Wallops Flight Facility UHF satcom system. Although the majority of missions supported by WFF are licensed via the NTIA the Ball Aerospace CIRIS mission is licensed through an FCC Form 442 application. To support the CIRIS mission for NASA will Earth Station services we request a corresponding FCC Form 442 license for the Westford 18 meter antenna system. This system has been equipped with a UHF phased array feed, transmitter system, and radio hardware under NASA support.

The content of this exhibit supports the Westford FCC Form 442 Application by incorporating key details related to the application and Westford system design.

2.0 Government Contract

Agency : NASA

Contract Number: 80GSFC22CA009

Government PoC : Therese Patterson

Government PoC Phone Number : 757-824-1066

3.0 Nature of the research project

This application is to support the Ball Aerospace CIRIS mission by providing satcom services for NASA to ensure coverage for the mission. The Ball Aerospace CIRIS mission is licensed for communications under FCC Form 442 and this is a corresponding application to operate the Westford antenna as a satcom Earth station.

3.1 Necessity of communications facility

The CIRIS mission currently uses the NASA Wallops Flight Facility (WFF) 18 meter UHF satcom system. The WFF system has reliability issues and cannot ensure consistent communication with supported missions including CIRIS. NASA has determined that it would be advantageous for MIT Haystack Observatory to provide a backup capability for the WFF system.

3.2 Why existing facilities are inadequate

The existing NASA WFF facility is not fully reliable but is currently the only NASA contracted system capable of UHF communications with CIRIS for data downlink. A large aperture antenna (e.g. 18 meters) is necessary to support downlink from L3 Cadet software radio systems. The Westford Radio antenna has been equipped by MIT under NASA support to act as a backup and is currently supporting NTIA licensed missions for NASA.

3.3 Mission Description

The Ball Aerospace CIRIS mission objective is technology demonstration for improved on-orbit radiometric calibration. The CIRiS calibration approach uses a scene select mirror to direct three calibration views to the focal plane array and to transfer the resulting calibrated response to earth images. The views to deep space and two blackbody sources, including one at a selectable temperature, provide multiple options for calibration optimization. Two new technologies, carbon nanotube blackbody sources and microbolometer focal plane arrays with reduced pixel sizes, enable improved radiometric performance within the constrained 6U CubeSat volume.

4.0 Description of RF communications

The CIRIS mission uses an L3 Cadet software defined radio for UHF communications.

CIRIS to ground downlink: 468 MHz Carrier with modulation: 3M00G1D. (**NOT PART of this APPLICATION** ; to be filed by the CIRIS MISSION)

Westford to CIRIS uplink (**this license application**): 450.15 - 450.25 MHz Carrier with modulation: 34K4F1D

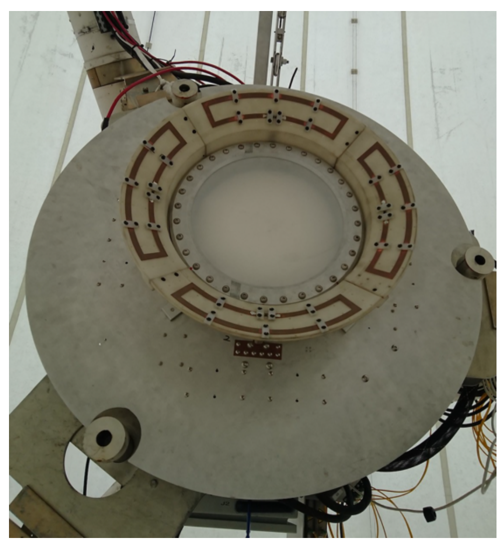
4.1 System Description

Longitude	71.49°W
Latitude	42.61°N
Height above m.s.l.	116 m

MIT Haystack Observatory
99 Millstone Rd
Westford, MA 01886-1299 U.S.A.
https://www.haystack.mit.edu

Parameter	Westford
primary reflector shape	symmetric paraboloid
primary reflector diameter	18.3 meters
primary reflector material	aluminum honeycomb
feed location	primary focus
focal length	5.5 meters
antenna mount	elevation over azimuth
antenna drives	electric (DC) motors
azimuth range	$90° - 470°$
elevation range	$4° - 87°$
azimuth slew speed	$3°\ s^{-1}$
elevation slew speed	$2°\ s^{-1}$

The Westford Antenna is Located approximately 70 km northwest of Boston, Massachusetts, the antenna is part of the MIT Haystack Observatory complex. The Westford antenna is an 18.3 meter parabolic reflector enclosed in a 28-meter air inflated radome constructed of a 1.2-mm-thick Teflon fabric (Raydel R-60). The primary frequency standard on site is an NR-4 Hydrogen maser. The antenna is equipped with feeds specific to the project or application. In this case a UHF phased array feed system has been developed to enable utilization of the telescope for satcom applications without disrupting use of the radio astronomy feed on the telescope.

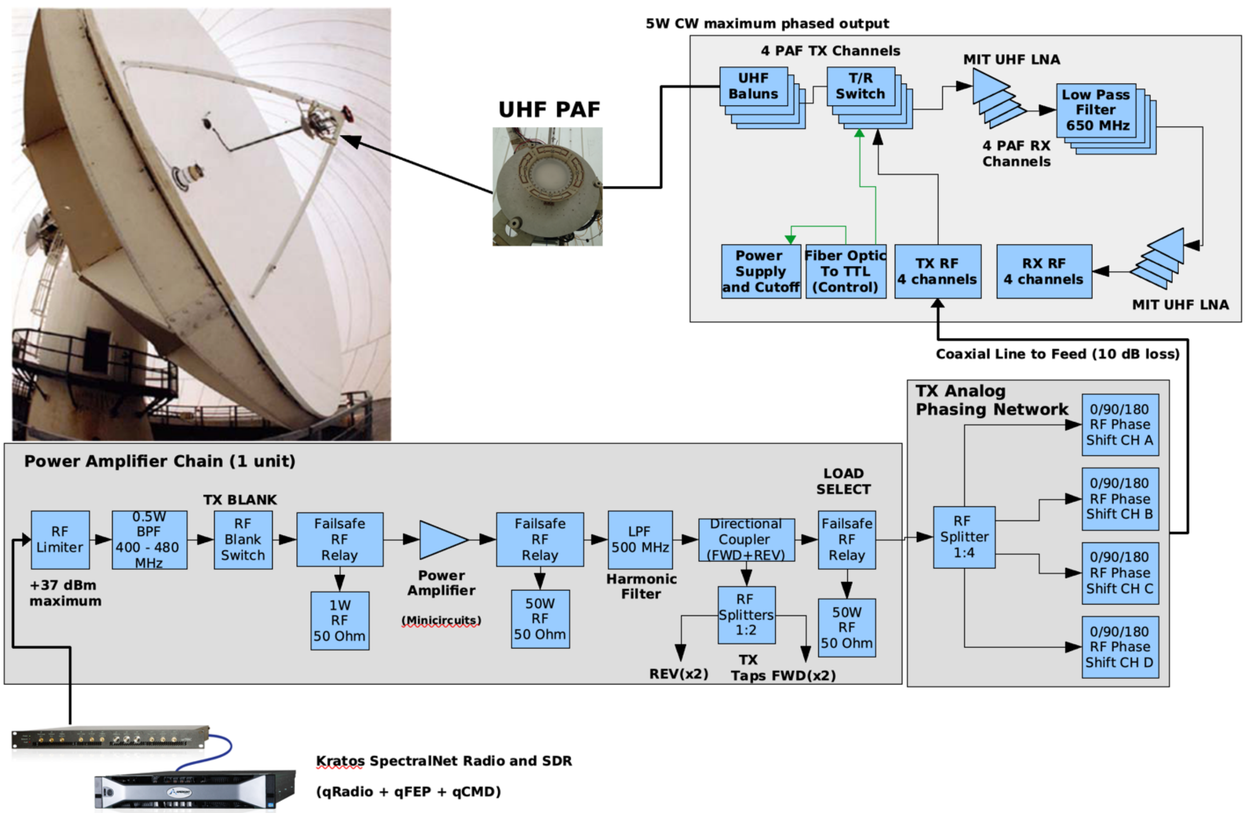


The new UHF feed designed and built for Westford to meet these criteria is a novel multi-element dual-linear array which operates on UHF radar and satcom frequencies from 400 MHz to 500 MHz. The UHF Multimode Array Feed enables simultaneous use of the broadband astronomy receive only feed. When used with software radio systems it is also capable of adaptive receive and transmit beamforming.

For CIRIS satcom applications at 450 MHz only analog transmit beamforming will be used to form the needed sum beam from the array feed.

4.2 Transmitter Details

Westford utilizes a custom transmitter implemented using COTS components and Minicircuits power amplifier to transmit signals generated by an Kratos SpectralNet radio in combination with a Kratos software radio stack (i.e. modulation, front end processor, demodulation, and mission interface). Transmit power is generated in the control room and split using an analog phasing network that enables RHCP, LHCP, linear H, or linear V operation. A cavity harmonic filter provides for suppression of out of band signal energy. Taps allow for monitoring of forward and reflected power. Cable losses from the phasing network to the feed limit the maximum phased output power to below 5W CW. A switch based T/R system is used at the feed to select between transmit and receive under fiber optic line control. The receive signal path is not shown here. The system is synchronized to the on site hydrogen maser frequency and time reference with stability better than 1 part in 10E13 at 1 second.



4.3 Antenna Details

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Basic Input Parameters

Band	Frequency Range GHz	Mid Frequency GHz	Power W	Gain dBi
UHF	0.45	0.451	5	31.4
Diameter: 18.3 m	Power (W)	Main (dBi)	1st side lobe	Back Lobe
RHCP / LHCP	5	31.4	3.2583	0.0

Band	Frequency		Mid	
UHF	0.430 - 0.470 GHZ DL	0.450-0.451 GHZ U/L	0.45	RHCP & LHCP DL/UL

4.4 Antenna Pattern

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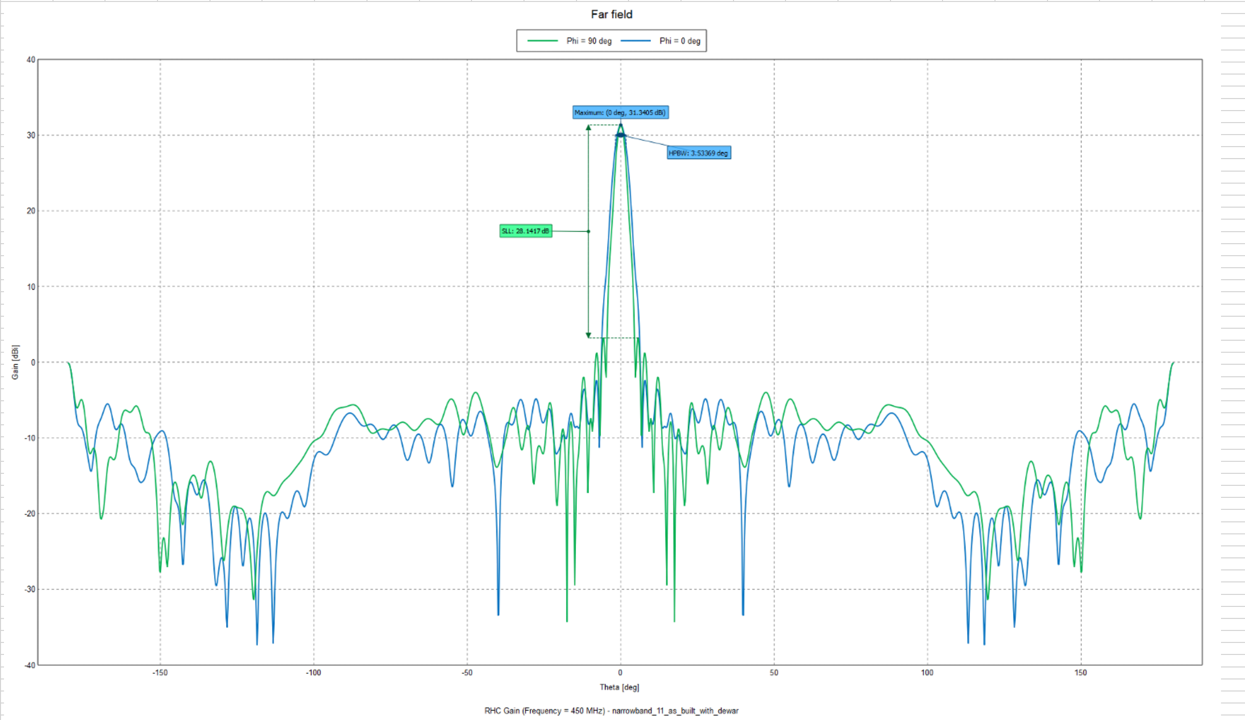
Pattern with UHF Phased Array Feed (RHCP)



5.0 RF Safety Information

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RF Safety Calculation

WESTFORD @ 0.450 GHz

Information Provided			Converted Values	
Frequency	0.45	GHz	450	MHz
Dish Diamenter	720.4724	inches	18.3	m
Transmit Power	5.00E+00	W	5.00E+00	W
Antenna Gain	31.4	dBi	31.4	dBi
Duty Factor	1		1	

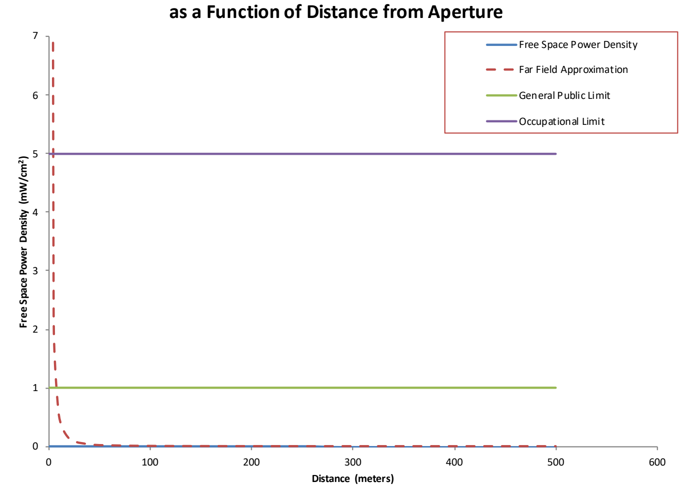
Limits (S_L)	MDPH		IEEE C95.1-2005/DoDI 6055.11 - 2009	
	General Public	Occupational	Action	Controlled
(mW/cm^2)	1	5	1	10

Parameter	Symbol	Formula	Value	Units
Antenna Diameter	D	*Input*	18.3	m
Antenna Surface Area	A	$\pi D^2/4$	263.02199	m^2
Frequency	f	*Input*	450	MHz
Wavelength	λ	$300/f$	0.6666667	m
Transmit Power	P	*Input*	5	W
Antenna Gain (dBi)	G	*Input*	31.4	dBi
Duty Factor	DF	*Input*	1	
Average Power	P_{ave}	*P*DF*	5	
Antenna Gain(factor)	G_{abs}	$10^{G/10}$	1380.3843	N/A
Pi	π	Constant	3.1415927	N/A
Antenna Efficiency	η	$G_{abs}\lambda^2/(\pi^2 D^2)$	0.1856161	N/A
Distance to Far Field	R_{ff}	$0.6D^2/\lambda$	301.401	m
On-Axis Power Density at Far Field	S_{ff}	$G_{abs}P/4\pi R_{ff}^2$	0.006046	W/m^2
			0.0006046	mW/cm^2
Extent of Near Field	R_{nf}	$D^2/4\lambda$	125.58375	m
Near Field Power Density	S_{nf}	$16.0\eta P/(\pi D^2)$	0.0141141	W/m^2
			0.0014114	mW/cm^2
Transition Region Power Density	S_t	$S_{nf}R_{nf}/R_t$		
Off Axis NF PD @ 1 Antenna Diameter	S_{OFNF}	$S_{nf}/100$	0.0001411	mW/cm^2
Distance of Intrest	R	*Input*	18.2	m
Power Denisty at distance R	R	$G_{abs}P_{ave}/4\pi R^2$	1.6581254	W/m^2
			0.1658125	mW/cm^2

		MDPH		IEEE C95.1-2005	
		General Public	Controlled	Action	Controlled
Distance (meters) to which the power density is equal to the limit using Far Field*	R_L	7.411055523	3.3143248	7.41105552	2.3435815
		16.6%	3.3%	16.6%	1.7%
Percentage of Limit at distance R*					

Note: Far Field Distance are not applicable if distance R is less than R_{ff}

Calculated Free Space Power Density as a Function of Distance from Aperture



Dstance	S	SFF	GP	Occ
Distance	Power Density	Far Field	General Public Limit	Occupational Limit
1	0.001411411	54.92374477	1	5
5	0.001411411	2.196949791	1	5
10	0.001411411	0.549237448	1	5
20	0.001411411	0.137309362	1	5
40	0.001411411	0.03432734	1	5
60	0.001411411	0.015256596	1	5
80	0.001411411	0.008581835	1	5
100	0.001411411	0.005492374	1	5
120	0.001411411	0.003814149	1	5
140	0.001411411	0.002802232	1	5
160	0.001411411	0.002145459	1	5
180	0.001411411	0.001695177	1	5
200	0.001411411	0.001373094	1	5
220	0.001411411	0.001134788	1	5
240	0.001411411	0.000953537	1	5
260	0.001411411	0.000812481	1	5
280	0.000633037	0.000700558	1	5
300	0.000590834	0.000610264	1	5
320	0.000553907	0.000536365	1	5
340	0.000521324	0.000475119	1	5
360	0.000492362	0.000423794	1	5
380	0.000466448	0.000380358	1	5
400	0.000443126	0.000343273	1	5
420	0.000422024	0.000311359	1	5
440	0.000402842	0.000283697	1	5
460	0.000385327	0.000259564	1	5
480	0.000369271	0.000238384	1	5
500	0.000354501	0.000219695	1	5
520	0.000340866	0.00020312	1	5
540	0.000328241	0.000188353	1	5
560	0.000316518	0.000175139	1	5
580	0.000305604	0.000163269	1	5
600	0.000295417	0.000152566	1	5
620	0.000285888	0.000142882	1	5
640	0.000276954	0.000134091	1	5
680	0.00011878	0.00011878	1	5
700	0.000112089	0.000112089	1	5
720	0.000105949	0.000105949	1	5
740	0.000100299	0.000100299	1	5
760	9.50896E-05	9.50896E-05	1	5
780	9.02757E-05	9.02757E-05	1	5
800	8.58184E-05	8.58184E-05	1	5
820	8.16831E-05	8.16831E-05	1	5
840	7.78398E-05	7.78398E-05	1	5
860	7.42614E-05	7.42614E-05	1	5
880	7.09243E-05	7.09243E-05	1	5
900	6.78071E-05	6.78071E-05	1	5
920	6.4891E-05	6.4891E-05	1	5
940	6.21591E-05	6.21591E-05	1	5
960	5.95961E-05	5.95961E-05	1	5
980	5.71884E-05	5.71884E-05	1	5
1000	5.49237E-05	5.49237E-05	1	5
1200	3.81415E-05	3.81415E-05	1	5
1400	2.80223E-05	2.80223E-05	1	5
1600	2.14546E-05	2.14546E-05	1	5
1800	1.69518E-05	1.69518E-05	1	5
2000	1.37309E-05	1.37309E-05	1	5