

VT ACF Plotting and Fitting Tool Guide

One of the fundamental SuperDARN data types is the RAWACF file, which contains the autocorrelation functions (ACFs) calculated for each range-beam cell. These ACFs are calculated from the voltage levels recorded in the receivers at specific sampling times and are fitted in order to resolve Doppler velocity, spectral width, and backscatter power. The ability to examine the individual ACFs can give us insight into how a particular radar is performing, and the ability to see what is happening within the fitting can give us insight into how software is performing.

Using the ACF plotting tool, one can both examine ACFs themselves as well as the fitting results. On the website, the user must select a fitting method (traditional FitACF, Fitex2, which we use here at VT, and LMFit, an experimental fitting method), hemisphere, radar, beam, year, month, day, hour, and minute. Once these parameters are selected and the user hits the “Plot” button, the processing and plotting takes about 15-20 seconds. When this is complete, an image will appear on the screen showing an overview of the selected time period. Figure 1 shows an example of such an overview. The data in Figure 1 are from 10 September 2011 at 04:30 UT on beam 7 of the west array of the Fort Hays, Kansas Radar. If one were to view a range-time parameter plot containing the selected time period, this overview would be the slice for the beam sounding at the selected time. This image also links to a high-resolution version of the image.

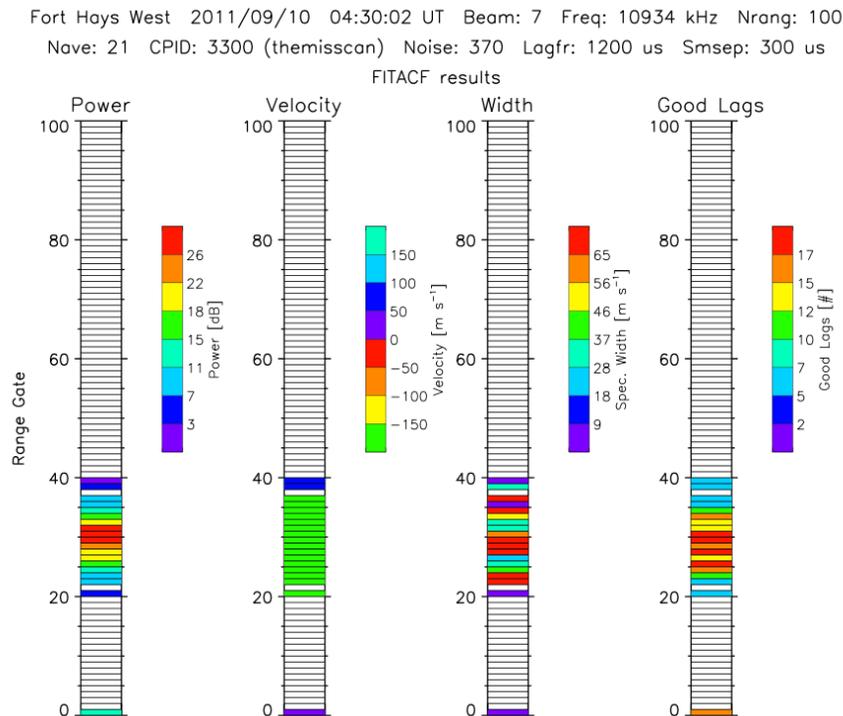


Figure 1. The front page that is produced by the ACF Plotting and Fitting tool.

Above this image on the webpage is a link to a PDF file. This PDF file contains a front page that is the same as in Figure 1. This is followed by as many pages as there were range gates for that beam sounding, so that the ACF presentation for a particular gate occupies its own page. Regardless of the fitting method

selected by the user, the first plot on each of the range gate pages is the raw ACF for that gate. An example of a raw ACF is shown in Figure 2. Again, radar parameters are output along the top of the page. The plot itself also contains a lot of information. The red symbols are used to indicate the real part of the ACF, and the blue symbols are used for the imaginary part. The solid circles connected by lines are the good lags of the ACF, i.e., those lags that are actually used in the fitting process. The open squares indicate lags flagged by the normal “badlags” routine as bad because of receiver blanking (transmitter pulse overlap). The open diamonds indicate lags flagged by the normal “badlags” routine as bad because of cross-range interference. The open triangles indicate lags flagged by the “more_badlags” routine as bad because of empirical “bad shape” criteria.

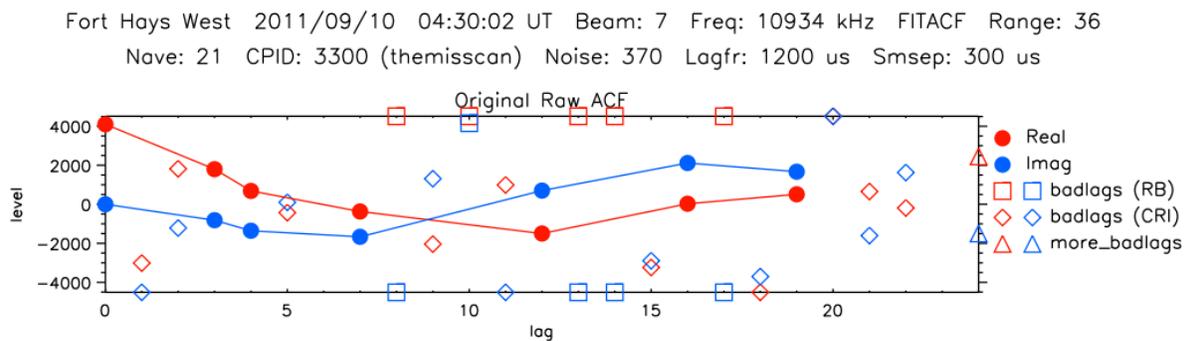


Figure 2. An example of a raw ACF plotted with the ACF Plotting and Fitting Tool.

The standard fitting routine for fitting ACFs and developing data products is fitACF. At VT, we have developed several other methods based on original work and suggestions by Ponomarenko and Waters. These new routines, named Fitex2 and LMFit, have been described and tested (along with Fitacf) using the radar simulator by Riberio et al. [2012]. The plotting tool makes available all three fitting procedures.

There is an additional complication in that the radar may have been operated with a non-standard control program, such as tauscan, which was developed by Greenwald and colleagues in order to generate more complete lag profiles. The three fitting procedures perform differently on non-standard control programs, as explained below. If your interest is only in standard control programs (e.g., katscan) then only entry [1] below is relevant. If your interest is further restricted to fitACF results, then only sub-entry [1a] is relevant.

Here we describe differences between the bad lag calculations of the three fitting routines (fitACF, fitex2, LMFit)

1. Standard Control Programs (e.g., katscan):
 - a. The same normal “badlags” routine is used in all 3 fitting methods. Therefore, regardless of fitting method, all non-tauscan control programs can show the RB and CRI badlags.
 - b. Only FitACF actually calls the “more_badlags” routine. This was removed from the other routines because of suggestions made by Ponomarenko and Waters at the 2004 SuperDARN Workshop.

- i. However, in both Fitex2 and LMFit, lags with power below the statistical fluctuation level are excluded from fitting, and these are plotted with the “more_badlags” symbol (triangle).

2. Tauscan Control Programs

- a. Tauscan calculates bad lags at runtime, and inserts 0's into the ACFs at these lags. This means that information about whether a lag is bad because of RB or CRI is lost. Consequently, for tauscan control programs, all normal bad lags will be plotted with the normal “badlags” symbol.
- b. Again, in both Fitex2 and LMFit, lags with power below the statistical fluctuation level are excluded from fitting, and these are plotted with the “more_badlags” symbol (triangle).
- c. FitACF should not be used for processing tauscan files. FitACF does not know that the bad lags have already been removed. Because of this, it will (incorrectly) recalculate which lags are bad. One can still use the plotting tool with FitACF on a tauscan period, but the fitting results will be incorrect.

Returning to the output of the ACF plotting tool, two more plots are shown on the individual range gate pages for all three fitting routines: a plot of the phase variation with lag (from $\text{atan}(I/R)$) and a plot of the power variation with lag (from $\sqrt{R^2+I^2}$). The phase plot is shown in Figure 3 and the power plot is shown in Figure 4. In both cases, the actual values from the ACFs are plotted as solid circles and the fits are plotted as open circles connected by dotted lines. The purpose of these panels is to show how well the fitting result approximates the original parameters from which they were derived.

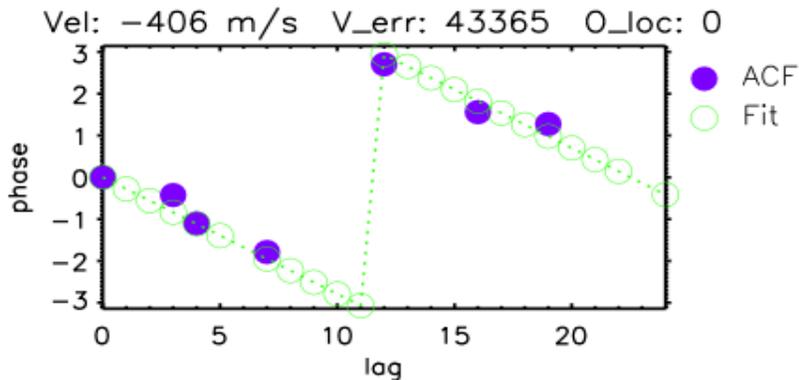


Figure 3. An example of a phase plot. The data are from the ACF shown in Figure 2.

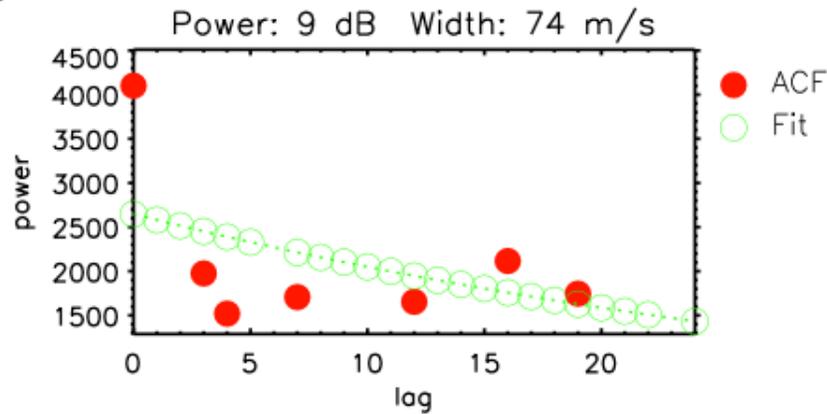


Figure 4. An example of a power plot. The data are from the ACF shown in Figure 2.

If one selects a fitting method other than FitACF, then additional plots will be presented. In the case of Fitex2, a model error comparison plot is shown. This plot shows the error in phase fits for 120 model phase variations (velocities). The lowest error value is then used as an input to the bisection method, which solves for velocity to arbitrary precision. An example of one of these plots is shown in Figure 5. In this figure, the blue dots show the error for each model, the orange dot shows the minimum error, and the horizontal line shows the minimum error for a model to be considered a good fit.

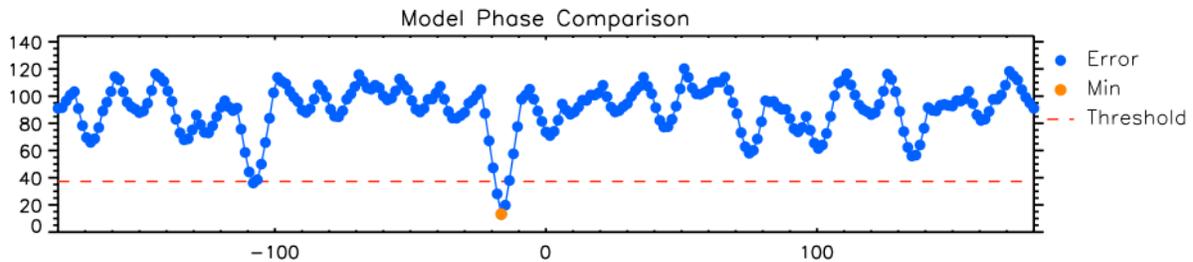


Figure 5. An example of a model phase comparison plot. The data are from the ACF shown in Figure 2.

If the user selects LMFit as the fitting method, there will be an extra plot showing a fitted ACF. This is presented because LMFit uses the Levenberg-Marquardt method to fit the real and imaginary parts of this ACF. Essentially, this solves for velocity, power, and spectral width simultaneously. An example of one of these plots is shown in Figure 6. In this figure, the red and blue circles represent the lags of the actual ACF, and the orange and light blue squares represent the fitted lags of the ACF. Note that LMFit is still in beta testing.

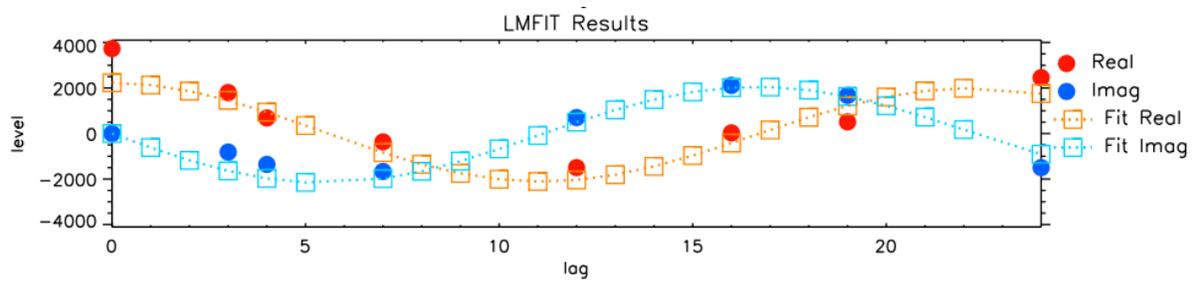


Figure 6. An example of a plot showing the results of LMFit. The data are from the ACF shown in Figure 2.