Portable Amateur Radio Telescope

Prof. Kedar Soni,
M.Sc. Radio Astronomy
Director, Abhinav Vidyalay, Dombivli
Ms. Pooja Bilimogga,
B.Sc. Physics
www.astro.abhinav.ac.in

PART Objectives

- Easy-to-make and **affordable** (< Rs.5000) RT
- **Mobile** – useful for science communicators
- Students (High school onwards) can build and use to **learn** radio physics & astronomy skills
- Advanced & serious amateurs can improve design to do useful **research**
- **Day time** astronomy in schools
- **… and then … just for fun**

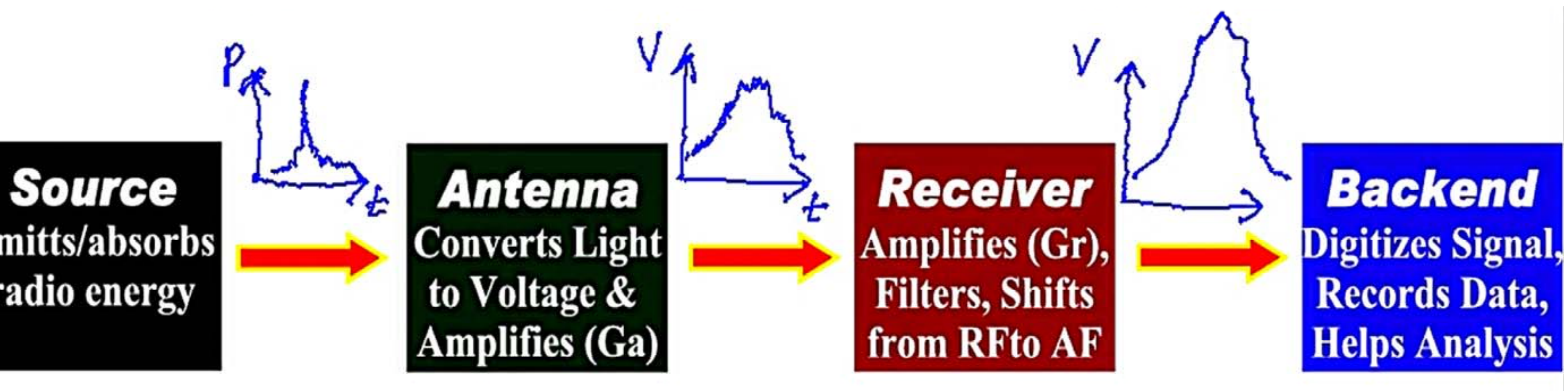
PART Constraints

- "**Hand-made**" induces uncomfortable errors
- Residences and industrial localities cause variety of **Radio Frequency Interference**
  - Tubes, fans, washing machines, drills, mobiles
- **Skill required** to analyze the signal
  - School students need physics teacher to guide
- Design prevents choosing frequency / band
- Testing / calibrating very difficult

Schematic of an RT

- A radio telescope is

1. An antenna which converts light into voltages
2. A receiver which converts radio frequency signal to audio/intermediate frequency and filters noise and amplifies
3. Backend is s/w or h/w which analyzes data to find power, spectrum, …

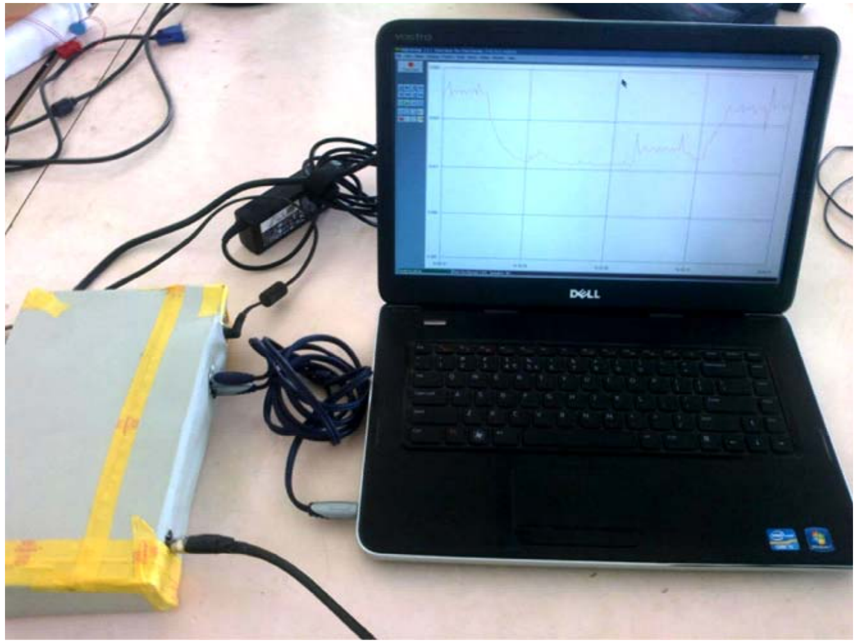


PART Front-end

- **Copper helix** mounted on PVC pipe for support
- Adapted to an optical telescope **Alt-Az mount**

PART Backend

- Signal from helix transferred to Digital TV **Set Top Box** via co-axial cable (75 Ohm)
- Audio o/p of STB to **PC sound card**
- Sound card input recorded using **charting software (Radio Sky Pipe)**
- Analyzed with **Excel** & **MathCAD**



Choice of Frequency & Antenna

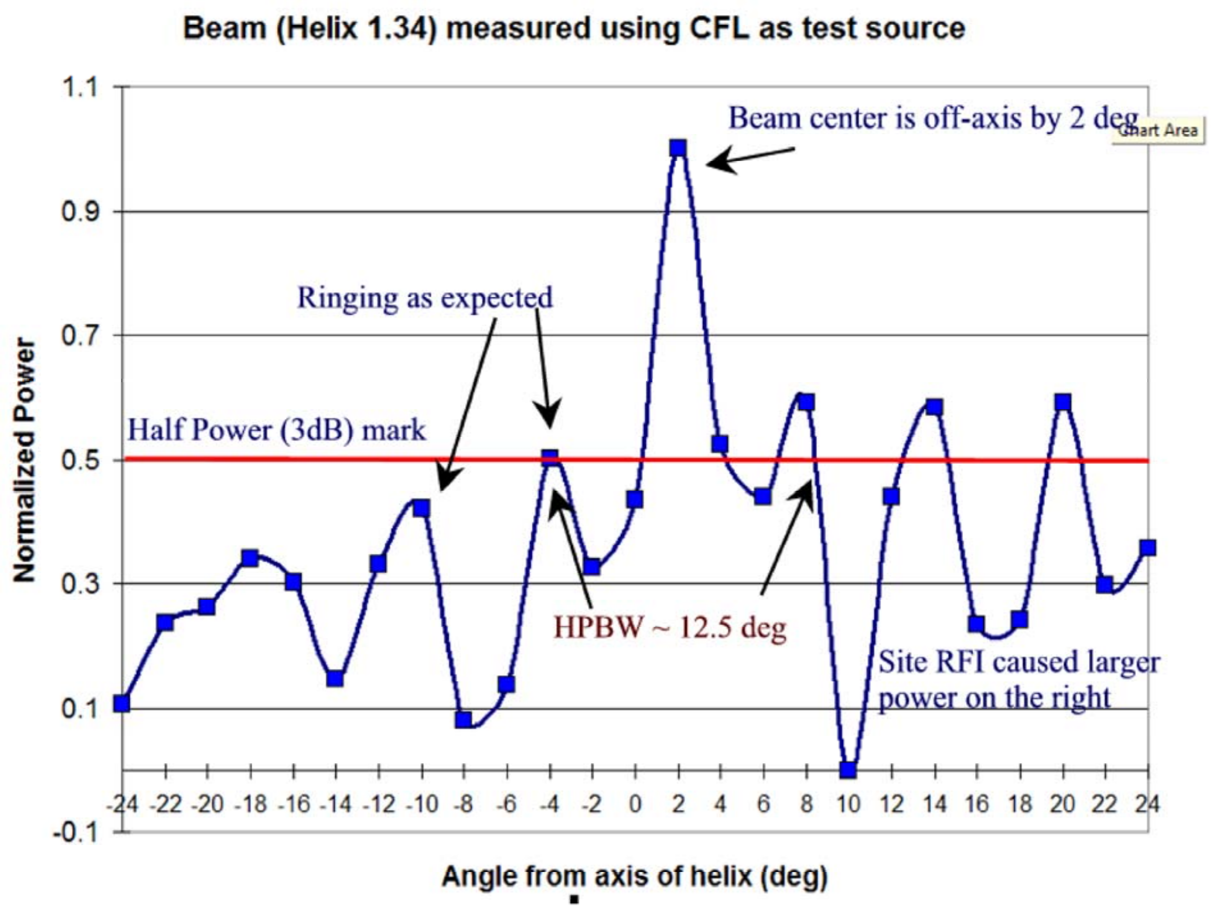
- Chose frequency around ~ 1.4 GHz as
  - One of the most studied (**neutral H**)
  - Away from **mobile bands** (950 / 2400 MHz), radio FM or AM bands (< 100 MHz)
  - Digital TV **set top boxes available** in this band
- Many kinds possible, however,
  - Horns, **Dishes too bulky** to maneuver / carry
  - Feeds, **Dipoles, Yagi too small** to give good gain
  - **Helix** easy to build with good gain / directivity

Design of Helix

- Frequency – 1.34 GHz,   B/w – 155 MHz
- Turns – 23, hence good gain ~ 18 dB
- Circumference = Wavelength hence axial mode, i.e. directive
- FWHM (effective beam) ~ 26 deg
- Impedance not matched, hence power loss
- Beam offset (2 deg) due to tilt in ground plane

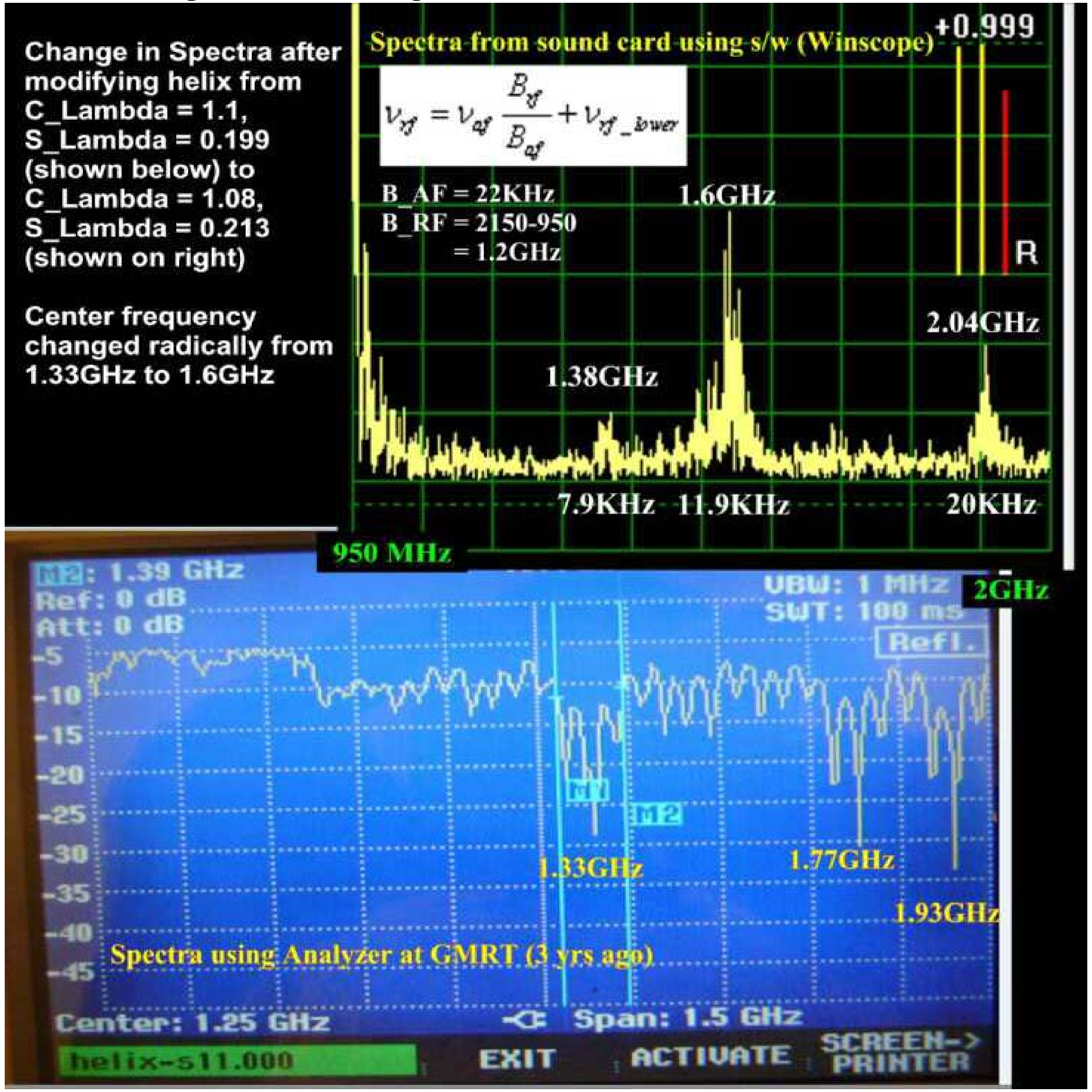
Measuring the beam

- CFL as test source (black body T ~ 6500 K)
- CFL kept at far field ($2D^2/\lambda$), i.e. > 15m
- Deflection observed for different angles
- HPBW ~ 12 deg??



Frequency Response

- Blue tested on spectral analyzer at GMRT
- Black on PC using Win-scope
- Designed ranges correspond
- RFI peaks at about 1.6 GHz due to 7KW UPS inverter at site



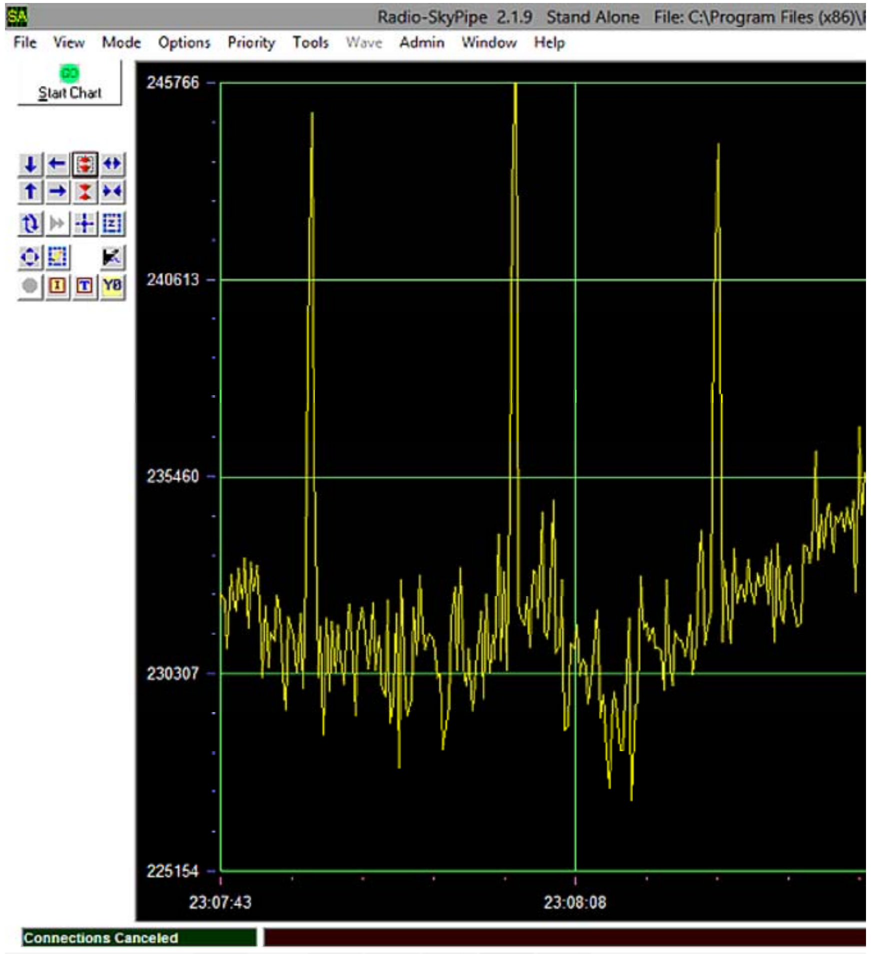
Receiver System

- The STB's are designed to take signal from the LNA / feed at 950-2150 MHz
- In absence of authentication, they only filter, amplify and down-convert L-band signal to audio (21KHz) / video (75 MHz)

- STB Noise temperature ~ 5-10K 0K
- PC Sound cards sample at different rates (8KHz – 48KHz), hence we can choose to ignore some of the bandwidth
- Sound cards have noise (T ~ few K)
- Sound cards catch PC activity (so keep PC clocking < 1 GHz)

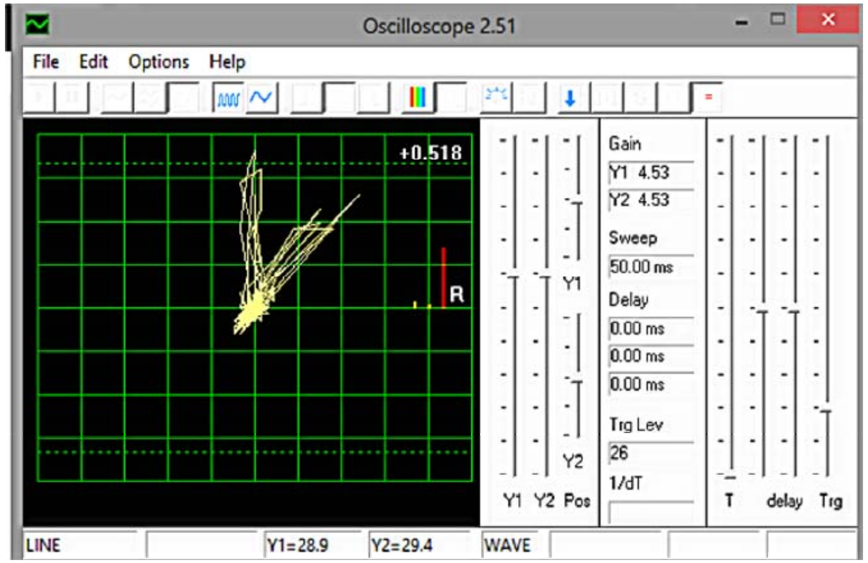
Software

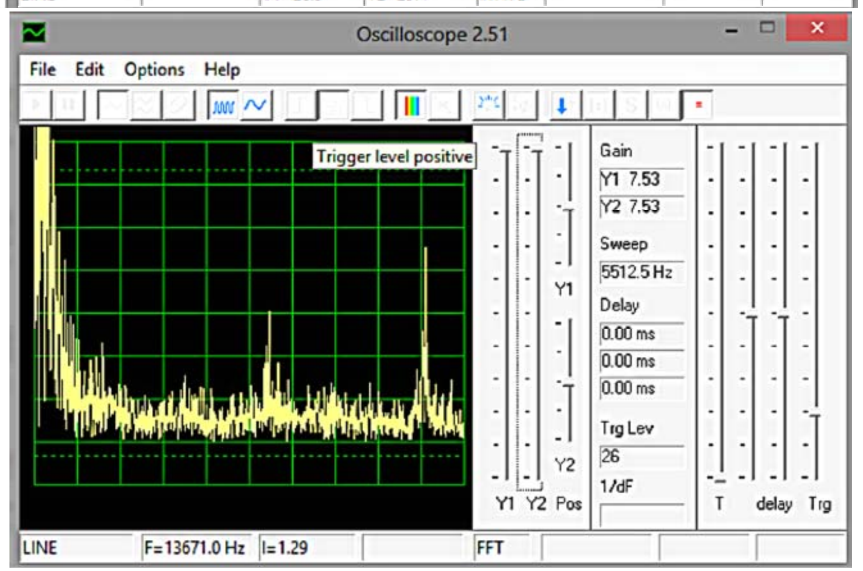
- Radio Sky Pipe II graphs the input signal as voltage or power (time series) with arbitrary y-axis values (even free version)
- You can change sampling rate from few ms to minutes
- Text data can be taken to MathCAD / Excel to analyze
- RSP Pro version costs ~ 5000/-



Software

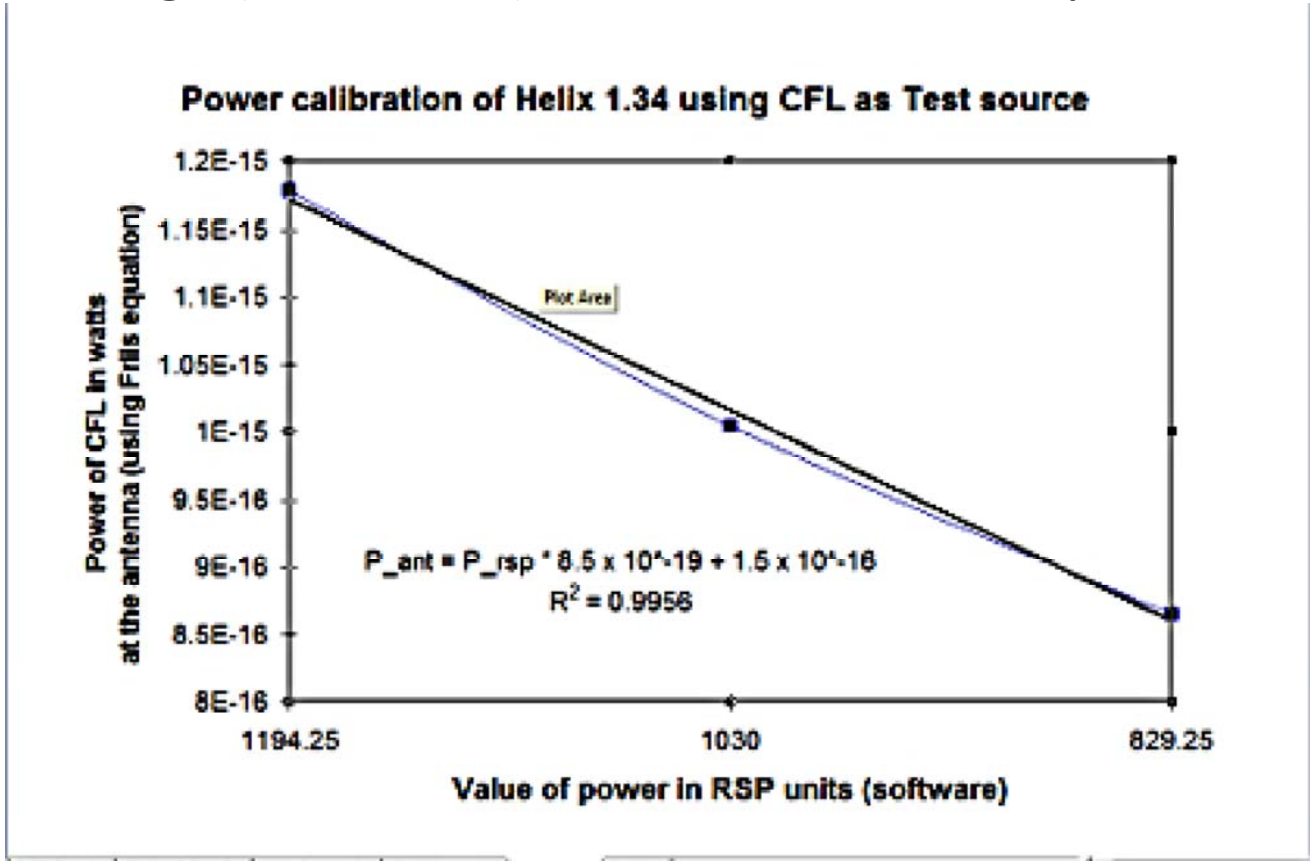
- Since the whole RT is mobile, cables tend to shift or come loose destroying signal correlation and making data value fluctuate wildly
- Digital oscilloscopes like Winscope (free) help monitor the phase of the signal and the audio spectrum





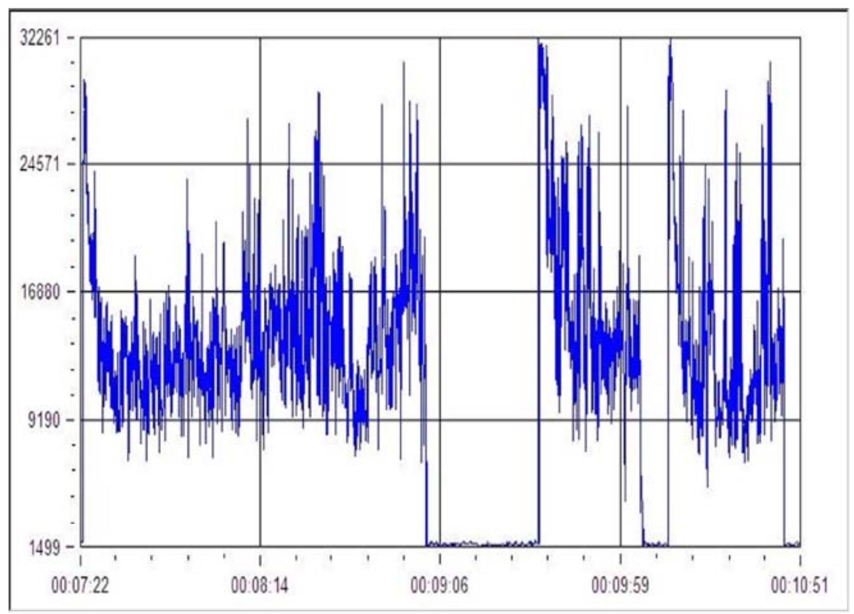
Power calibration

- CFL at different distances used find response of system, i.e. how much change (deflection) is seen for a certain power received



Results

- Observed – Quiet Sun, Solar flares, Nebulae, AGN, bright pulsars (objects up to a few Jansky)
- Spillover changes on a timescale of minutes (hence artifacts)
- RFI spikes are random
- Hence fast sampling and long integration resolves most



Some more data

- Pointing to the Sun (on and off) gives some change in average power
- This corresponds to a Flux of ~ 500 Jy for the Sun

Sun	start	end	average	deflection
on	17:21:33	17:21:41	238631	
off	17:22:01	17:22:10	237388	1243
on	17:23:04	17:23:13	237110	-278
off	17:23:28	17:23:39	241688	-4578
on	17:24:33	17:24:44	241228	-460
off	17:25:05	17:25:17	242083	-855
				-985.6

Challenges

- RFI most unpredictable and site dependant
- Faraday caging for receiver & better DSP
- Looks at Left Circular Polarization, though catches ½ the power; Objects give only 5-10% o/p in CP.
- Understanding signal, noise and DSP
- Large open ground for testing & calibration
- Noise source for accurate calibration

Possible directions

- Pointing not accurate, needs motorized mount (NEQ6???)
- Interferometer (2 helix) will get beam down to a few degrees
- Producing Sky maps at 1.4 GHz in LCP
- Observing Sun periodically

- … Well … in short … Sky is the LOWER Limit

- Visit us at ***astro.abhinav.ac.in***