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## Secondary Beam Pattern Measurements for Broadband feeds for the GMRT

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**Abstract:**

This report describes a new technique to measure Secondary Beam Pattern for Broadband feeds at GMRT observatory and the usage of

- a) Spectrum Dump Code: To record the RF data into a file using LabVIEW code.
- b) Curve Fitting Algorithm: To fit the raw data with Gaussian fit and to get FWHM.

**1. Introduction:**

The Giant Metrewave Radio Telescope (GMRT) is a national facility, thrown open to the international community of Radio Astronomers at metre wavelengths (0.2 to 2.0 m.) in 1995. This facility houses 30 antennas, each of 45 m. diameter, spread over an area whose circular equivalent radius is nearly 14 km. All these antennas work on an aperture synthesis mode to yield a synthesised beam of 20 to 2 arcsec, covering a frequency band of 150 MHz. to 1420 MHz. . Antenna arrays can be formed out of these 30 parabolic dishes, where separate sub-arrays can work on different frequency bands concurrently. The digital backends offers multitude of facilities to operate the array in coherent or otherwise modes to facilitate the different needs of the astronomers.

The metre wavelength operation offers a unique feature for the parabolic dish. The reflector surface is made-up of wire meshes, having cell sizes ranging from 10 mm. to 20 mm., thus making the backup structure very light compared to solid reflector surfaces. The steerable portion of the dish thus weighs 38 tons. The dish has prime-focus feeds at four faces of a rotating turret to cover frequencies of 150,233,327,610 & 1420 MHzs. One of the turret face houses a dual frequency feed operating at 233 & 610 MHz. Simultaneous observations in both these bands are feasible with one polarization channel per frequency-band. This is a coaxial waveguide feed, which can also offer dual polarization outputs at any one of the frequency band. Where 233 MHz feed covers 227 to 237 MHz and 610 MHz feed covers 590 to 700 MHz. The rest of the 3 feeds offer dual polarization outputs: at 150 MHz. The feed is an array of thick, folded-dipoles which covers 120 to 240 MHz and a corrugated horn for 1420 MHz which covers 1000 to 1580 MHz. The 327 MHz. Band feed is a dipole-disk antenna with a beam-forming ring which covers 295 to 400 MHz.

The bandwidths mentioned above are the feed's BW. The RF electronics behind the feed limit them to useful levels of 40MHz, 100MHz and so on. Efforts are in way to improve the BWs of feeds and the RF receiver chain too. In this regard a conical reflector feed is replacing the 327 MHz feed, which will now cover 250 to 500MHz. On 3 antennas, this feed has been installed now. This report describes the procedure for doing the beamshape measurement of the wideband feed using a spectrum analyser at the antenna base or at the OF output at the Rx room. The method eliminates the requirement of backends and hence can be a set up for antenna feed characterization.

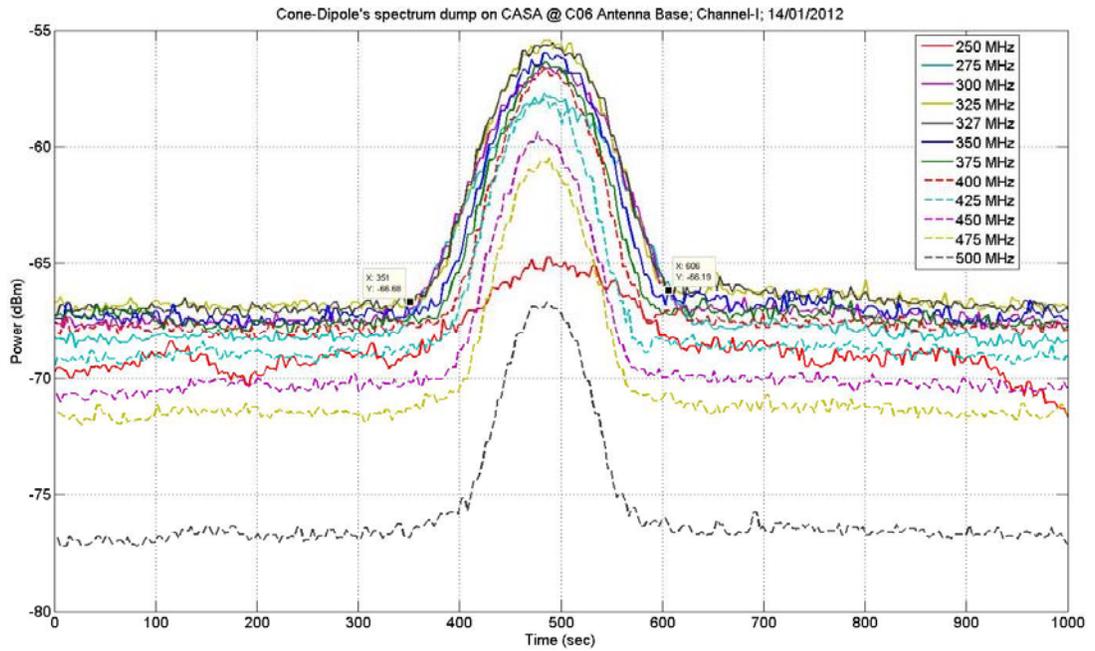
## 2. Procedure for Secondary Beam Pattern Measurement:

This experiment can be performed by tapping the RF signals (either narrow or broad band) at FE output (i.e, before IF system) and at the output of Broadband Fibre Optic Link located in GMRT receiver room. Let us consider an example, Cone-Dipole Feed 250-500MHz @ C06 Antenna.

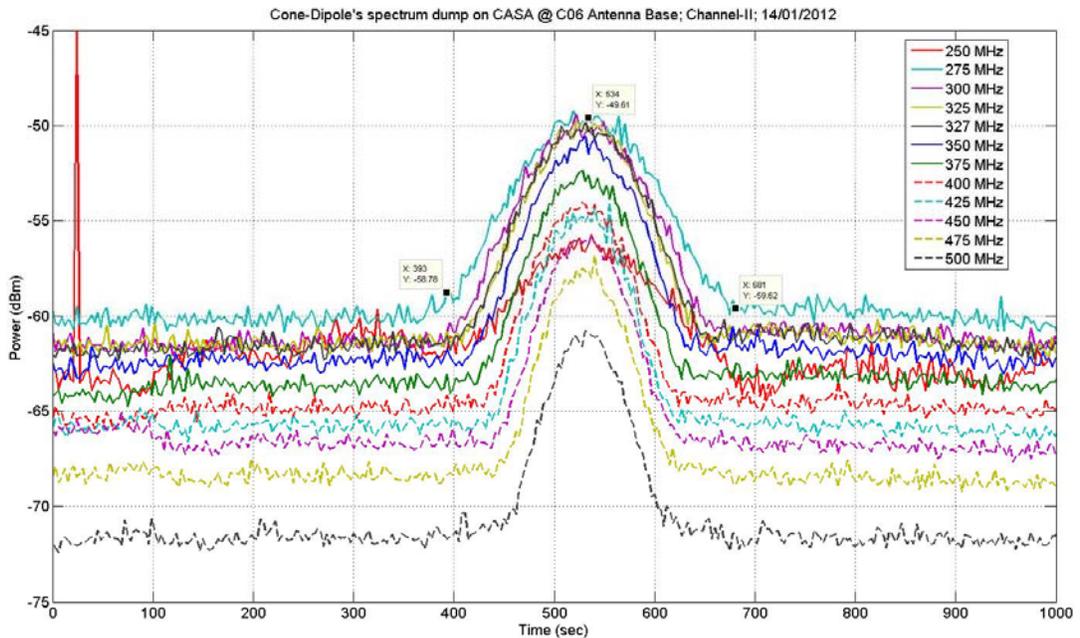
- 1) Switch ON the Spectrum Analyzer and set the Spectrum Analyzer for
  - a) Center Frequency: 400MHz
  - b) Span: 400MHz
  - c) Resolution BW: 300 KHz
  - d) Video BW: 3KHz
- 2) Place markers as required
- 3) Switch ON the Laptop, which is loaded with Labview 8.0 and 8.2 versions.

Note: Both the versions are necessary to run the application "Spectrum\_Dump.vi".

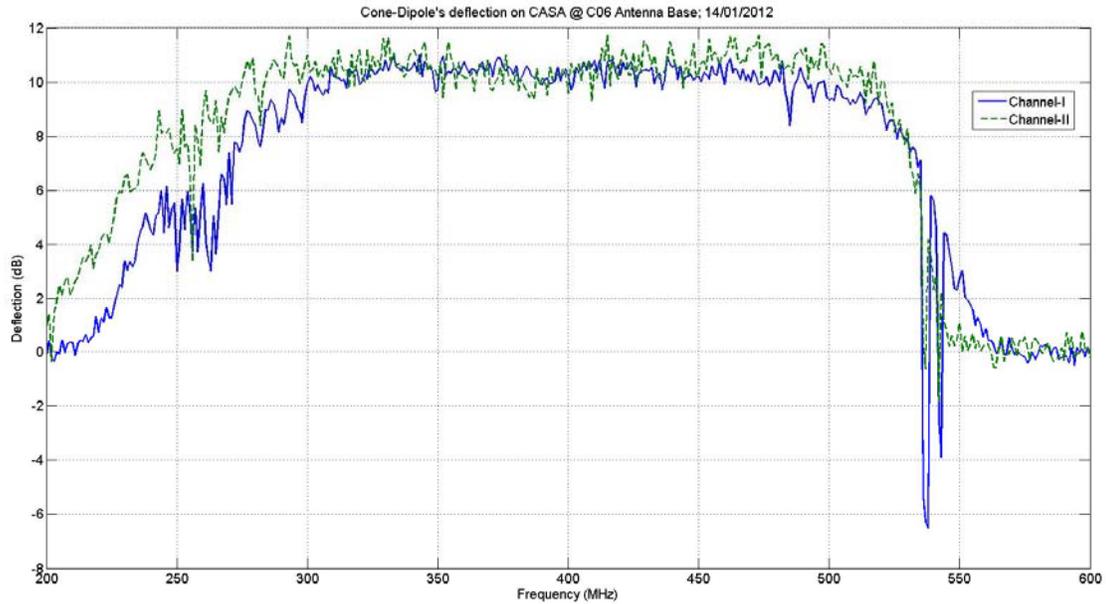
- 4) Connect the National Instruments Interface unit "GPIB-USB-HS" to the Laptop and Spectrum Analyser and Open the application "G:Hanuman/labviewprg/Spectrum\_Dump.vi". And set
  - a) Delay Time (S): 3 sec (We can set upto 1 sec)
  - b) Name or Relative path: SPD\_C06\_ch1.txt (Name of the file)
  - c) Base Path: G:/Hanuman/Labviewprg (Location of the file)
- 5) Instruct the control room operators via hot line telephone (incase Antenna base Measurements)
  - a) To focus the Cone-Dipole Feed 250-500MHz to the parabolic dish and set default setting to activate and select RF 327MHz since Cone-Dipole Feed 250-500MHz is sitting on the turret at the same face of 327MHz Kildal Feed. See **Appendix-A** for the settings of Narrow Band Beam Shape Measurement.
  - b) Slew the Antenna across a strong source like CASA, CYGA, Virgo, etc., (But don't go for extended source like CRAB) for 16 minutes with 50 arc-min/min (slew rate) either elevation or azimuth direction and get the raw data (SPD\_C06\_ch1.txt file) from the Spectrum Dump's Labview Program (Fig:1 & Fig:2). See **Appendix-B**.



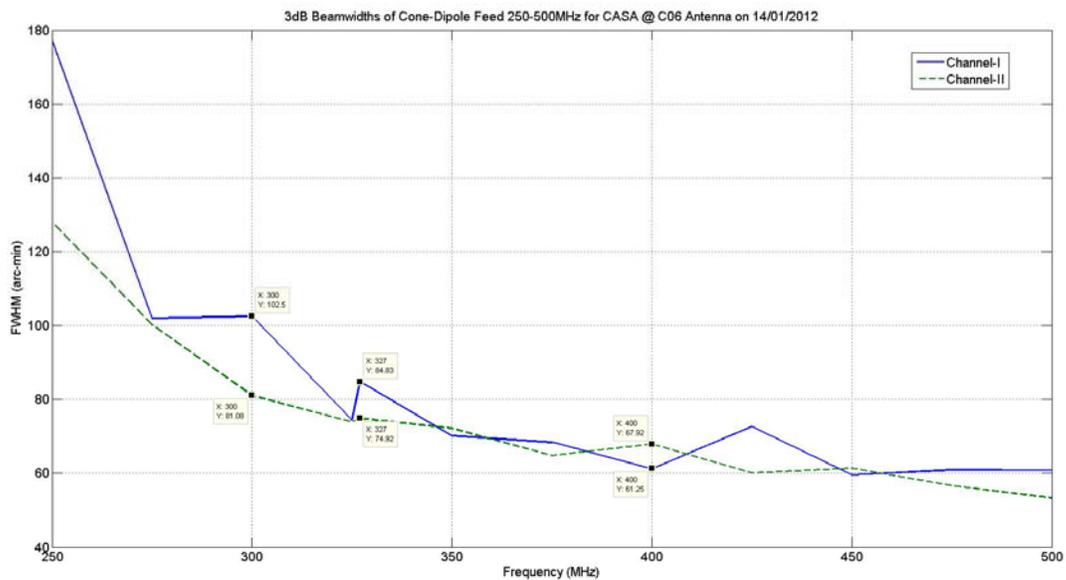
**Fig 1:** Sample plot of raw data of CDF 250-500MHz @ C06 Antenna base; RF CH-I.  
 c) Repeat 5, to get the raw data for RF Channel-II (SPD\_C06\_ch2.txt) (fig-spd2).



**Fig 2:** Sample plot of raw data of CDF 250-500MHz @ C06 Antenna base; RF CH-II.  
 d) After getting the raw data from both the channels, one can get the plots for sensitivity/Source Deflection. As shown in the fig



**Fig 3:** Sample plot of Sensitivity/Source Deflection of CDF 250-500MHz on CASA @ C06 Ant.  
 e) Fed the raw data to the MATLAB software and get the FWHM plots after fitting the raw curves to Gaussian fit. See **Appendix-C**



**Fig 4:** Sample plot of Secondary Beam Pattern of CDF 250-500 MHz @ C06 antenna.

#### 4. Conclusion

The method outlined here illustrates the independent nature of the procedure. This can be used for any type of future feeds in any GMRT antenna. Dependency on the backend is completely avoided and hence the procedure can be used by any technician or lab asst. with prior white slot booking of the antenna. Any maintenance day this could be done also. A more rigorous code of curve fitting will be shown in the forthcoming ITR.

#### 5. Acknowledgement

I would like to thank **Prof.Y.Gupta, Shri.A.Praveen Kumar** and **Shri.S.Suresh Kumar** for their constant motivations. I would like to thank my guide **Shri.G.Sankar**. And I also thank **Mr.Atul Ganla & Mr. Sanjeet Rai** for providing a labVIEW code for data acquisition. Finally, I would like to thank the staff at NCRA workshop, Control Room operators and Colleagues at FE lab, for making the experiment successful.

#### References:

1. GMRT antenna power pattern in L band Data from 27-28 December 2000 by Nimisha G. Kantharia & A.Pramesh Rao, July 20,2001.
2. G. Sankar, GMRT Antennas and Feeds (chapter-19), "Low Frequency Radio Astronomy", 3rd Edition.
3. Kolundzija, B., et. al., "WILP-D Pro v7.0, 3D Electromagnetic Solver Professional Edition User's Manual", *WIPL-D Ltd.* 11070 Belgrade, Serbia, Europe.

## **Appendix-A (Settings for Narrow Band Beam Shape Measurement):**

The standard grid-pointing (in self) in elevation on Source (Virgo or Hydra or CASA) at the frequencies listed below.

The final bandwidth and IF bandwidth will each be 32 MHz. The other settings are LO-4 = 51 MHz, LO-5 = 149, 167 MHz (default values), and 2 second integrations (Ita=1). Also, do power equalization at the first setting and will stay with this equalization for all later settings.

The settings are:

(1) LO-1 : 275 MHz

TPA 326 326 275 275 51 51

(2) LO-1 : 210 MHz

TPA 261 261 210 210 51 51

(3) LO-1 : 475 MHz

TPA 424 424 475 475 51 51

(4) LO-1 : 545 MHz

TPA 494 494 545 545 51 51

(5) LO-1 : 510 MHz

TPA 459 459 510 510 51 51

(6) LO-1 : 315 MHz

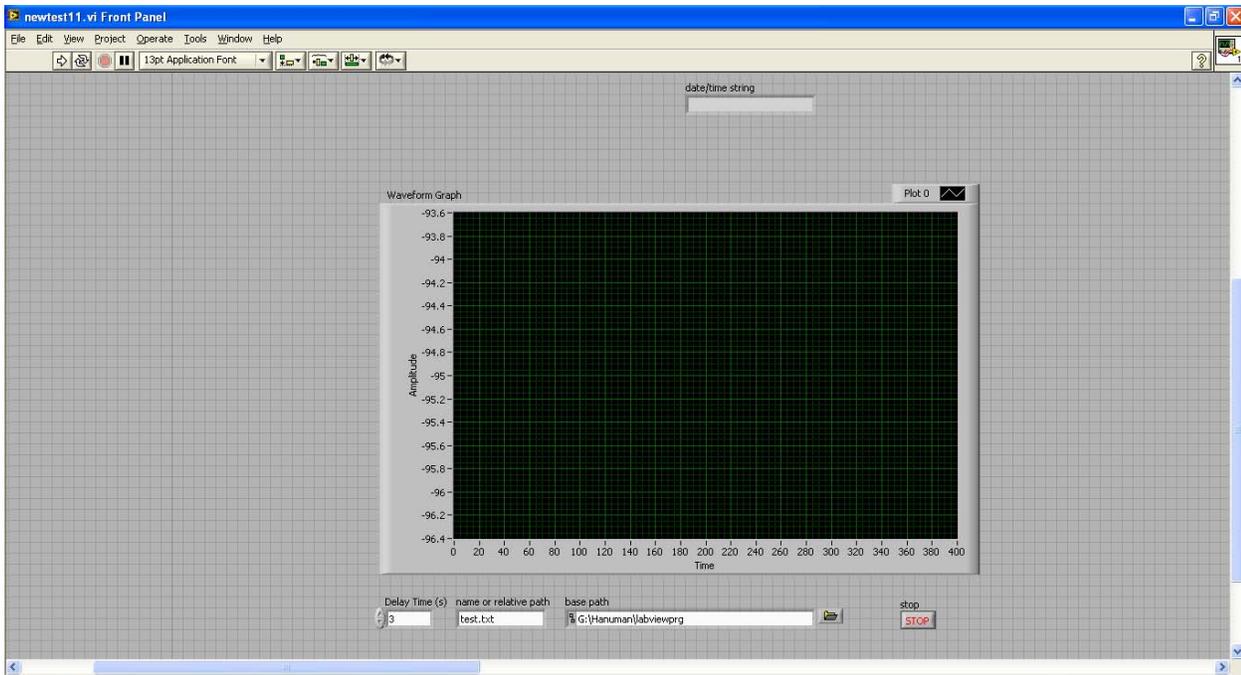
TPA 366 366 315 315 51 51

At each frequency, have to run getoffsets, and save the output plots, and also save a log file with all the details (scan rate, peak time, etc....).

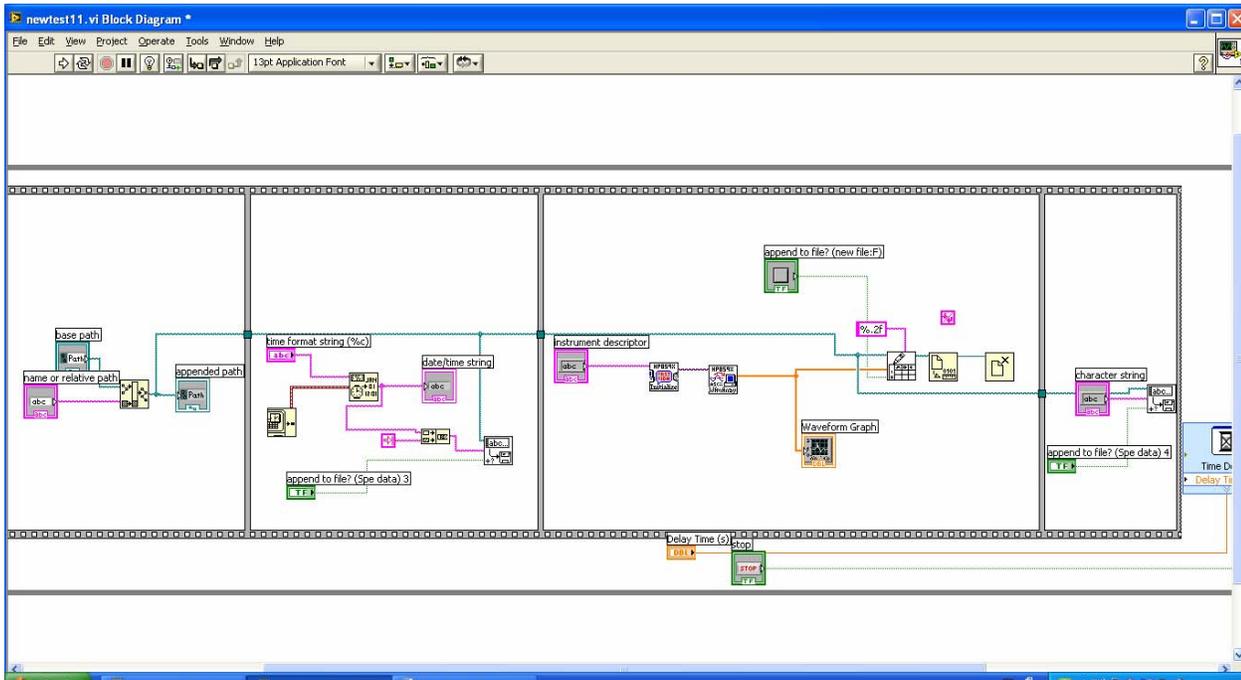
## Appendix-B (Spectrum Dump code):

**Spectrum Dump:** It is an Labview Application programmed by **Mr.Atul Ganla & Mr. Sanjeet Rai** colleagues at GMRT observatory, consists of an algorithm connecting all the blocks (see Fig 5, Fig 6)

- a) Instrument Descriptor: A string that uniquely identifies the instrument to open or initialize.  
Parameters (default value):
  - i) bd-GPIB board (0)
  - ii) prim addr-GPIB primary address (1)
  - iii) sec addr-GPIB secondary address (none)
  - iv) logical addr- VXI logical addressExample: A GPIB instrument on GPIB board 0, at primary address 5, and no secondary addressing.
- b) hp859x Initialize.vi: This block connects to the spectrum analyser (hp859x) and calls the protocols/drivers related to the spectrum analyzer.
- c) hp859x Read Wvfm to Array Ascii.vi: This block converts the waveform details into ASCII format and writes to the file as mentioned in Name or Relative path.
- d) Delay time (s): Specifies how many seconds to wait. The value you wire to this input overrides the value you set in the configuration dialog box, which stores the data (400 points) per every 3 seconds from Spectrum Analyzer to a text/excel file.
- e) Spreadsheet file.vi: This block describes the type of the file to be stored.
- f) Name or Relative path: This is the name of the file, where data gets stored.
- g) Base path: This string tells us about the Location of the file to write the spectrum values.
- h) Waveform: This block shows the spectrum (Like window on spectrum analyzer).



**Fig 5:** Front Panel of Spectrum Dump LabVIEW code



**Fig 6:** Block Diagram of Spectrum Dump LabVIEW code

## Appendix-C (Curve Fitting Algorithm)

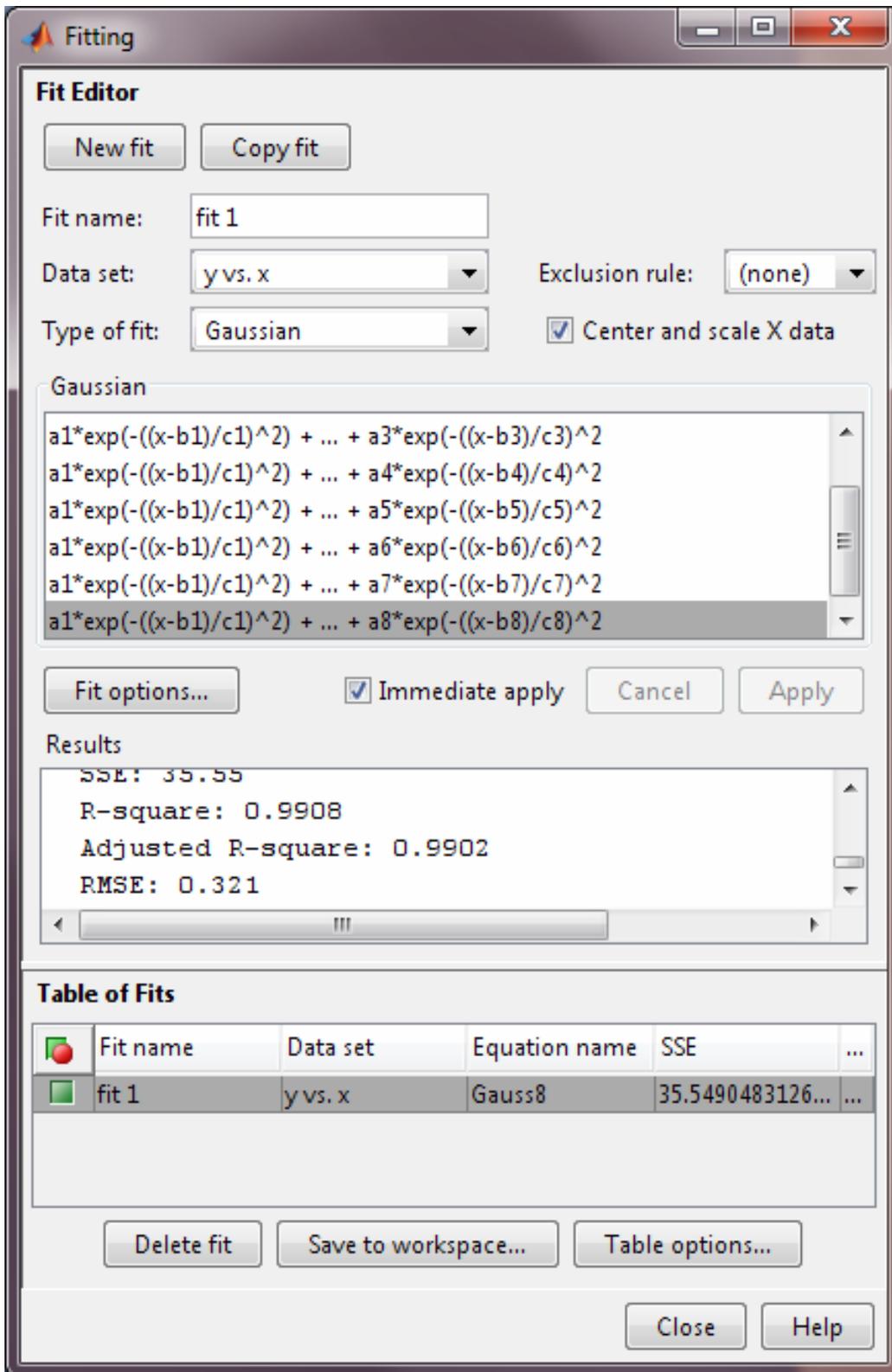
Curve fitting, also known as regression analysis, is used to find the "best fit" line or curve for a series of data points. Most of the time, the curve fit will produce an equation that can be used to find points anywhere along the curve. In some cases, you may not be concerned about finding an equation. Instead, you may just want to use a curve fit to smooth the data and improve the appearance of your plot.

We have used MATLAB technical programming language for the curve fitting, code as follows

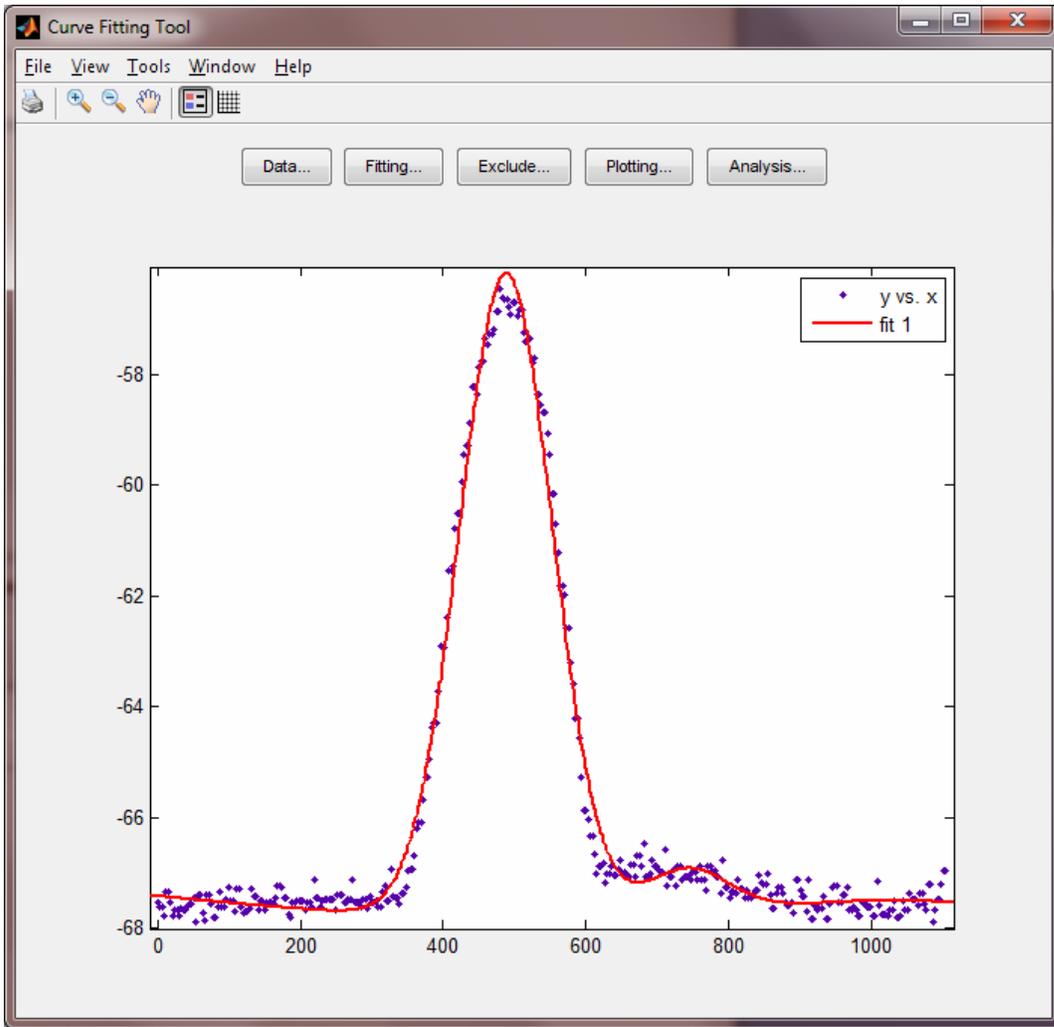
- 1) Load the files, SPD\_C06\_ch1.txt and SPD\_C06\_ch2.txt
- 2) Assign each column (Amplitude data for each frequency) to different variables. i.e.,  
a=SPD\_C06\_ch1(:,1) [First column consists of Time (sec)  
b=SPD\_C06\_ch1(:,2) [Second column consists of Power (dB) of corresponding freq]  
. . .  
. . .  
n=SPD\_C06\_ch1(:,14) [14<sup>th</sup> column.....]

and So on... upto last column

- 3) Use curve fitting tool to get, Gaussian fit for as shown in Fig 8.



**Fig 7:** Curve fitting Editor



**Fig 8:** Curve Fitting Tool