

# ***A Multifrequency Interferometry Telescope for Radio Astronomy: MITRA***

Girish Kumar Beeharry    Stuart MacPherson & Gary van Vuuren  
Mauritius Radio Telescope    Department of Electronic Engineering  
Department of Physics    Faculty of Engineering &  
Faculty of Science    the Built environment  
University of Mauritius    Durban University of Technology

*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014    Girish  
Kumar Beeharry*



# Outline

- Overall description
- Station outline
- Recent developments
- Preliminary tests
- People
- Future & funding

*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014*      *Girish Kumar Beeharry*



# ***MITRA: Overall description***

- A sensitive high resol multi-frequency dual polarity
- Frequency range 200 to 800 MHz
- Multiple independent stations of low-cost dipoles
- Baselines: ~metres, 250-500-1000-3000-5000 km-
- Instrument & station: modular & subsets
- Technical specifications function of number of stations

*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014      Girish  
Kumar Beeharry*



## ***MITRA: Station outline***

- Each station can observe on its own.
- Sufficient sensitivity and resolution built in.
- The front-end & the back-end should be integrated with the data acquisition locally.
- The data pipeline should also cater for intra-station as well as inter-station correlation.
- Local hub managing system which will be synchronised, centrally, with other stations.

*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014*  
*Kumar Beeharry*

*Girish*



# *Sensitivity 1*

- Sky noise  $\sim 300$  K at 150 MHz; up to 1000 K in the Galaxy (Golap 1998, Issur 2003)
- No cooling of field electronics: science & cost factor
- $\sim 250$  mJy point source sensitivity per station for 1024 antennas. (Golap 1998, Pandey 2006, Daiboo 2012). 32 EW 16 NS: BL 1 MHz BW, 16 s integration, area  $\sim 4000$  m<sup>2</sup>
- Aim to improve:  $\Delta S \sim (\Delta\nu \cdot n \cdot \Delta t)^{-1/2}$ ,





# *Sensitivity 2*

- The w term
- Convolution & Gridding
- Primary beam
- Phasing & Bandwidth decorrelation
- Ionospheric effects



# Resolution

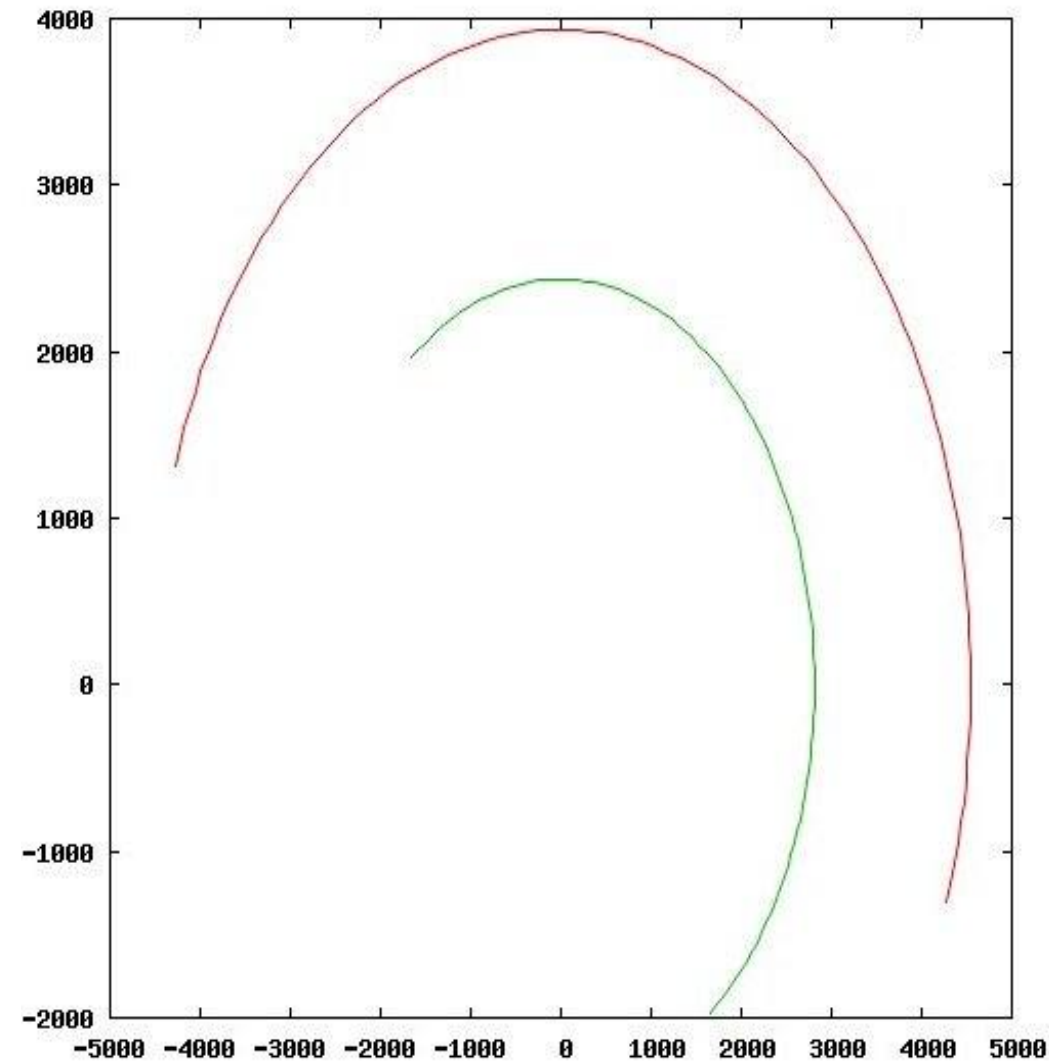
$\nu$	$\lambda$	Resolution							
MHz		10m	100m	1km		500 km	2500km		
5000km									
<----- arcseconds ----->									
50	6.0	123758.9	12375.9	1237.6	5.0	2.5	1.24	0.495	0.248
100	3.0	61879.4	6187.9	618.8	2.5	1.2	0.62	0.248	0.124
200	1.5	30939.7	3094.0	309.4	1.2	0.6	0.31	0.124	0.062
300	1.0	20626.5	2062.6	206.3	0.8	0.4	0.21	0.083	0.041
400	0.8	15469.9	1547.0	154.7	0.6	0.3	0.15	0.062	0.031
500	0.6	12375.9	1237.6	123.8	0.5	0.2	0.12	0.050	0.025
600	0.5	10313.2	1031.3	103.1	0.4	0.2	0.10	0.041	0.021
700	0.4	8839.9	884.0	88.4	0.4	0.2	0.09	0.035	0.018
800	0.4	7734.9	773.5	77.3	0.3	0.2	0.08	0.031	0.01

90 MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014

Girish Kumar Beeharry



# uv coverage 2 stations

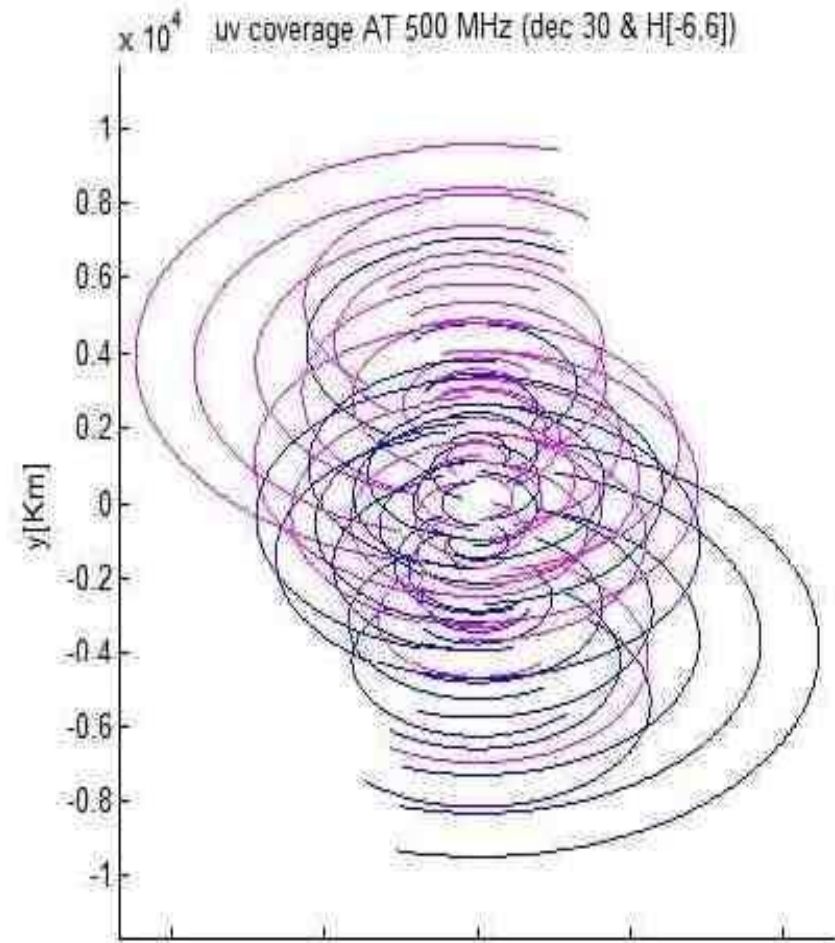


*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014*  
*Girish Kumar Beeharry*





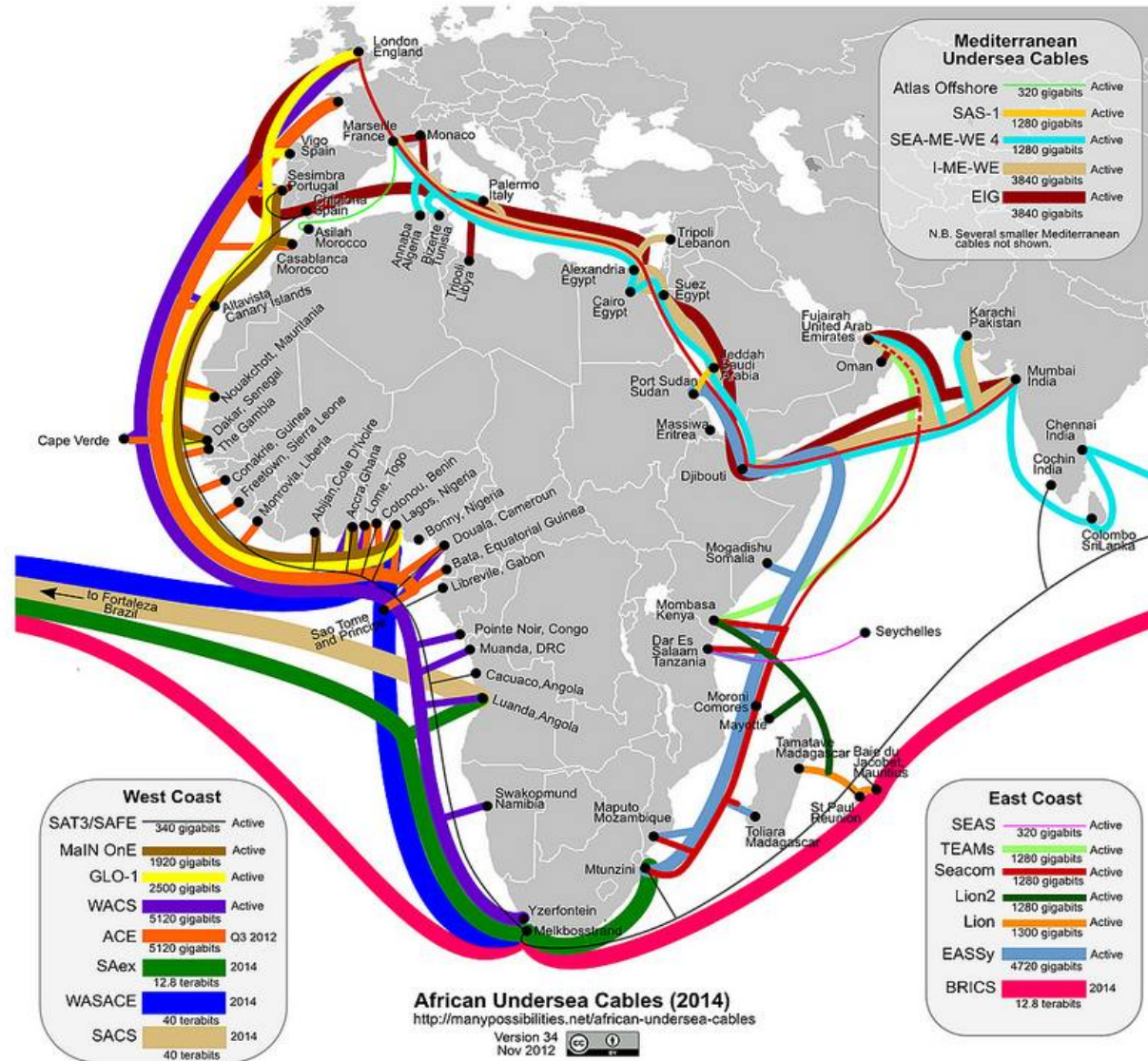
# uv coverage 9 stations



*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014*  
*Girish Kumar Beeharry*



# Connectivity



MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014

Girish Kumar Beeharry

<http://manypossibilities.net/african-undersea-cables>





# *Extremely wide field imaging with heterogeneous non coplanar arrays*

- Short spacing
- w/n term, sampling & visibility
- Primary beams: size and dep, on position
- Bandwidth decorrelation
- Imaging & CLEANing etc
- Future problem for the SKA

*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014  
Girish Kumar Beeharry*

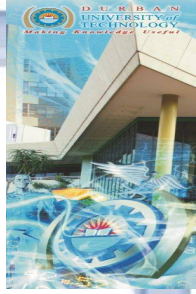


# *MITRA: Science I*

- Solar: flares, coronal mass ejections (de Pontieu et al 2011, Zaarashvili et al 2013)
- The Milky Way, Galactic centre star forming regions (Yusef-Zadeh et al 2013)
- Galaxies and clusters of galaxies (van Weeren et al 2011)
- Pulsars & Supernova remnants (Stappers et al 2011, Han et al 2013)

*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014*  
*Girish Kumar Beeharry*





## ***MITRA: Science II***

- Low brightness wide sources (Dodson 1997)
- Transient sources (Nithyanasdan et al 2011, Bannister et al 2011, Schmidt et al 2013)
- Spectral and recombination line observations (De Pree et al 1997)
- Spectral indices of sources (Miley et al 2008)
- Interstellar scintillation, Jupiter (Rickett et al 2002, Zarka et al 2005, de Pater et al 2003)
- Ionospheric and Space Weather (Judd et al 1987)

*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014*

*Girish Kumar Beeharry*



# ***MITRA: Technology I***

- Receiver system design (Ginourie 2009, Lutchumon 2011, Mahadu 2011, Bhoyrub 2012, Chataroo 2012, Armoogum 2013)
- Data acquisition system design (N. Pirthee 2013)
- Radio Frequency(RF) Electronics  
(UOM & DUT projects with collaboration)
- Networking (Conhyea 2007, Armoogum 2013)

*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014*  
*Girish Kumar Beeharry*



# ***MITRA: Technology II***



- Data Management (Brunner et al 2001, Morgan et al 2013, Grange et al 2012)
- High Capacity Multi-Parallel-Correlation (Begeman et al 2011, Jheengut 2008, Platel 2010, Mondon 2011, N. Pirthee 2013)
- Antenna design (Muthoor 2005, Ramdohee 2007, Mohur 2007, Boyjpnauth 2008, Nursimhulu 2009, Nunkoo 2009, Prayag 2011, Shibchurn 2013)
- VLBI and e-VLBI (e.g EVN)

*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014*  
*Girish Kumar Beeharry*





# *MITRA Preliminary work: Antenna design Version 1*



Prayag, Lalbarry

*MFAA All hands @ meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014*

*d'Eau, Mauritius Girish Kumar Beeharry*





# *MITRA Preliminary work: 1<sup>st</sup> antenna 100-850 MHz*



MRT  
Bras  
d'Eau  
Mauritius

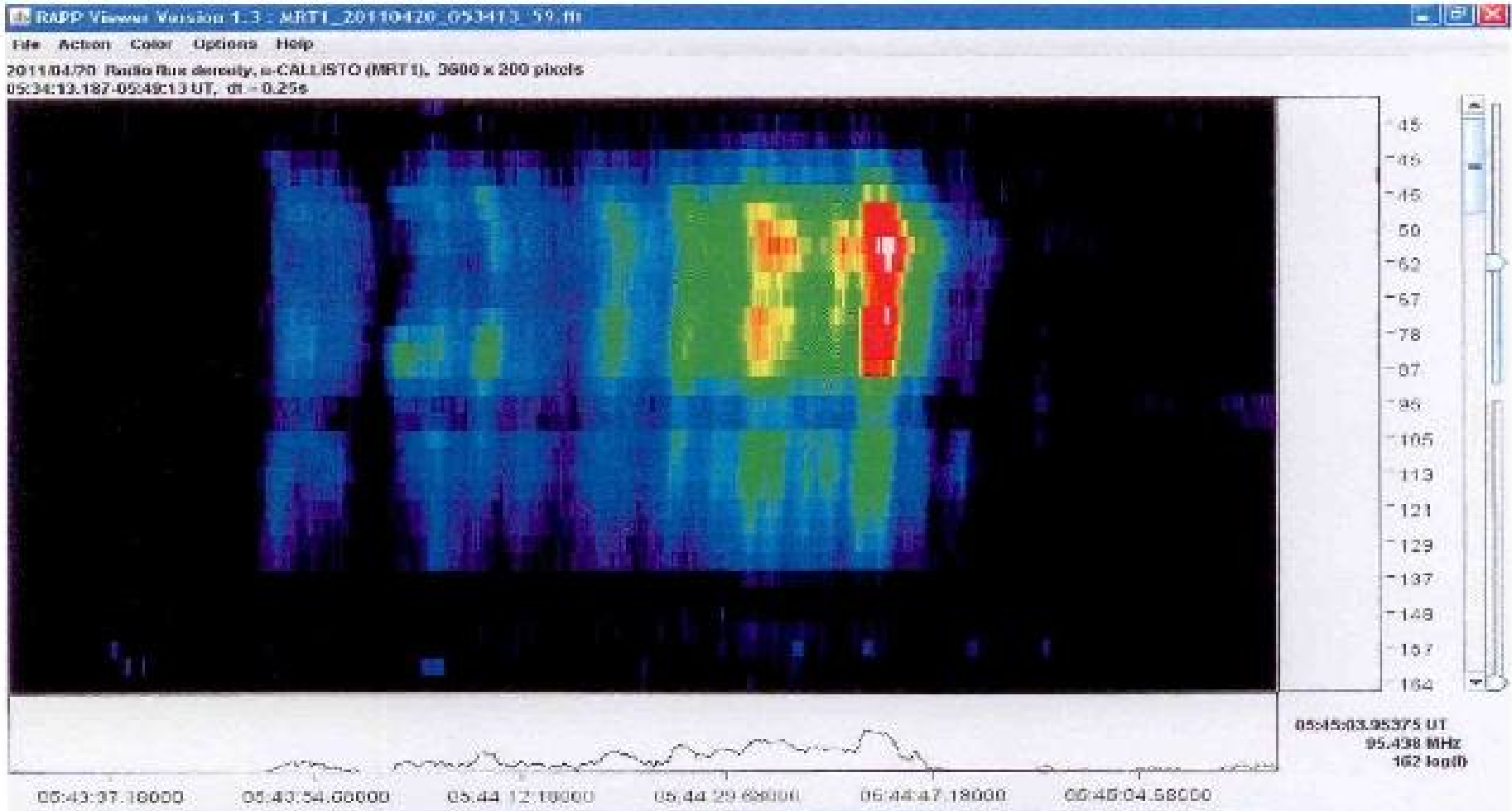


DUT  
Durban  
RSA

*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014*  
*Girish Kumar Beeharry*



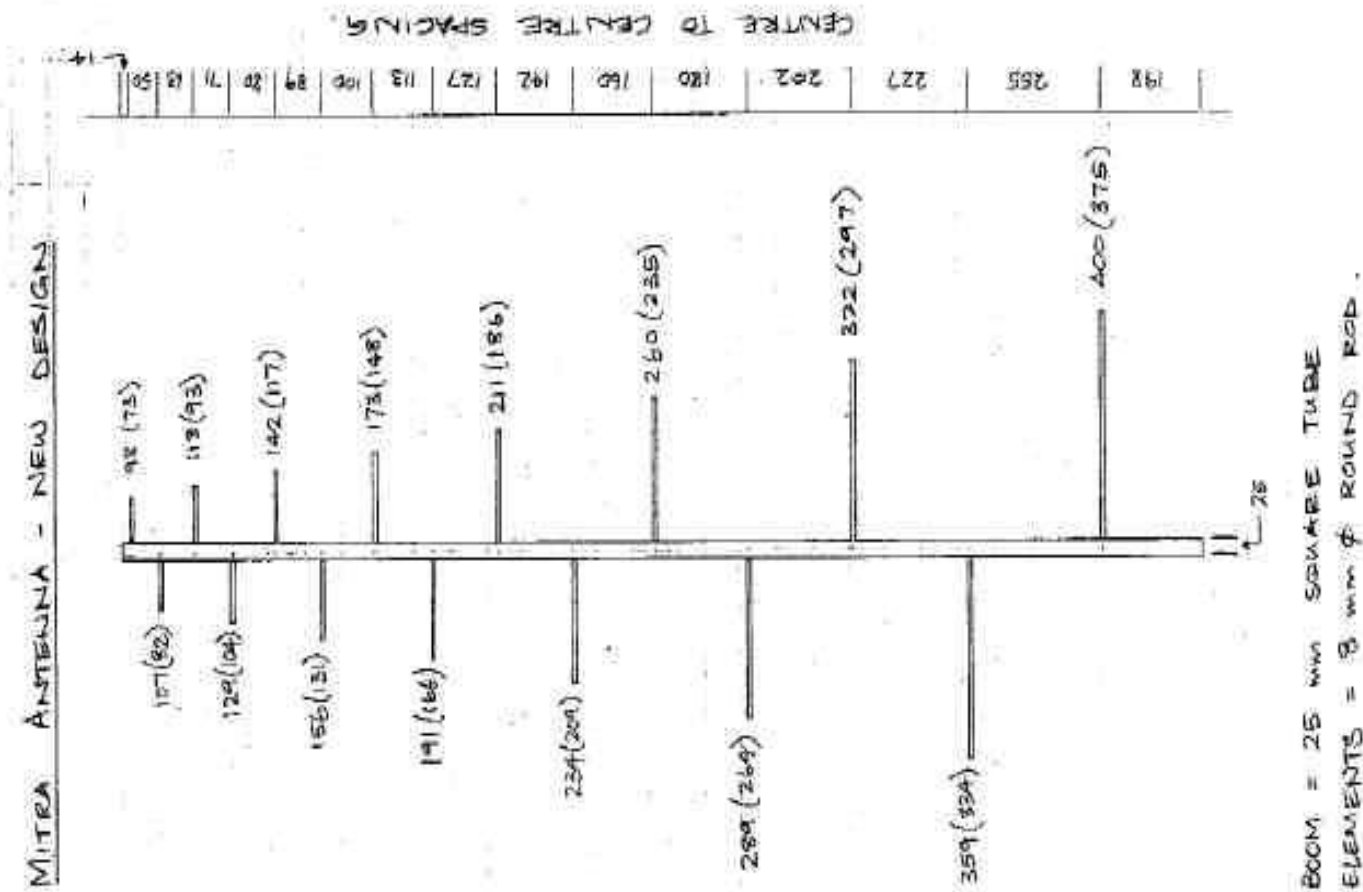
# *MITRA Preliminary work: Type 3 Solar flare antenna V1 20.4.2011*



*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014  
Girish Kumar Beeharry*



# MITRA Preliminary work: new antenna design 200-800 MHz



MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014

Girish Kumar Beeharry

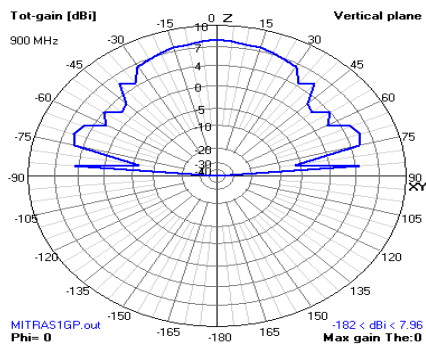
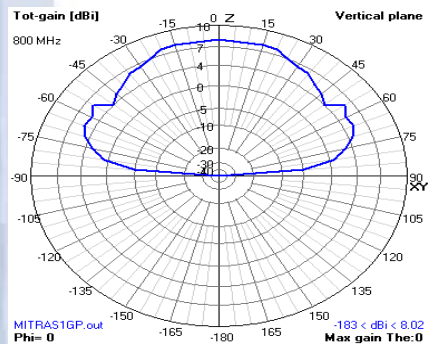
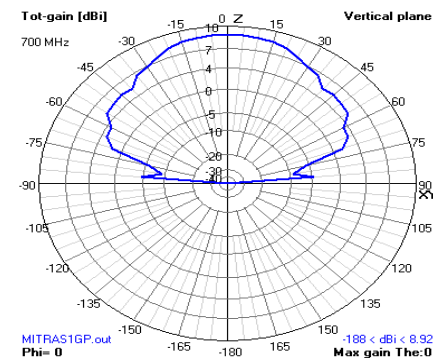
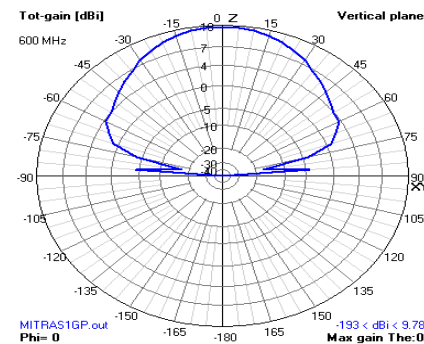
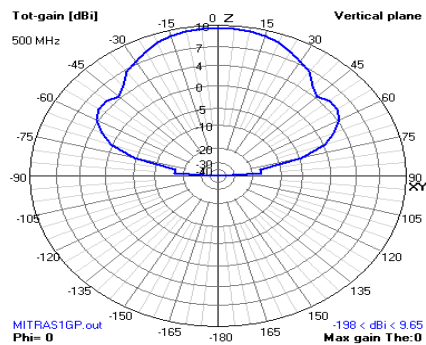
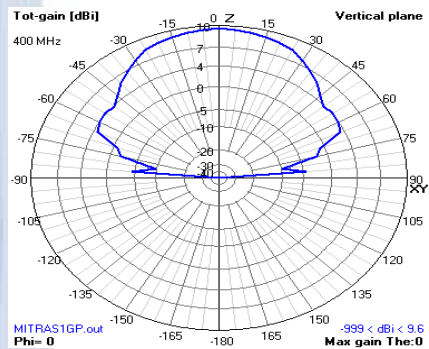
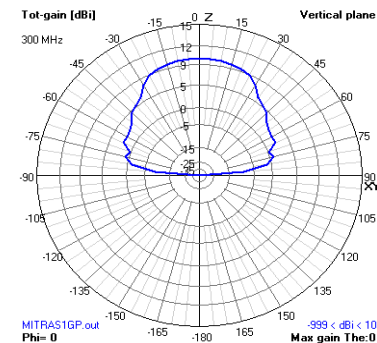
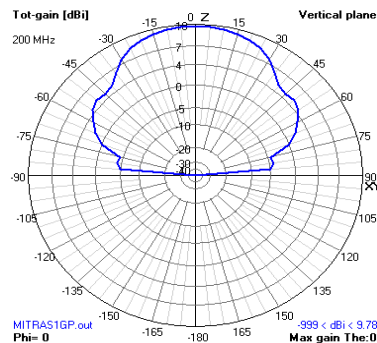
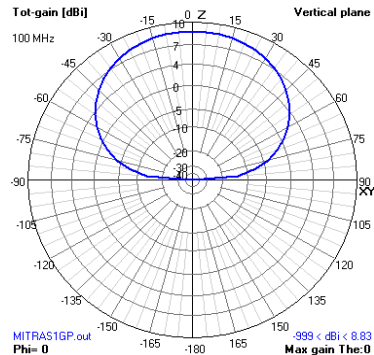
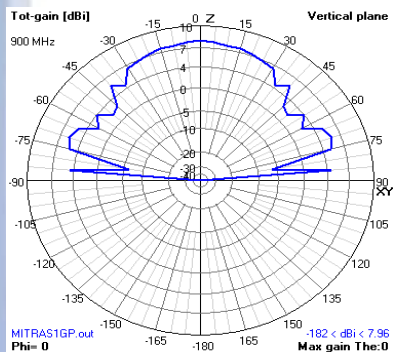
Durban, RSA

Antenna@MKT Bras  
d Eau, Mauritius





# MITRA Preliminary work: New Antenna design 200-800MHz



Group Model fit needed

MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014

Girish Kumar Beeharry





# *MITRA Preliminary work: Antenna design Version 2*



*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014*

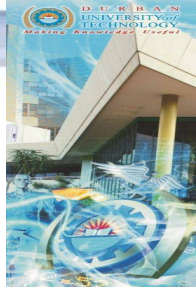
*Girish Kumar Beeharry*

*Shibchurn, Lalbaree, Beeharry @ Bras d'Eau,*





# *MITRA Preliminary work: Front end 15.02.2014*



*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014*

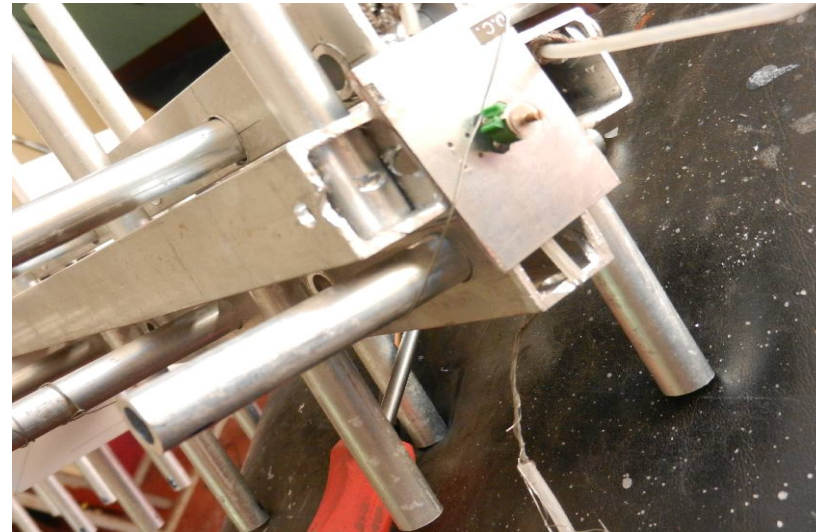
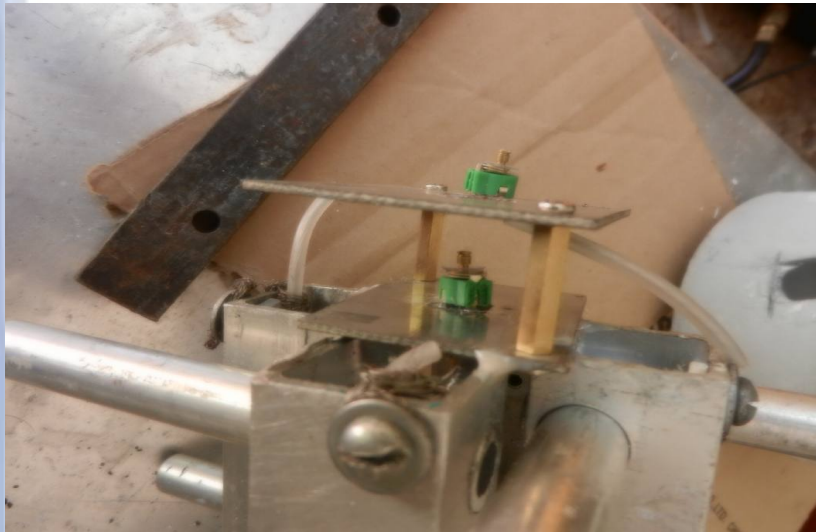
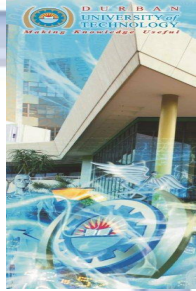
*Girish Kumar Beeharry*

*K Bhojrub & A Chataroo Bras d'Eau, Mauritius*

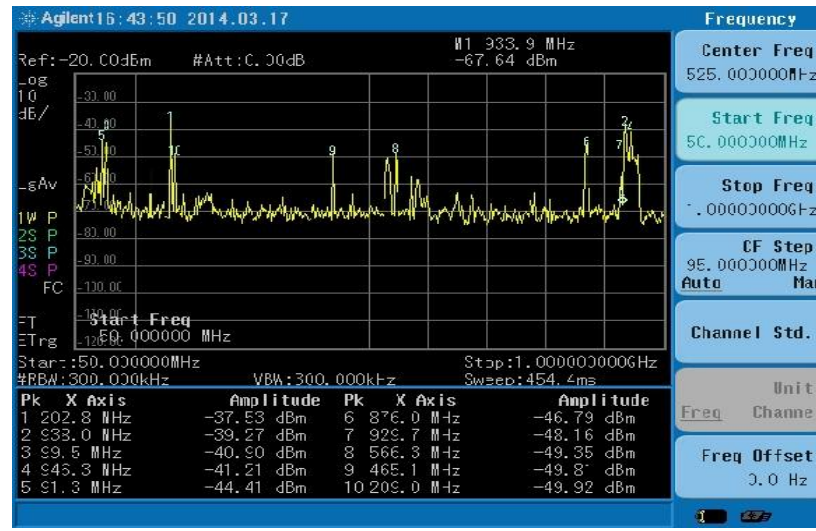
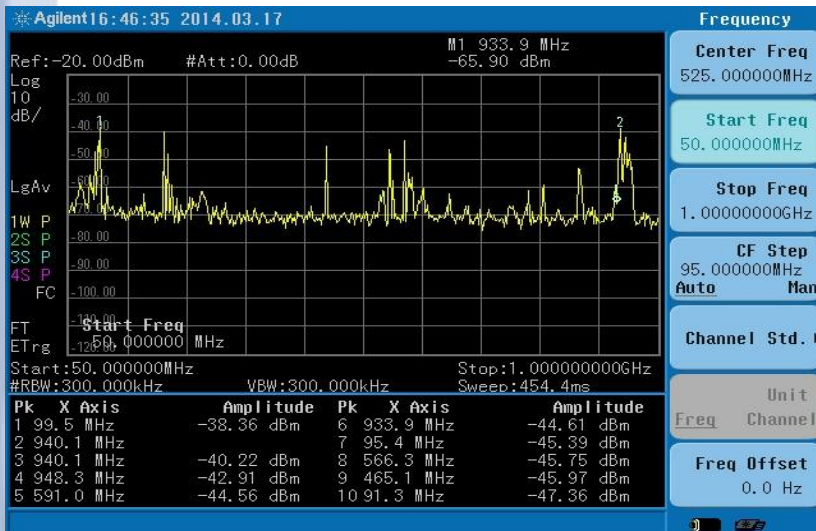




# MITRA Preliminary work: Antenna design Version 3 March 2014



*Sug.  
H.Reader  
Feb 2014  
Stellenbosch  
meeting*



*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014*

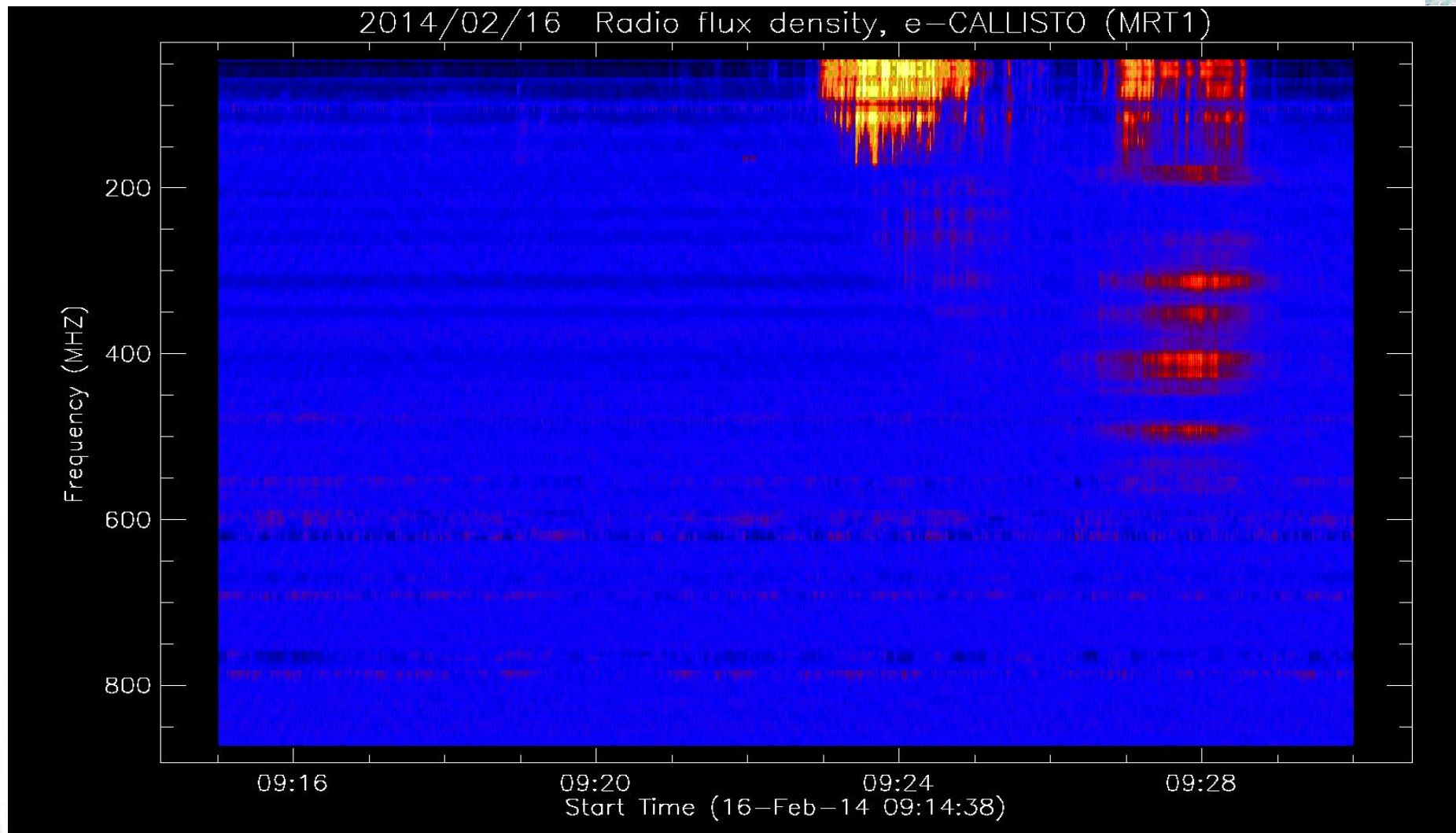
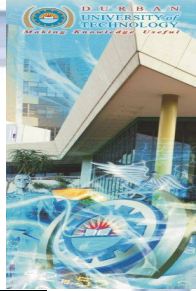
*Girish Kumar Beeharry*

Shibchurn, Lalbaree, Beeharry @ Bras d'Eau,





# *MITRA Preliminary work: Solar flare with antenna V2 16.2.2014*



*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014  
Girish Kumar Beeharry*



# *MITRA Preliminary work: 16 channel receiver pre-processor*



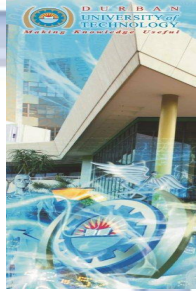
*Two 16  
channel  
receivers  
built in  
parallel  
UoM&UdM*

*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014*

*Girish Kumar Beeharry*

*K Bhojrab & A Chataroo Bras d'Eau, Mauritius*





# *MITRA Preliminary work: Antenna V2 18.02.2014*



*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014*

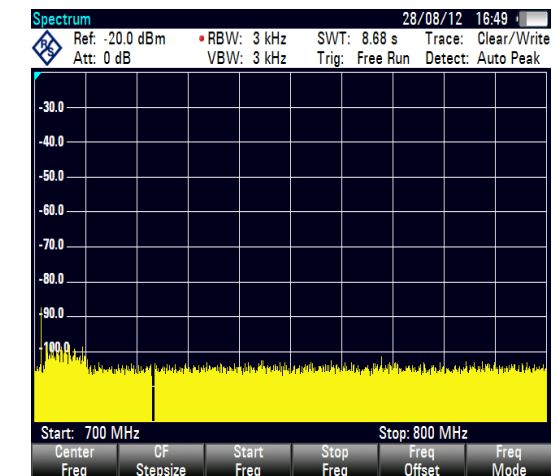
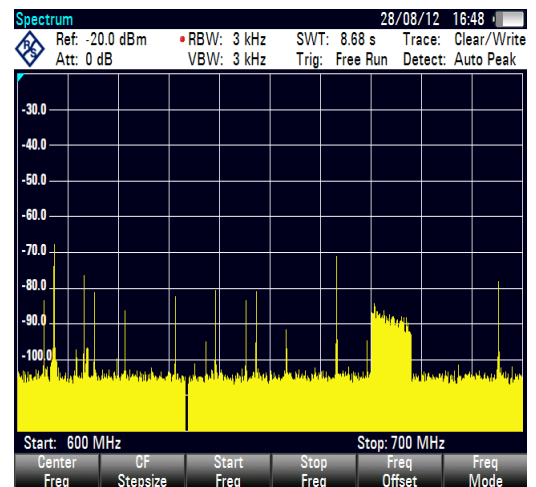
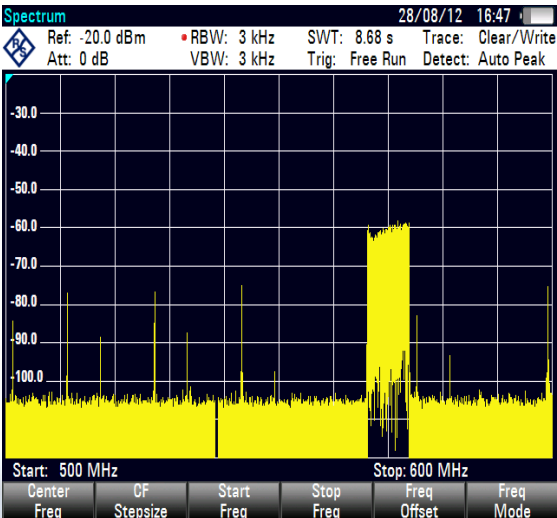
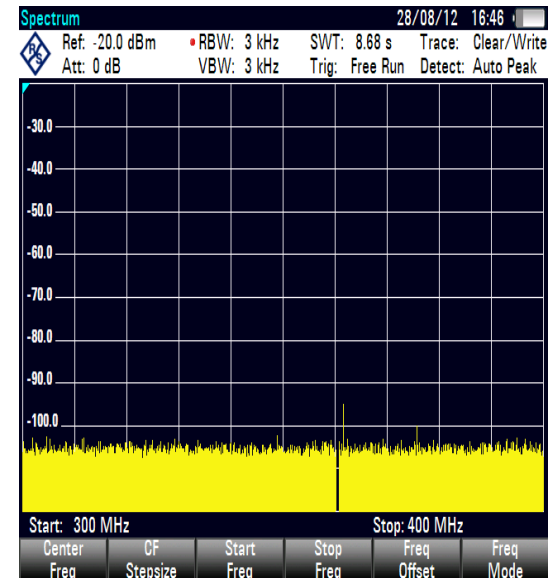
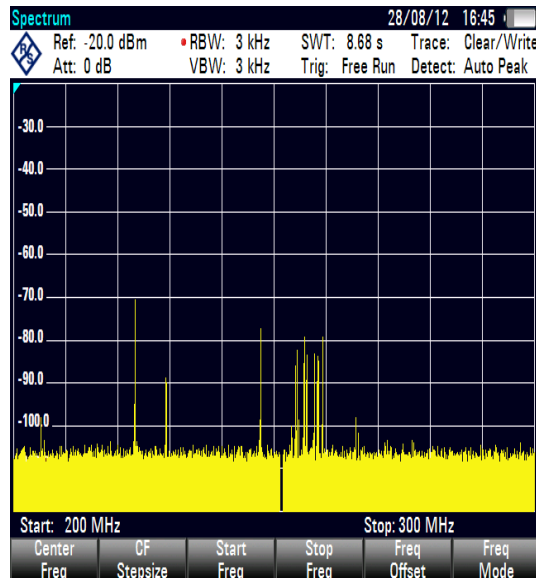
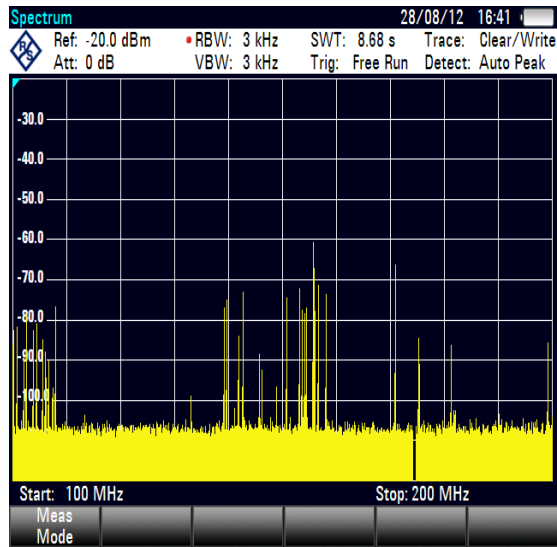
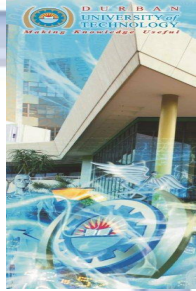
*Girish Kumar Beeharry*

*K Bhojrub & A Chataroo Bras d'Eau, Mauritius*





# MITRA Preliminary work: back end: Durban



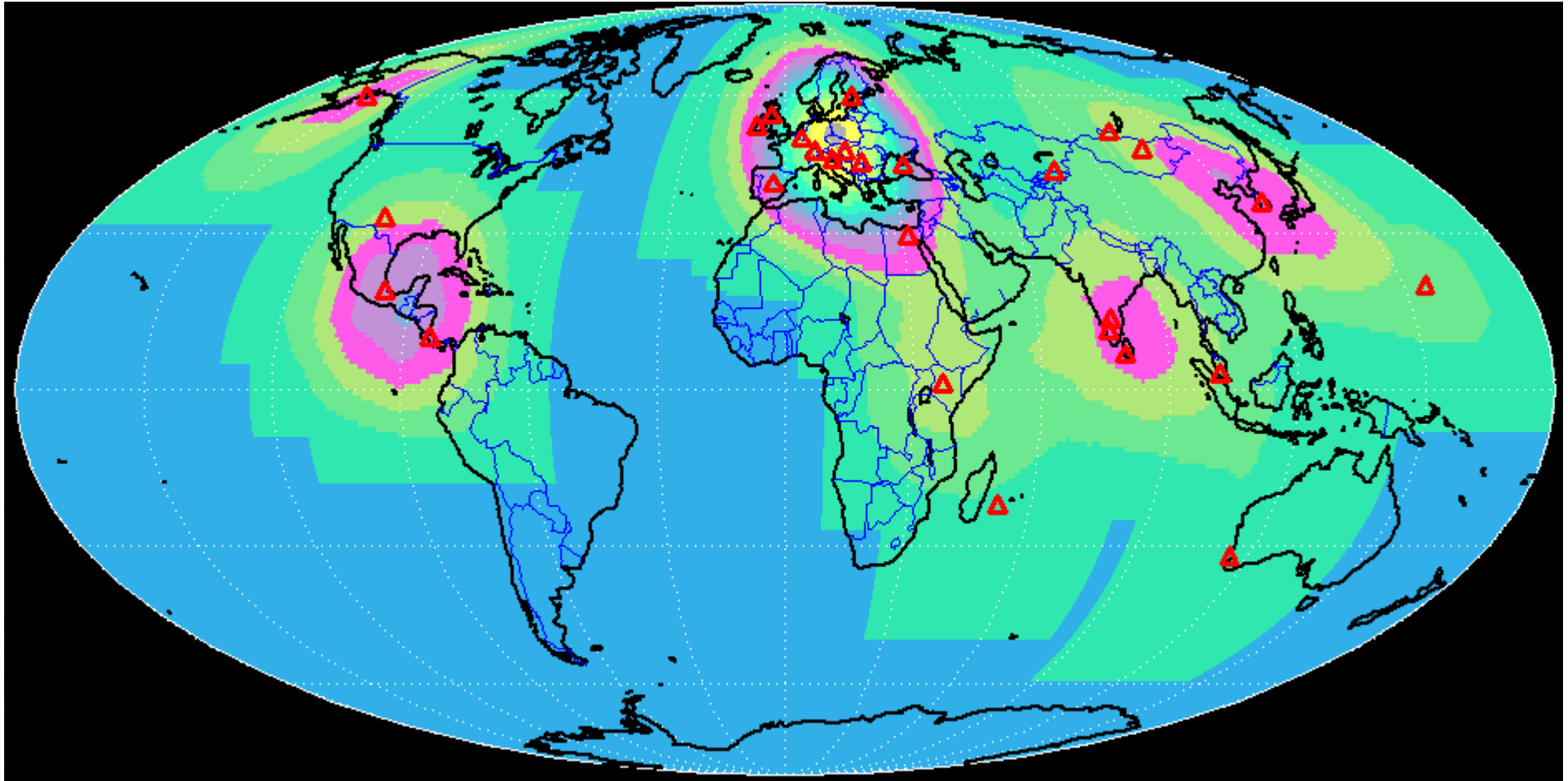
MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014

Girish Kumar Beeharry

Dominique Ingaia @DUT



# *MITRA Preliminary work: Interference Mauritius*



*C.Monstein 2013*

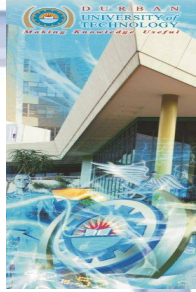
*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014*

*Girish Kumar Beeharry*

*Dominique Ingala @DUT*



# *MITRA Preliminary work 16 antenna array Durban*



S. MacPherson,  
G. van Vuuren,  
D Ingala DUT  
2013

*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014  
Girish Kumar Beeharry*



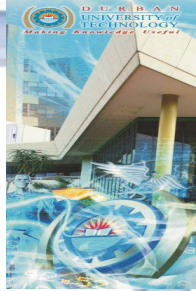


# *MITRA Preliminary work 16 antenna array Mauritius*



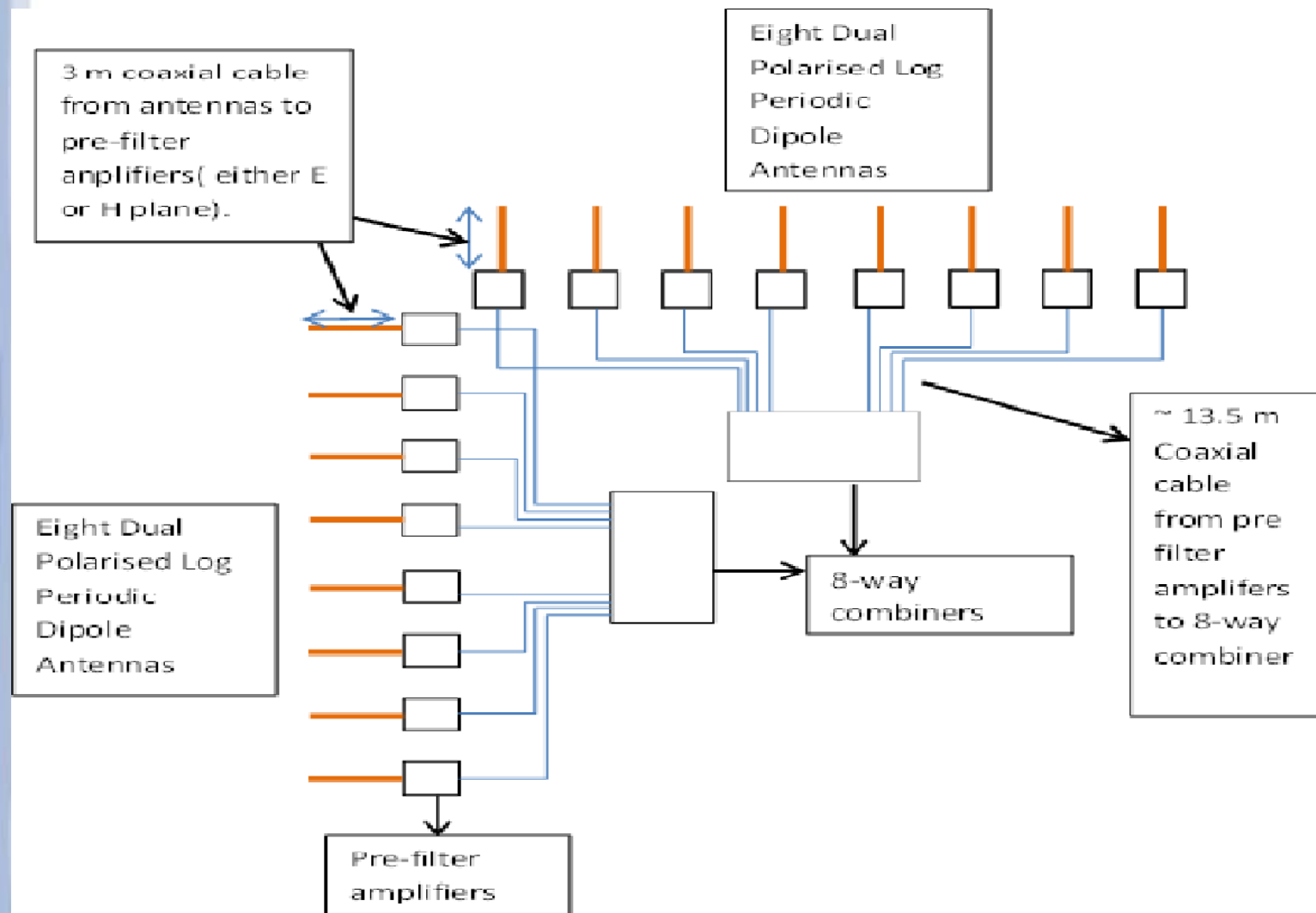
J. Shibchurn  
G.K. Beeharry  
& MRT team  
2013

*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014  
Girish Kumar Beeharry*



# MITRA Preliminary work 16->64 antenna array March 2014

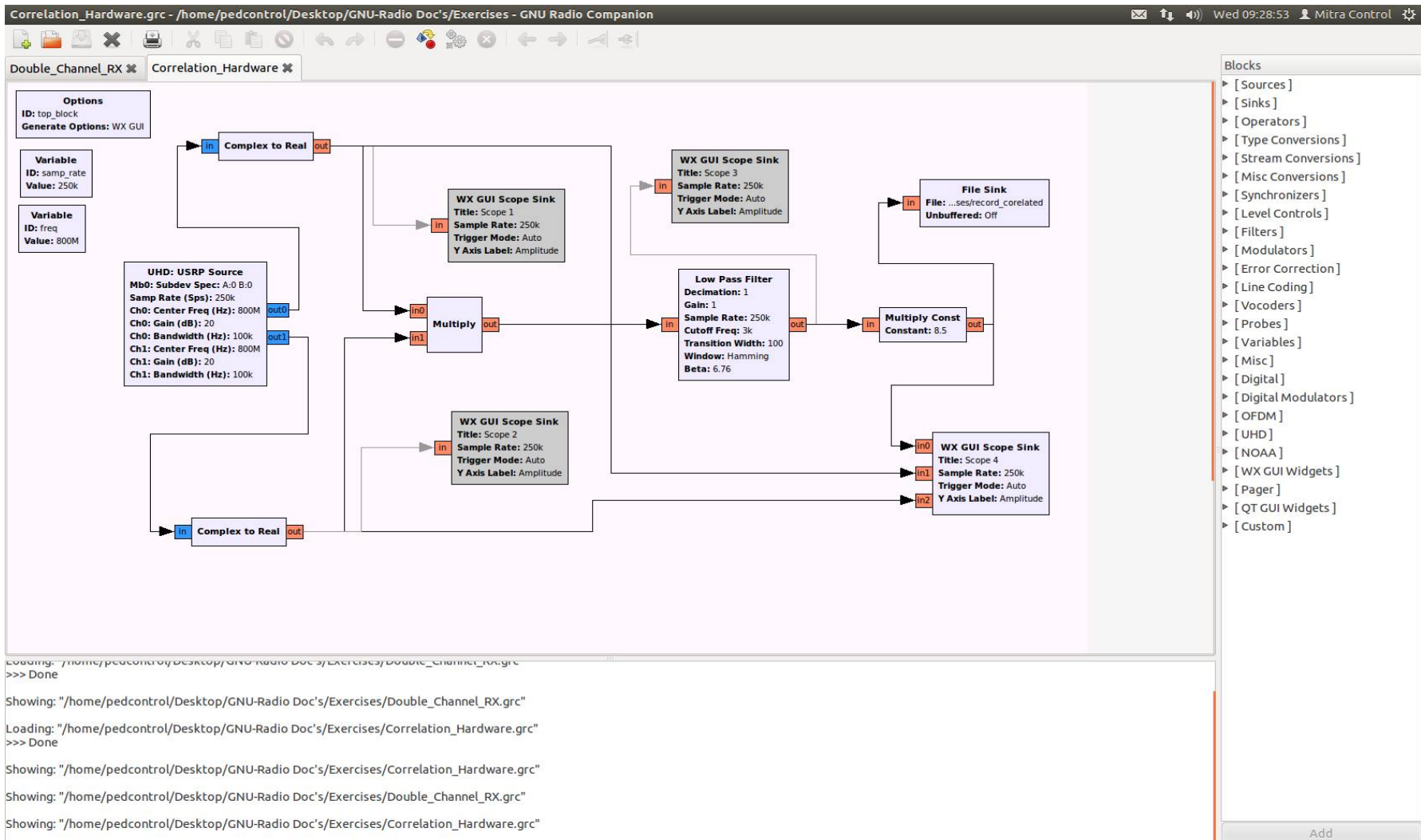
C.L. Bissessur  
& MRT team  
2013



MFAA All hands on meeting AsSTRON Dwingeloo 2<sup>nd</sup> April 2014  
Girish Kumar Beeharry



# MITRA Preliminary work: USRP control using GNU Radio Companion

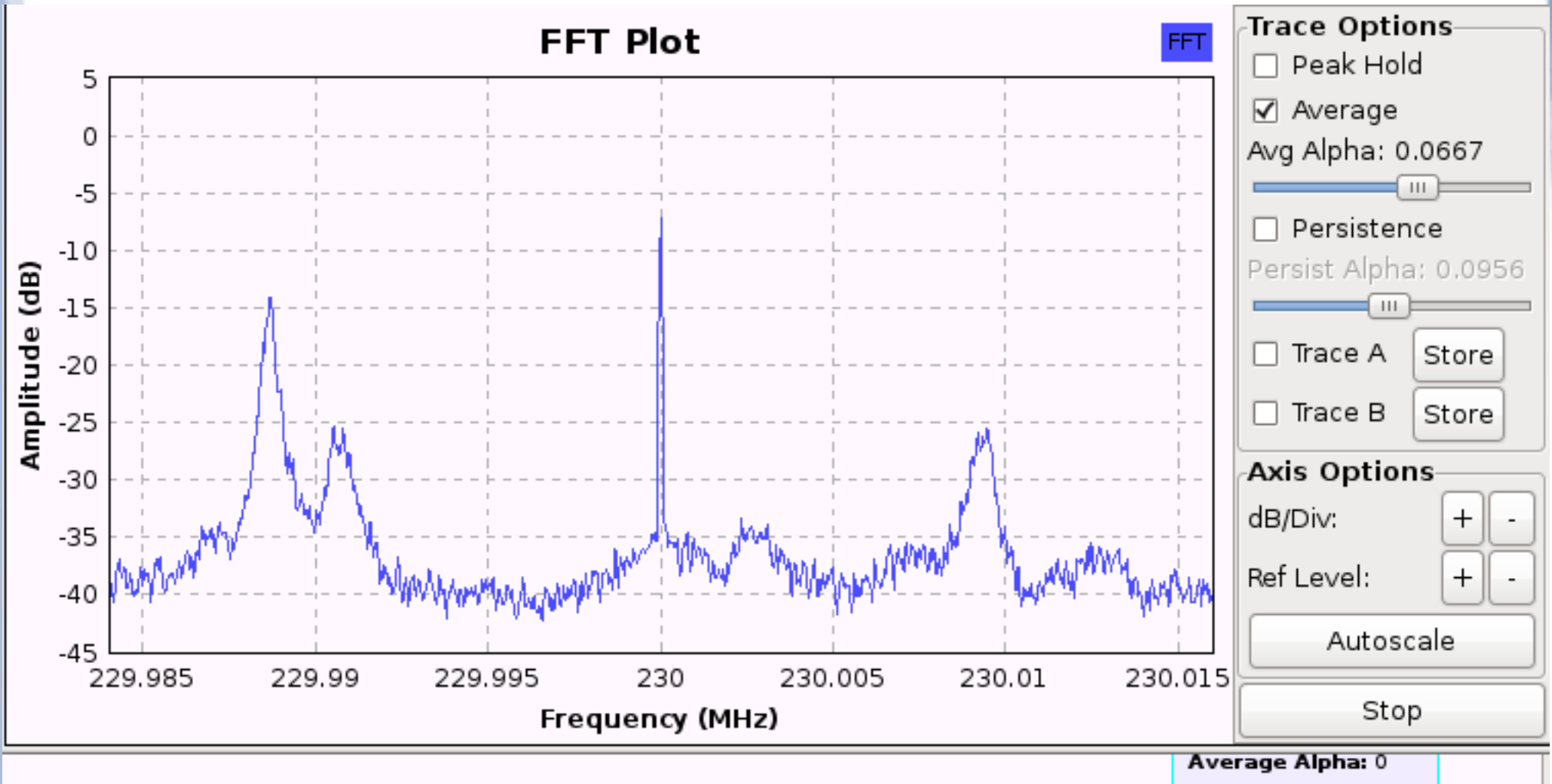
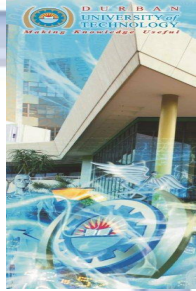


MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014  
Girish Kumar Beeharry





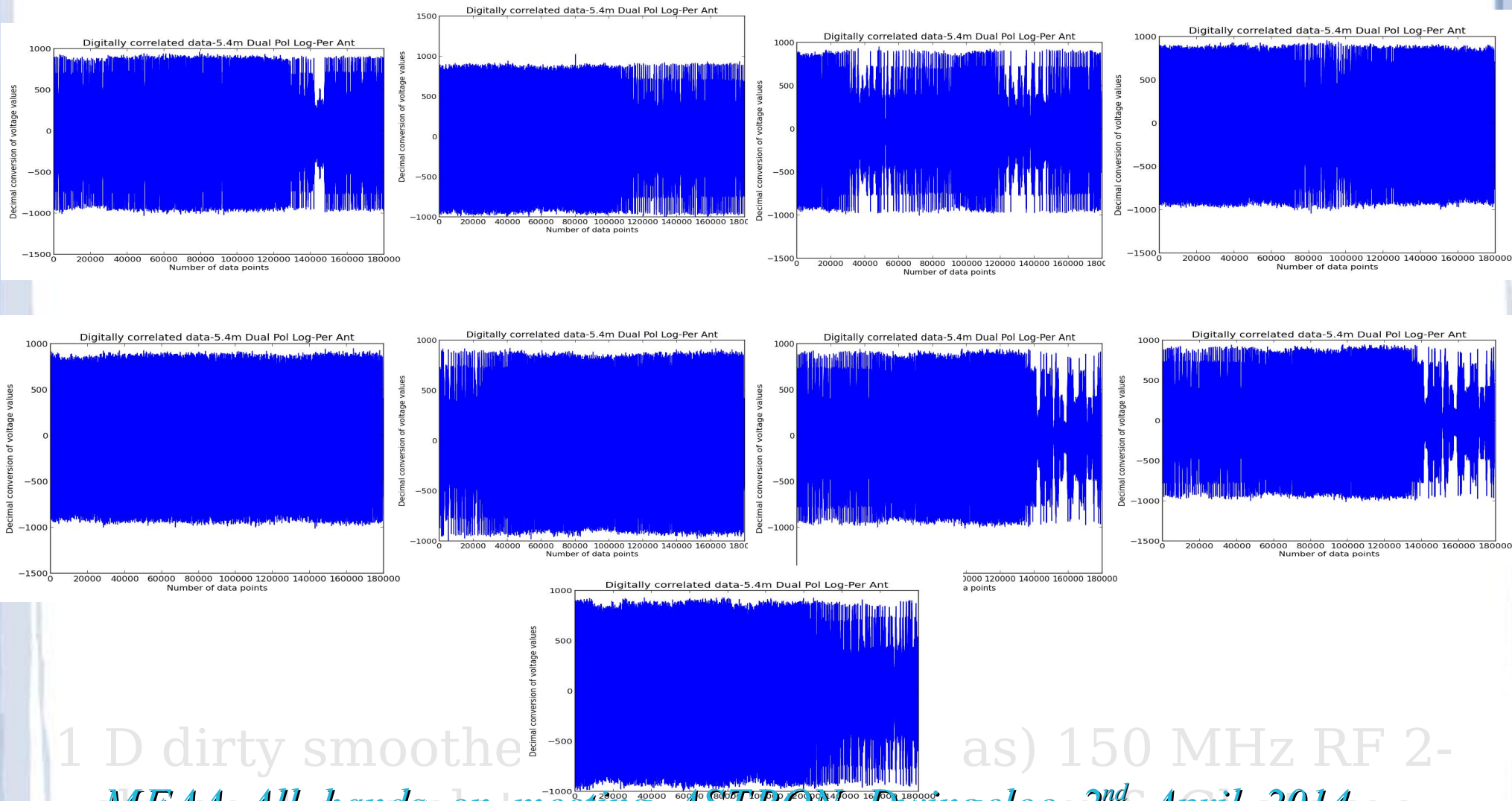
# MITRA Preliminary work: FFT



MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014  
Girish Kumar Beeharry



# MITRA Preliminary work 15 min obs files 21.02.2014



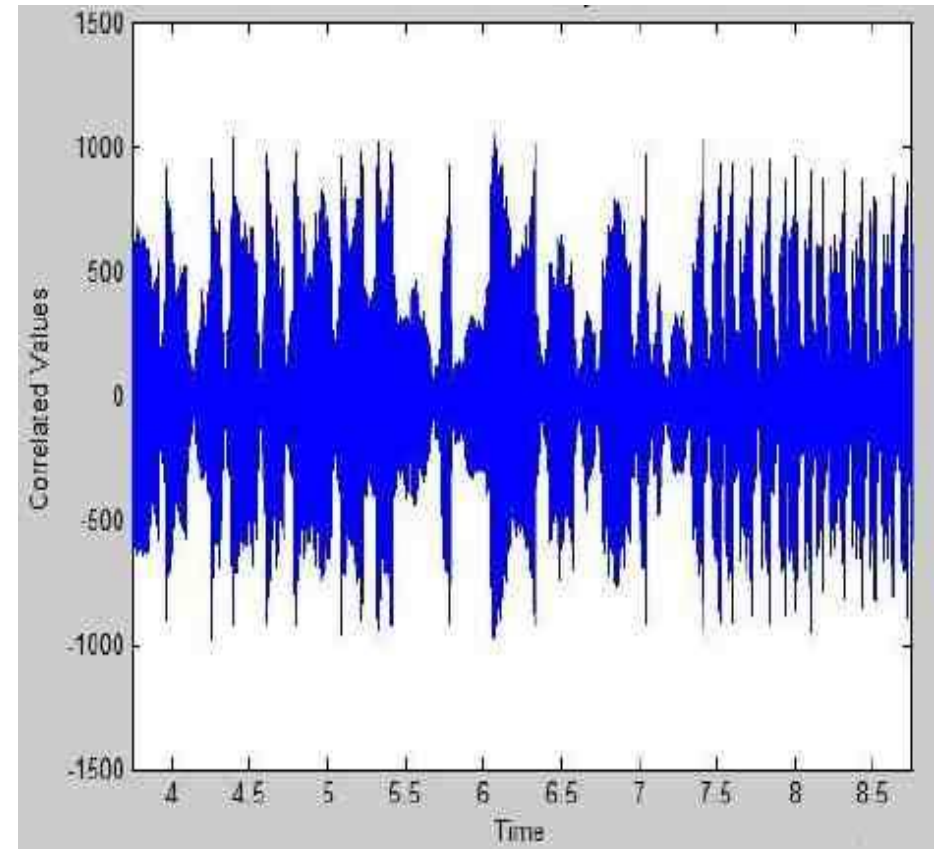
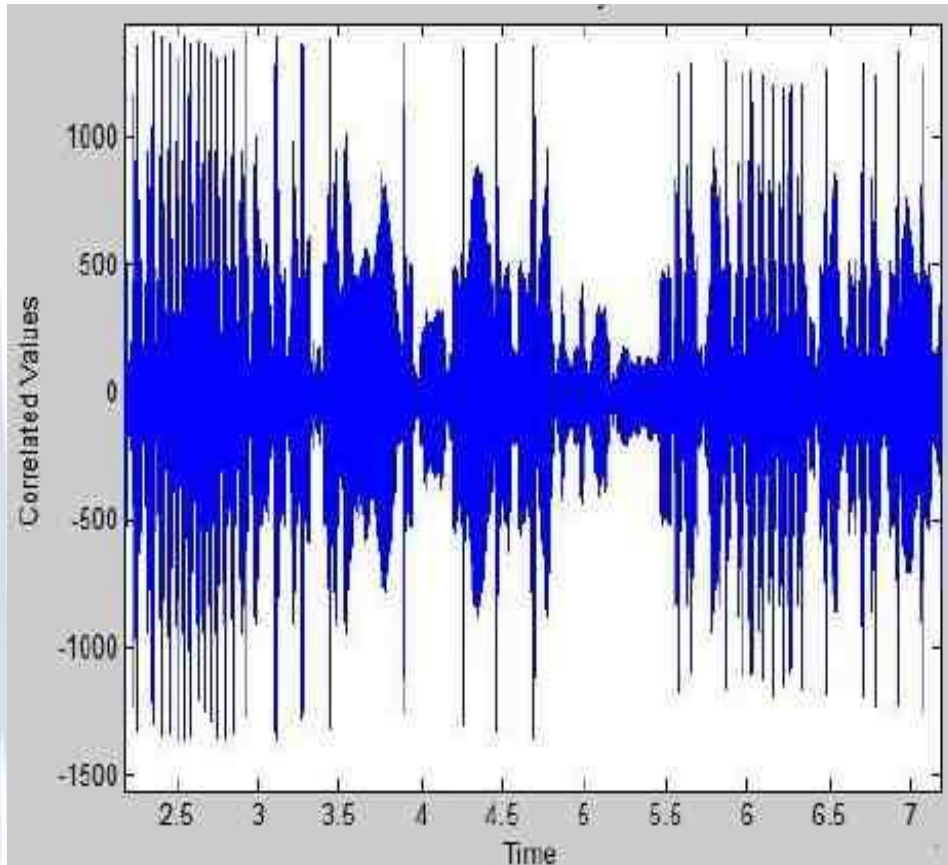
1 D dirty smoothed as) 150 MHz RF 2-

MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014

Girish Kumar Beeharry

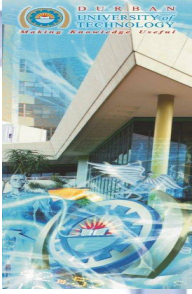


# *MITRA Preliminary work antenna V1 31.03.2014 (Betchoo) Pictor A 150 MHz & Hydra A 408 MHz*



1 D dirty smoothed scan (8 antennas) 150 MHz RF 2-  
*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014*  
*Girish Kumar Beeharry*





# ***MITRA Preliminary work: Recent relevant software***

Software correlation on CPU (Jheengut)

ADC card acquisition software CPU (Ginourie)

ADC card acquisition software GPU (Platel)

CALLISTO flare detector (Benfifi)

USRP1 programming (Mondon)

*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014  
Girish Kumar Beeharry*



# *MITRA Preliminary work: Recent & future*

Design & construction of a 16 channel receiver  
(Bhoyrub & Chataroo 2011-12}

Front end

Construction of 2 groups, with 8 antennas per group  
(Shibchurn 2012-13) May be extended to 8 x 8.

Set up of optical fibre network (Armoogum 2012-13)

Back end

Integration of receiver & USRP programming using  
GNU Radio companion (N.Pirthee 2012-13, Prayag)

*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014*

*Girish Kumar Beeharry*



# *MITRA Preliminary work: Correlator*



FX FPGA Correlator

Preliminary work on low cost FPGA on the USRP board

GPU array

ROACH board

Uniboard

*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014  
Girish Kumar Beeharry*





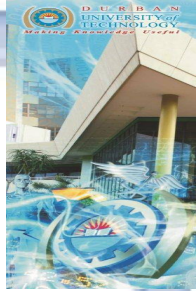
Item	Quantity	Cost (MUR)	Cost (ZAR)	Notes
DPLPDA	8	16,928	4,445	local made
PF Amp	8	11,520	3,032	Minicircuits
8way C	1	4,446	1,170	ZFSC-8-43+
RFOpto	1	57,440	15,116	High cost 57.5%
Opt Fib	50 m	4,800	1,253	Cost down/coax
DC pow.	1	4,800	1,263	
8 A1pol		99,934	26,299	
8A 2 pol		182,940	48,143	
<u>64 G 512 A</u>		<u>11,708,160</u>	<u>3,081,152</u>	

Item	Quantity	Cost (MUR)	Cost (ZAR)	Notes
------	----------	------------	------------	-------

RFO dem	1	38,400	10,105	68% cost 2.4 GHz
Hyb junct	1	640	168	Monitorings
LNA	3	4,480	337	3 stage amp
SBL-1 mixer	2	640	168	
BP Filter	2	960	253	Manuf local
16pow.com.	1	11,488	3,023	ZC16 PD-252
8 A1pol		56,608	14,896	
8A 2 pol		113,216	48,29,792	
<u>64 G 512 A</u>		<u>7,245,824</u>	<u>1,906,688</u>	



# Cost: Scenarios



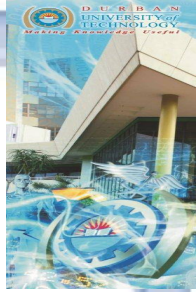
	Station 512 antennas	Station 1024 antennas	Relayive Sensitivity
Version 1 (MUR)	18,953,984	37,907968	1
Version 1 (ZAR)	4,987,740	9,975,480	1
Version 2 (MUR)	12,820,224	24,640,448	0.7
Version 2 (ZAR)	3,473,596	6,747,152	0.7
Relative sensitivity	0.7	1.0	

*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014  
Girish Kumar Beeharry*





# *People in Mauritius*

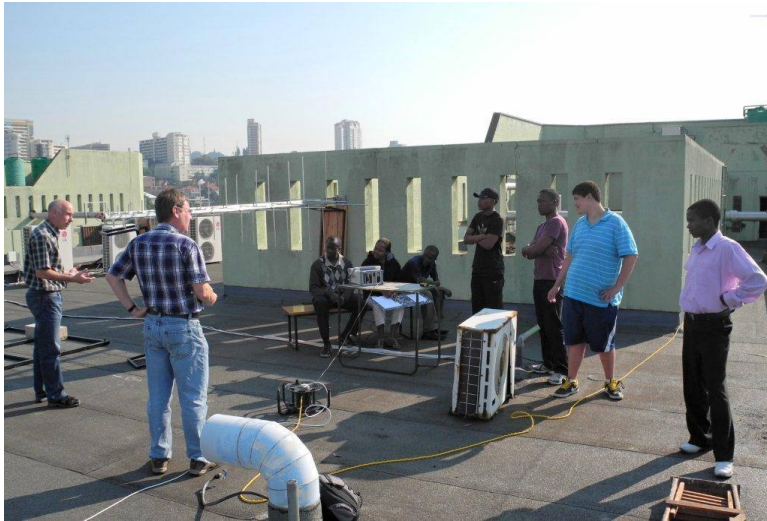
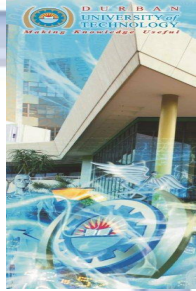


*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014  
Girish Kumar Beeharry*



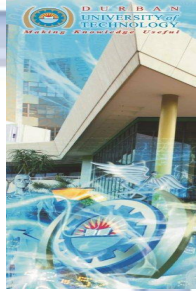


# *People in Durban South Africa*



*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014  
Girish Kumar Beeharry*



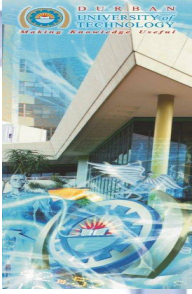


# *Future: 8x8 array*



*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014*  
*Girish Kumar Beeharry*





## *Future: Plans*

- Collaborations: DUT, SUN, CPO, Astron, SKA
- Training ground for African students, academics, engineers, technicians,
- Bursary programme
- Running our MSc

*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014*  
*Girish Kumar Beeharry*



***Thanks!***

*MFAA All hands on meeting ASTRON Dwingeloo 2<sup>nd</sup> April 2014*  
*Girish Kumar Beeharry*