Calibration in Radio Astronomy

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What is Calibration ?

Calibration typically involves measuring some parameter of a system using a known Input and the measured Output.

$O = P.I$ or $P = I^{-1}O$

($P \rightarrow$unknown parameter, I known, O measured).

Measured versus True visibilities

$V'_{ij} = G_{ij}(t,\nu).V_{ij} + \epsilon_{ij} + \eta_{ij}$

where, $G_{ij} = g_i.g_j^*$

$\epsilon_{ij} \rightarrow$ Offset, $\eta_{ij} \rightarrow$Noise

Note: V' is not a continuous visibility function as in imaging.
Also, remember that all the quantities are complex in general.

Determining Calibrations

Make sense when ϵ_{ij}, $\eta_{ij} \ll G_{ij}.V_{ij}$

Interested in $\mathbf{V_{ij}}$.

$G_{\text{ij}}(t,\nu) \approx G_{\text{ij}}(t).G_{\text{ij}}(\nu)$

Interested in lesser no. of variables.

Antenna based solutions.

Bandpass Calibration (g_ν)

Observe a strong Calibrator (flux=S).

$$V'_{\text{ij}}(t,\nu) = (g_i(t).g_i(\nu)).(g_j(t).g_j(\nu))^*.S \qquad (1)$$

$$V'_{\text{ij}}(t,\nu_0) = (g_i(t).g_i(\nu_0)).(g_j(t).g_j(\nu_0))^*.S \qquad (2)$$

ν_0 is the Ref. chan.

(1)÷(2):

Visibilities normalised w.r.t. a frequency channel.

$$V'_{\text{ij}}(t,\nu) \div V'_{\text{ij}}(t,\nu_0) = (g_i(\nu)/g_i(\nu_0)).(g_j(\nu)/g_j(\nu_0))^*$$

$g_i(\nu)/g_i(\nu_0)$ $\rightarrow$Bandpass calibration.

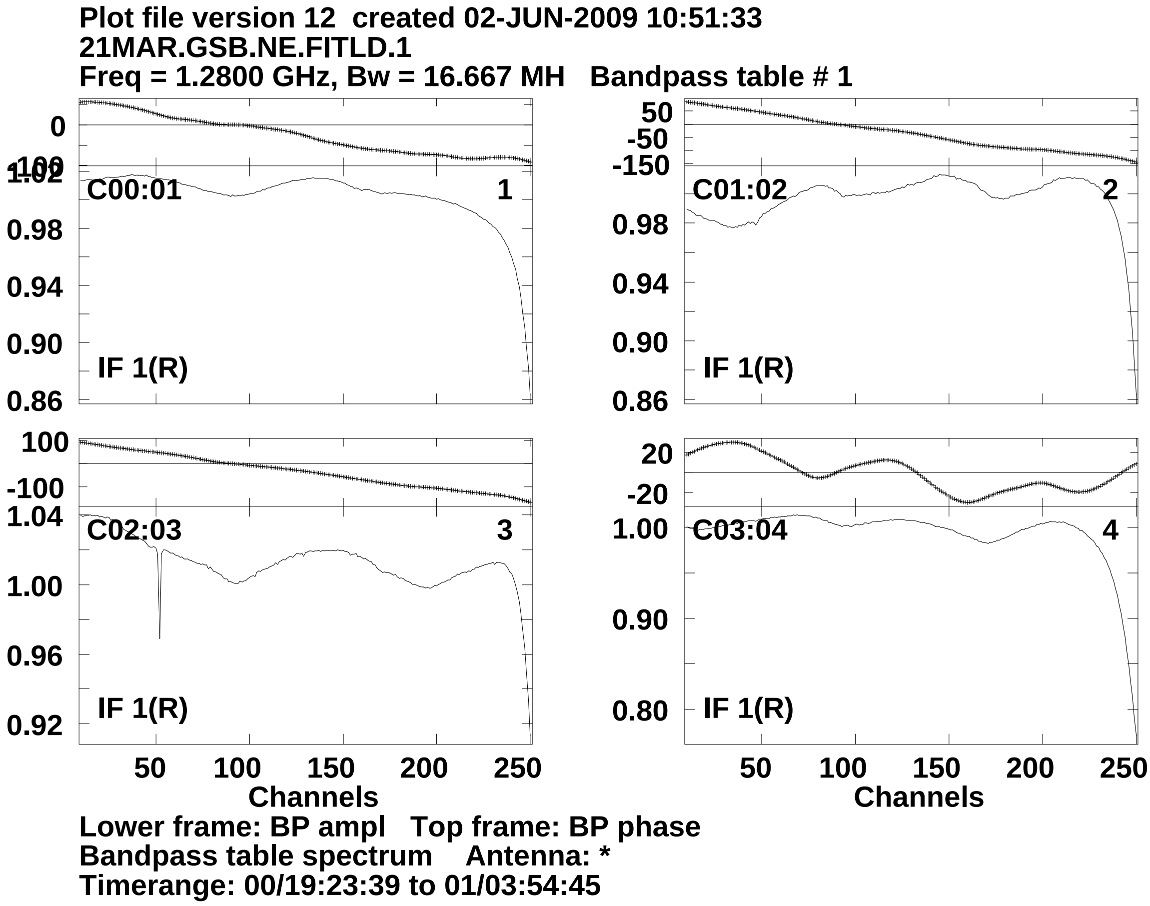

Figure 1. Typical Bandshape for GMRT antennas.

All the Freq. channels have prop. similar to ν_0.
Collapse Channels.

Calibration $g(t)$

Now $g(t,\nu) = g(t).g(\nu_0)$

$$V'_{\rm ij}(t) = g_i(t).g^*_j(t).S$$

Primary and Secondary calibrator:

Ionospheric phase Direction dependent.

Observe calibrator close to source.

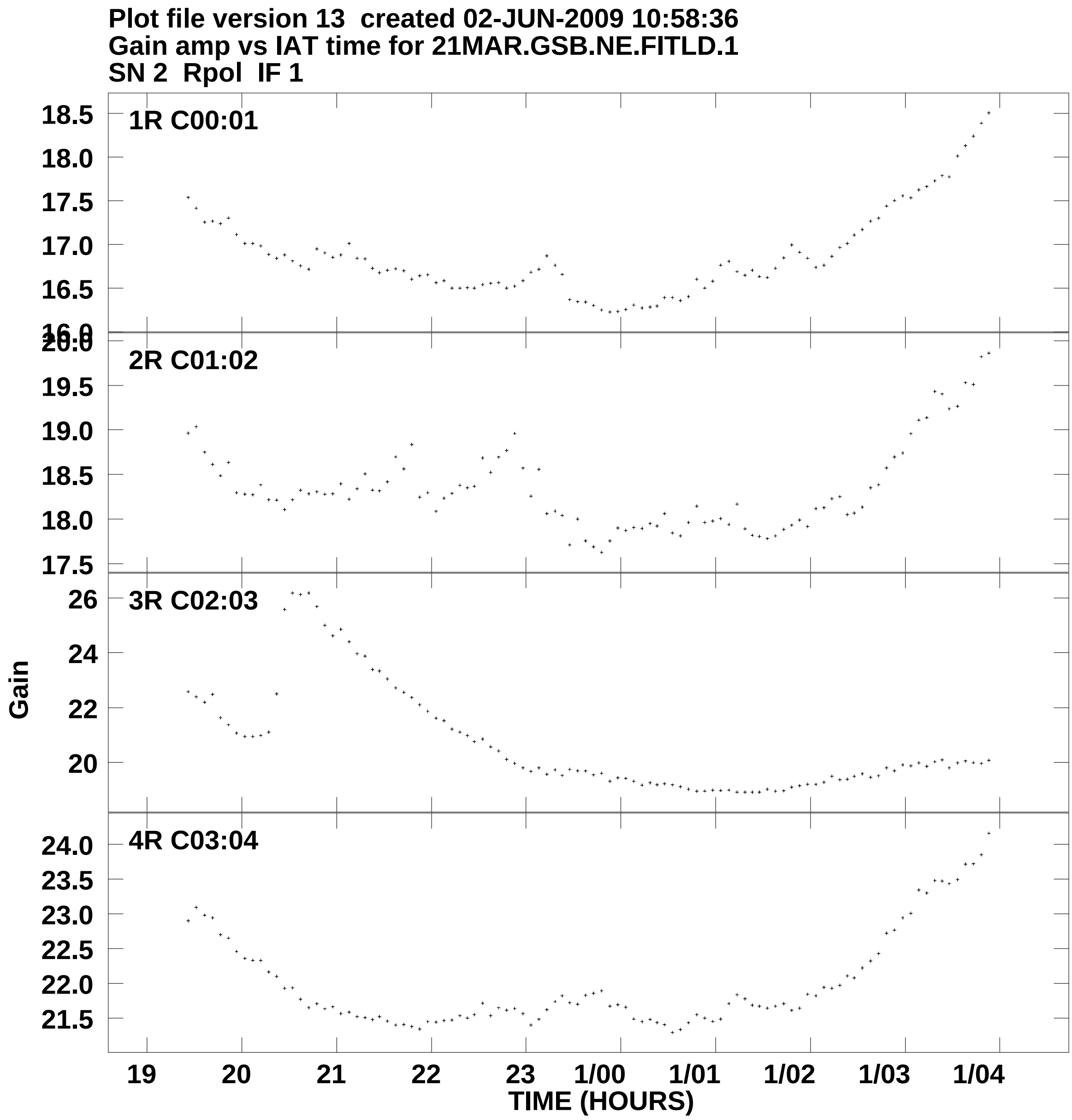

Figure 2. Gain amplitude of Antennas

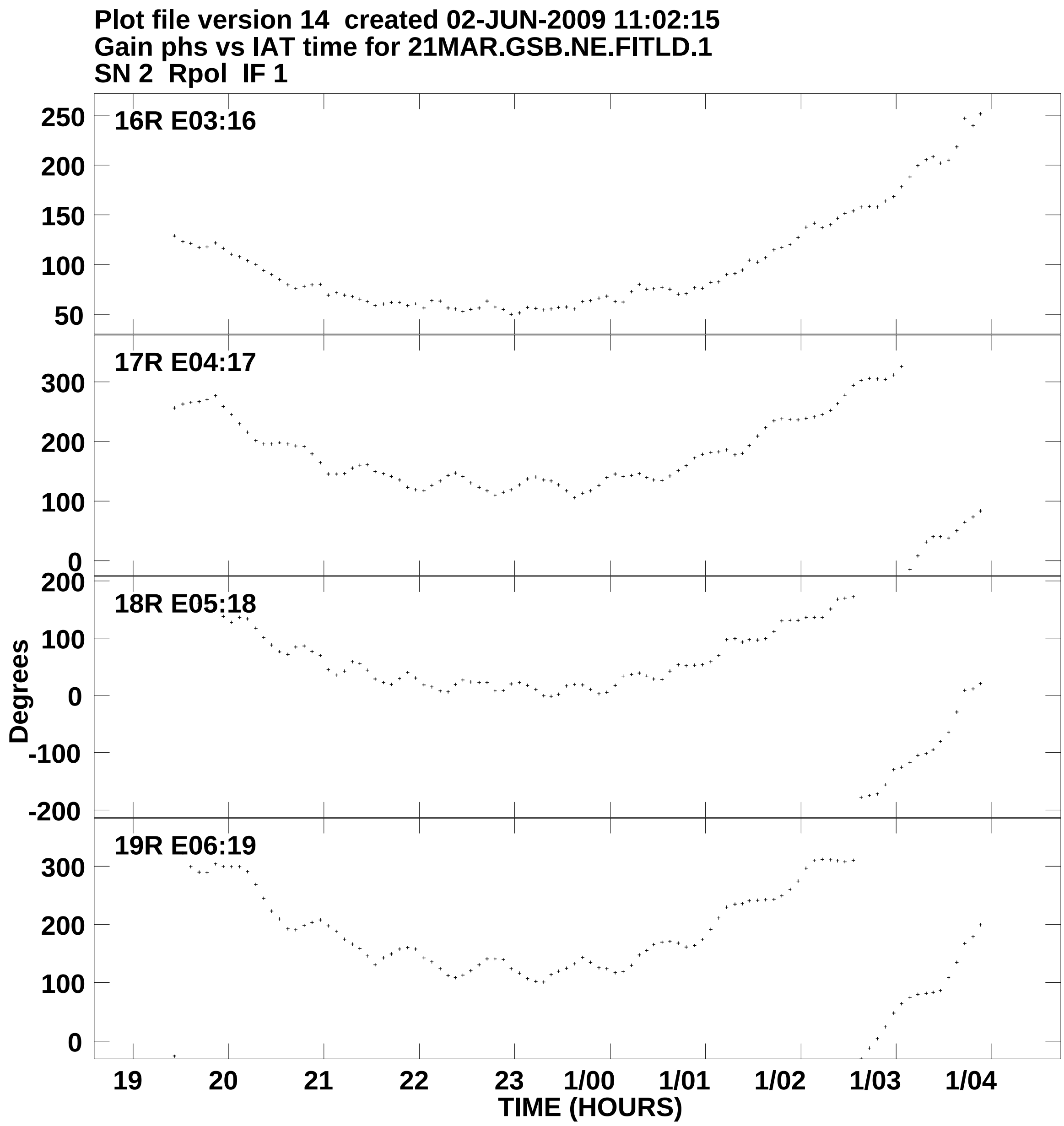

Figure 3. Antenna based Phases

Most calibrators Variable.

Determine Secondary flux densities using non-variable cal. (Primary).

Editing data

Certain techniques

Amplitude check.

(i) Stability of Phases(t) for calibrator.

(ii) Smooth variation of Amplitude and Phase for Source in time and frequency.

(iii) Visibility Amp. and Ph. for parallel handed Stokes should be close.

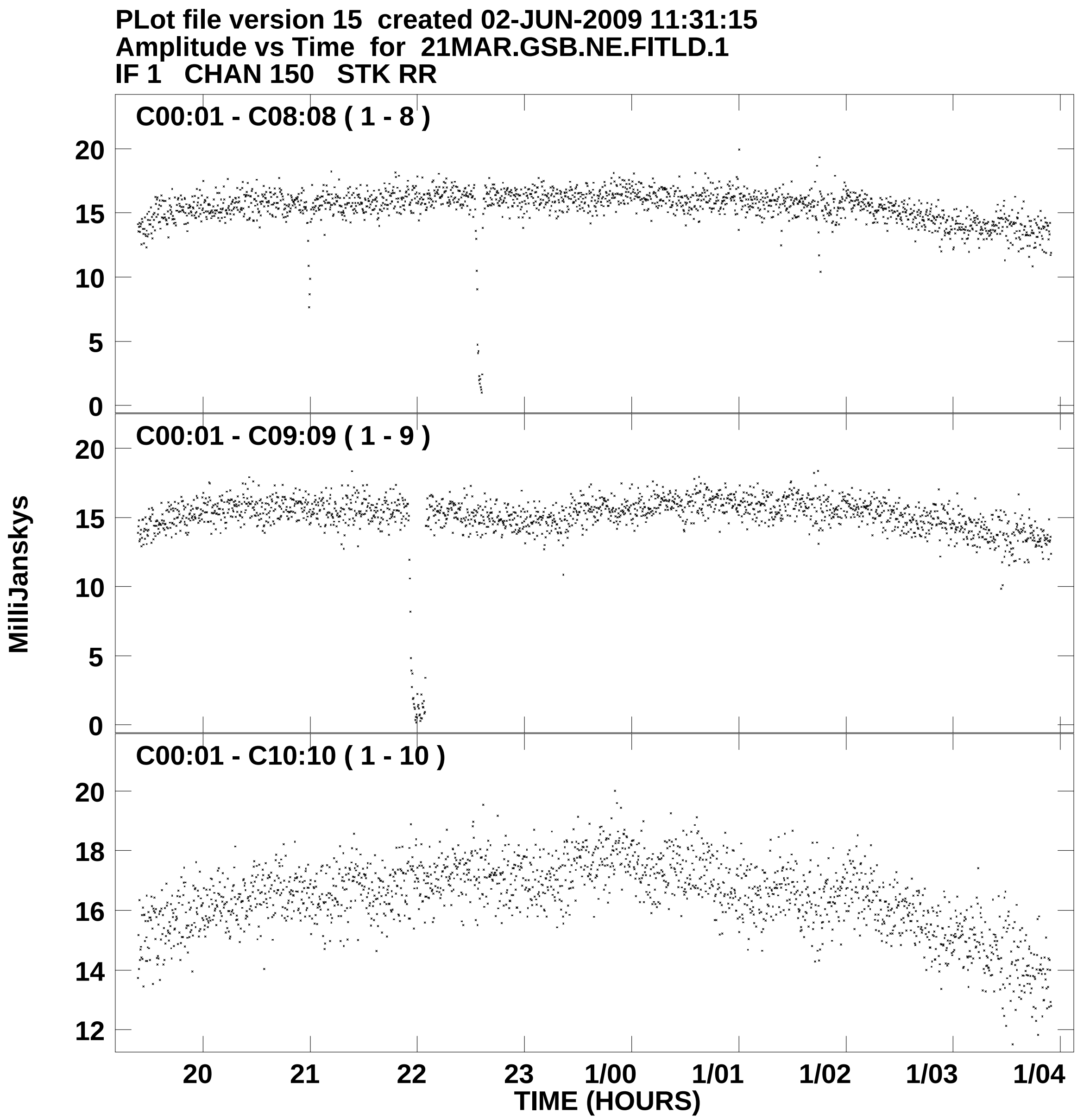

Figure 4. Actual data on a Cal. (t, ν_0)

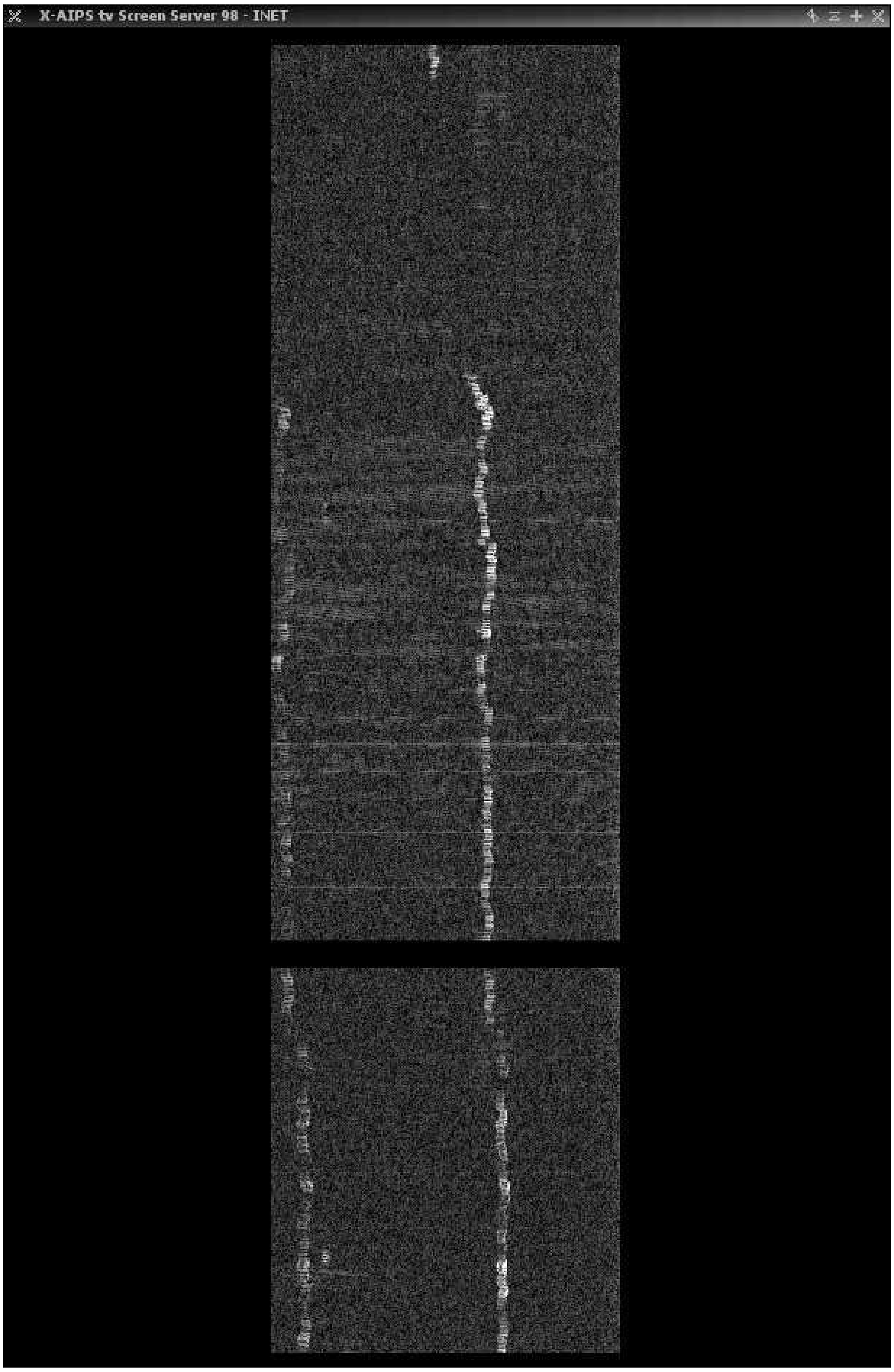

Figure 5. RFI across the band.