

21cm CDR Outline Proposal

Dave McGinnis

Fermilab

April 9, 2009

Process

- Form Working Groups
 - Same as CDR Outline
- Develop Requirements
 - Input
 - Output
- Make Design Choices
 - not to be done before requirements
- Write-up Design

CDR Outline and Working Groups

- Science Case & Requirements
- Telescope Design
 - Antenna
 - Reflector
 - Feed
 - Analog Front End
 - Digital Front End
 - Beam Forming
- Data Handling
 - Storage
 - Calibration
 - Analysis
- Infrastructure
- Cost and Schedule

Schedule

- Working Groups formed by April 23.
- Science Requirements written by May 1
- Sub-system requirements by May 15
- Design Choices completed July 15
- Write-up Completed September 1
 - Ready for Fall Proposal Season

General Requirements

General Requirement Formulae for the 21cm Cylindrical Radio Telescope

Dave McGinnis
April 7, 2009

Frequency:

$$F(z) = \frac{1.4\text{GHz}}{1+z} \quad (1)$$

Frequency resolution:

$$\Delta F(z, \Delta z) = F(z) \frac{\Delta z}{1+z} \quad (2)$$

where Δz is the required resolution in redshift.

Feed Spacing¹

It is assumed that the feed antenna will have a wide field of view, especially for the polarization perpendicular to the length of the cylinder. For a phased array in which each feed is digitized separately, the first alias will show up on the horizon when the feed spacing d is given as:

$$d(\Delta\theta_D, z) = \frac{\lambda(F(z))}{1 + \sin\left(\frac{\Delta\theta_D}{2}\right)} \quad (3)$$

where λ is the wavelength at the required redshift, $\Delta\theta_D$ is the span in declination that the telescope must cover.

Number of Feeds¹

$$N_{feed}(\Delta\theta_D, z, \delta\theta_D) = \frac{\lambda(F(z))}{d(\Delta\theta_D, z) \delta\theta_D} \quad (4)$$

where $\delta\theta_D$ is the pixel size in declination.

Cylinder Length:

$$L(\Delta\theta_D, z, \delta\theta_D) = N_{feed}(\Delta\theta_D, z, \delta\theta_D) d(\Delta\theta_D, z) \quad (5)$$

Cylinder Width²

Since the sky will scan through the antenna beam of a cylinder, the width of a cylinder is determined by the amount of integration time needed to obtain the necessary amplitude resolution:

$$W_{cyl}(\tau_s, z, \Delta z, \Delta T_s, T_s, g, T_a) = \frac{1}{2\pi} \tau_s \Delta F(z, \Delta z) \lambda(F(z)) \left(\frac{\Delta T_s}{T_s + \frac{1}{g} T_a} \right)^2 \quad (6)$$

where τ_s is the total integration time of the survey, ΔT_s is the amplitude resolution, T_s is the average sky temperature, g is the antenna efficiency, and T_a is the amplifier noise temperature.

Number of Cylinders

The number of cylinders is determined by the resolution required in right ascension

$$N_{cyl}(\tau_s, z, \Delta z, \Delta T_s, T_s, g, T_a) = \frac{\lambda}{\Delta\phi_R W_{cyl}(\tau_s, z, \Delta z, \Delta T_s, T_s, g, T_a)} \quad (7)$$

where $\Delta\phi_R$ is the required resolution in right ascension.

Amplifier Gain and Phase Variation.

If the gains of the feeds are not calibrated against each other, a point source will not be localized in the pixel map. The level of pixel noise referenced to the signal level of a point source is given as:

$$\frac{\Delta P_{rms}}{P_{psf}} = \frac{\Delta g_{rms}}{\sqrt{N_{feed}}} \quad (8)$$

where Δg_{rms} is the rms variation in gain in the amplifiers along a cylinder. Similarly for phase noise

$$\frac{\Delta P_{rms}}{P_{psf}} = \frac{\Delta\psi_{rms}}{\sqrt{N_{feed}}} \quad (9)$$

where $\Delta\psi_{rms}$ is the rms variation in phase in the amplifiers along a cylinder.

¹ "Phased Array Antenna," D. McGinnis, November 2007, <http://projects-docdb.fnal.gov:8080/cgi-bin/ShowDocument?docid=471>

² "Integration Time for 21cm Parabolic Cylinder Radio Telescope," D. McGinnis, April 2009, <http://projects-docdb.fnal.gov:8080/cgi-bin/ShowDocument?docid=469>

Comments on Overall Concept

- For a given amplitude sensitivity, the width of the cylinders controls the speed of the survey
 - Narrow cylinders -> fast survey
- The concept of analog summing pairs of adjacent feeds before digitization is not viable because of severe alias side lobes
 - See <http://projects-docdb.fnal.gov:8080/cgi-bin/ShowDocument?docid=474>
 - Because of the large bandwidth, we need a better alias lobe strategy
 - Operating at $d=\lambda/2$ at highest frequency requires a lot of channels
 - Operating at $d>\lambda/2$ at highest frequency reduces sky area because of alias unless feed antenna can shape the beam

General Requirement Table

Number	Requirement	Limit	Average	Limit	Unit	Parent Requirements								
1.01	Maximum Redshift	1.80	0.87	0.40										
1.02	Redshift Resolution	0.0169	0.0075	0.0042										
1.03	Center Declination	30.0	30.0	30.0	degrees									
1.04	Declination Span	180.0	80.0	26.8	degrees									
1.05	Declination Pixel Size	33.1	22.1	16.5	arc-Min									
1.06	Right Ascension Resolution	30.0	20.0	15.0	arc-Min									
1.07	Amplitude resolution	81.6	100.0	115.5	uK									
1.08	Survey Time		1		years									
1.09	Polarization Imbalance		-20		dB									
1.10	PSF calibration		-20		dB									
2.01	Minumum Antenna efficiency		80		%									
2.02	Maximum Sky Temperature		10		K									
2.03	Maximum Amplifier Noise Temp		50		K									
3.01	Center Frequency		750		MHz	1.01								
3.02	Frequency Span		500		MHz	1.01								
3.03	Average Frequency Resolution		3.0		MHz	1.02	3.01							
3.04	Feed Spacing		24.3		cm	1.04	3.01							
3.05	Number of Digital Channels per Cylinder per Polarization		256			1.05	3.01	3.04						
3.06	Number of Feed Antenna per Cylinder per Polarization		256			3.05								
3.06	Length of Cylinder		62.3		meters	3.04	3.05							
3.07	Width of Cylinder		11.5		meters	1.07	1.08	2.01	2.02	2.03	3.01	3.03		
3.08	Number of cylinders		6.0			1.06	3.01	3.07						
3.09	RMS Amplifier Gain Variation		0.33		dB	1.10								
3.10	RMS Amplifier Phase Variation		4.58		degrees	1.10								

Writeup for formulae can be found in "General Requirement Formulae for the 21cm Cylindrical Radio Telescope," Dave McGinnis, April 2009

<http://projects-docdb.fnal.gov:8080/cgi-bin/ShowDocument?docid=473>

Collaboration Tools

- Setup a Google Account
 - Name: crt21cmcollab@gmail.com
 - Password: 21cmUser
- Google Accounts contain:
 - Web page (<http://www.google.com/ig>)
 - Web site (<http://sites.google.com/site/crt21cmcollab/>)
 - Calendar (<http://www.google.com/calendar/>)
 - Documents (<http://docs.google.com/>)
 - Text Files, PDF files, Spreadsheets, Presentations, etc.
 - Mail (<http://mail.google.com/>)

Web Page

iGoogle - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://www.google.com/ig?hl=en&refresh=1

Most Visited Fermilab Java SDSS Weather CERN Slot Array Simulation ... 21cmcollab

Web Images Maps News Video Gmail more

crt21cmcollab@gmail.com | Classic Home | My Account | Sign out

iGoogle

Google Search I'm Feeling Lucky

Advanced Search
Search Preferences
Language Tools

Get artist themes | Change theme from Stars | Add stuff >

Home

- Gmail (1)
- World Clock
- Google Calendar
- Google Bookmarks

Chat

Search, add, or invite

- crt21cmcollab
Set status here ▾
- David McGinnis

Options ▾ Add friends

Google Bookmarks

[Add bookmark - Edit bookmarks](#)

Show label:

- [Crt21cm Collaboration Documents](#)
- [Crt21cm Collaboration Web Site](#)
- [Fermilab 21cm Document Database](#)

World Clock

New Clock:

- Casablanca:** 2:30:14 pm - Wednesday, 04-8-2009 x
- Central:** 9:30:14 am - Wednesday, 04-8-2009 x
- Paris:** 4:30:14 pm - Wednesday, 04-8-2009 x
- Sydney:** 12:30:14 am - Thursday, 04-9-2009 x
- New York:** 10:30:14 am - Wednesday, 04-8-2009 x

Google Calendar

« April 2009 »

S	M	T	W	T	F	S
29	30	31	1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	1	2
3	4	5	6	7	8	9

Tomorrow (Thu, Apr 9)

- 8:30am Collaboration Telecon

Tue, Apr 14

- 8:00am 21cm Feed Meeting

Showing events until 5/15. [Look for more](#)

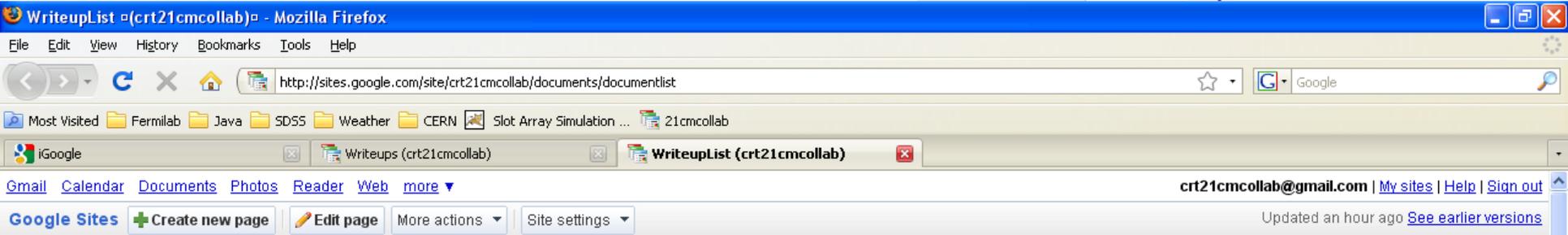
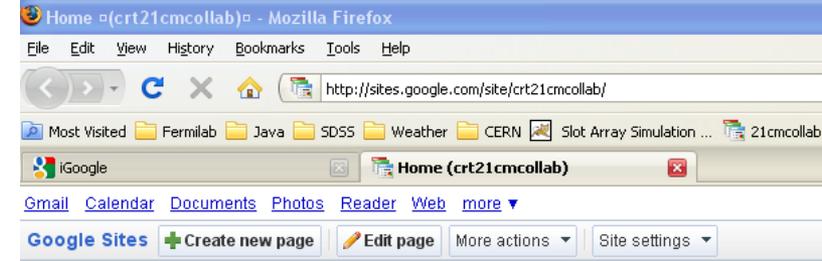
[Today](#) | [Add](#) [Options](#) ▾

Gmail (1)

[Inbox \(1\) - Compose Mail](#)

- David** - 21cm Requirements - Hi, I put the General 21cm Requirement table on a Google Apr 7

Web Site



crt21cmcollab

Navigation

- [Home](#)
- [WorkingGroups](#)
- [Writeups](#)
- [Meetings](#)
- [Sitemap](#)

[Edit sidebar](#)

[Writeups](#) >

WriteupList

crt21cmWriteups

1-29 of 29 Rows per page: 250 Go

Row ▲	Title	Author	Date	Type	Location
+ Add	all	all	all	all	all
1	Edit 3-D Intensity Mapper Project Description	Peterson	3/3/2008	Technical Notes	http://projects-docc
2	Edit 21-cm Baryon Acoustic Oscillation Survey	Scott Dodelson	3/3/2008	Technical Notes	http://projects-docc
3	Edit Directivity of a Parabolic Cylinder Antenna	David McGinnis	5/5/2008	Technical Notes	http://projects-docc
4	Edit Digitized response function of a phased array of Antennae	John Marriner	3/3/2008	Technical Notes	http://projects-docc
5	Edit Rates and Resolutions	Chris Stoughton	3/3/2008	Technical Notes	http://projects-docc

Calendar

Different Time Zones
Displayed

The screenshot shows the Google Calendar interface in Mozilla Firefox. The browser window title is "Google Calendar - Mozilla Firefox". The address bar shows the URL "http://www.google.com/calendar/render". The page header includes navigation links like "Gmail", "Calendar", "Documents", "Photos", "Reader", "Web", and "more". The user's email "crt21cmcollab@gmail.com" and status "Offline Beta" are displayed. The main content area shows a week view for "Apr 5 - 11 2009". The time zones "Chicago" and "GMT" are listed at the top of the calendar grid. The Chicago time zone is highlighted in blue. The GMT time zone is highlighted in yellow. A calendar event "8:30 - 9:30 Collaboration Telecon" is visible on Wednesday, April 8th. The event is represented by a blue bar with the text "8:30 - 9:30 Collaboration Telecon".

	Sun 4/5	Mon 4/6	Tue 4/7	Wed 4/8	Thu 4/9	Fri 4/10	Sat 4/11
Chicago							
GMT							
5am							
6am							
7am							
8am							
9am							
10am							
11am							