DEFINING FIRST-ORDER REGION BOUNDARIES

Mar 5, 2002

One of the most critical features of SeaSonde analysis is the empirical determination of the frequencies that define the Bragg (first-order) region. In section (a) we discuss the visual identification of the first- and second-order regions, giving special cases in section (b). Section (c) describes the computational methods used in the analysis to define the Bragg region frequencies and the control parameters set in the header file.

(a) How to recognize first and second-order echo.

SeaSonde backscatter cross spectra have a characteristic appearance: dominant first-order peaks occur due to scatter from the Bragg ocean waves with wavelength one half the radar wavelength. In the absence of ocean currents these would be delta functions in frequency, but are broadened by the varying currents in the radar scatter area. Fig. 1 shows typical sea-echo spectra from the monopole antenna. The first-order peaks (shaded) are surrounded by a higher order continuum, predominantly caused by the interaction of the radar wave with pairs of ocean waves, one of which has a wavelength approximately equal to the Bragg wave, the other being a longer wave carrying significant energy. Closest to the Bragg frequency, the second wave of the pair is the longest wave present on the ocean surface. Further away in frequency, the second ocean wave gets shorter and shorter, until the radar echo falls beneath the noise floor.

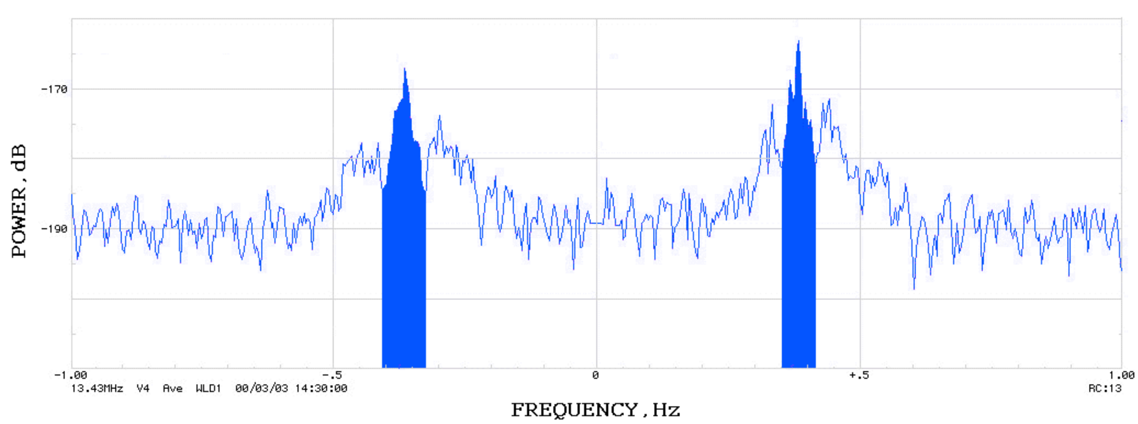


Fig. 1a

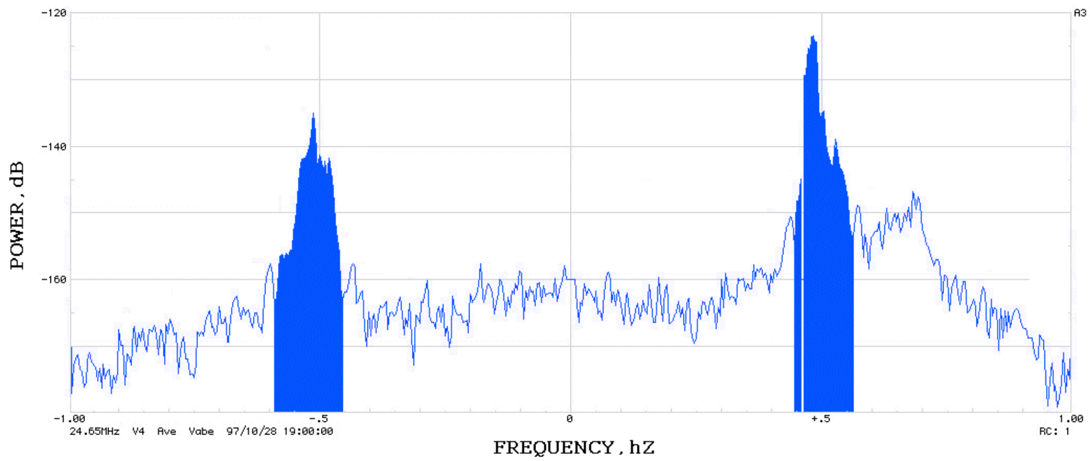


Fig. 1b

Figure 1: Typical radar spectra from ocean sea-echo, with the dominant first-order region (shaded) surrounded by the higher-order echo, superimposed on a noise floor.

(a) : The dominant ocean waves have a long period; hence the second-order peaks are close to the first-order region.

(b) :The dominant waves are shorter, and the second-order structure is further displaced from the first.

We can use the following features to distinguish between first and second-order regions of the spectrum:

(1) Second-order spectrum typically is an order of magnitude below first

(2) Second-order peaks surround first-order peak

(3) Second-order frequencies are approximately symmetric about the Bragg frequency.

(b) Special cases

(1) No second-order echo: Where there are no long waves, there is negligible second-order echo, e.g. in ports, rivers. The first-order region falls straight to the noise floor (e.g. Fig.2)

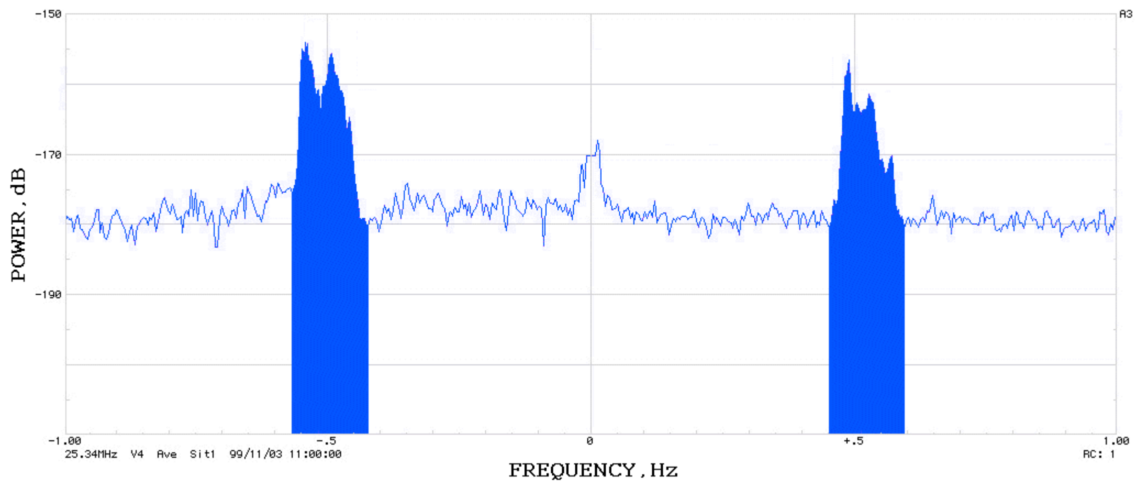


Fig. 2: First-order peaks falling to the noise floor. Due to the absence of long ocean waves, there is no second-order echo.

(2) Contamination by ionospheric echoes or radar interference from other sources: Radar echo from another source is superimposed on the sea-echo signal, as in Fig 3.

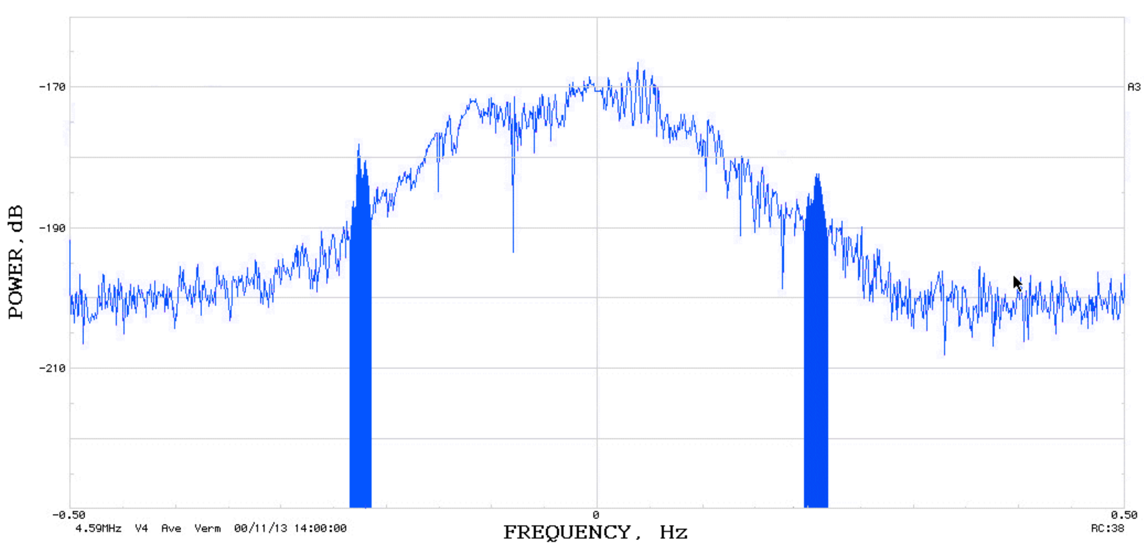


Fig. 3: Radar spectrum showing ionospheric echo superimposed on the sea-echo spectrum. The first-order peaks are just visible above the ionospheric echo.

(3) Extremely strong currents that spread the first-order region over the surrounding higher-order spectrum, as in Fig 4.

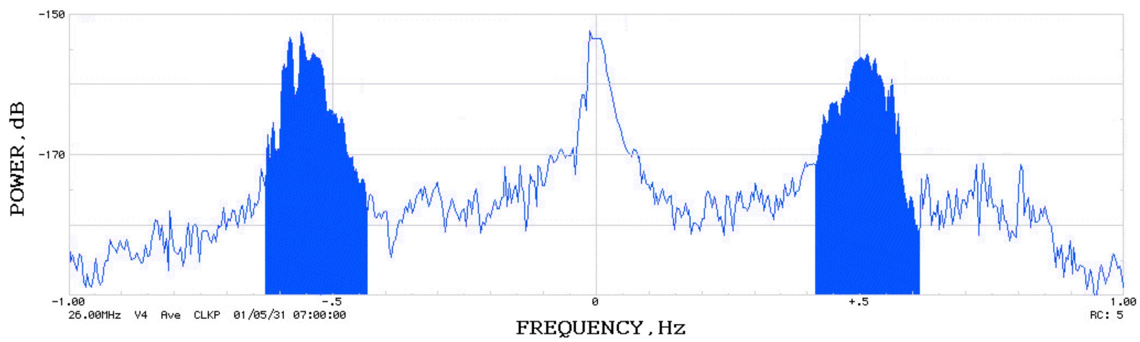


Fig. 4a

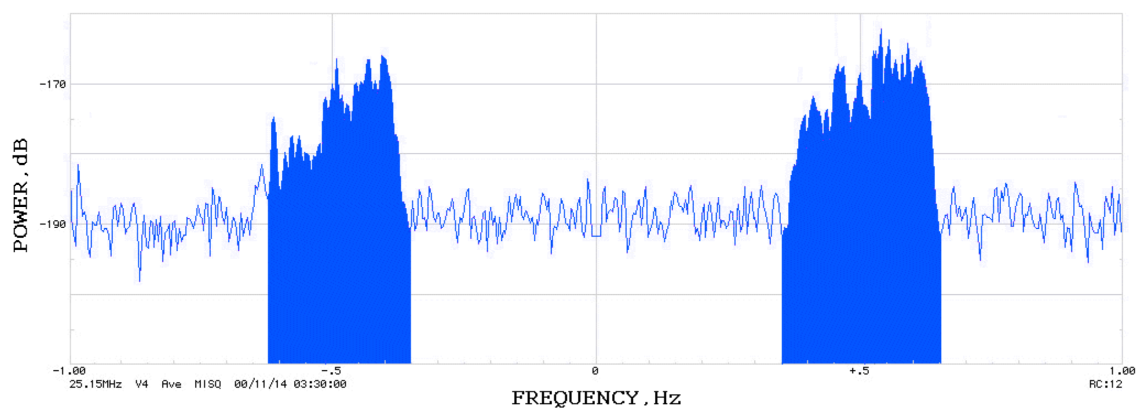


Fig. 4b

Fig. 4 : Examples of radar spectra when there are strong currents: The first-order region has spread over the surrounding higher order structure.

(4) Saturated radar spectra:

When the ocean waves are high, the radar spectrum becomes saturated, resulting in the breakdown of the perturbation expansion on which our analysis is based. The expansion is in terms of h/l where l is the radar wavelength and h is the significant wave height. For the expansion to converge, h/l must be less than 0.5 (approximately), so the spectrum becomes saturated when the wave height exceeds l/2. This limit on the significant wave height is given in the following table for commonly used SeaSonde transmit frequencies.

Radar frequency	***Upper limit on significant wave height***
25.0 MHz	6.0 m.
13.0 MHz	11.5m.
5.0 MHz	30.0m.

When this saturation occurs, there is no clear division between first and second-order spectra, as they merge together. See Fig 5. The current vectors derived from such spectra are highly suspect.

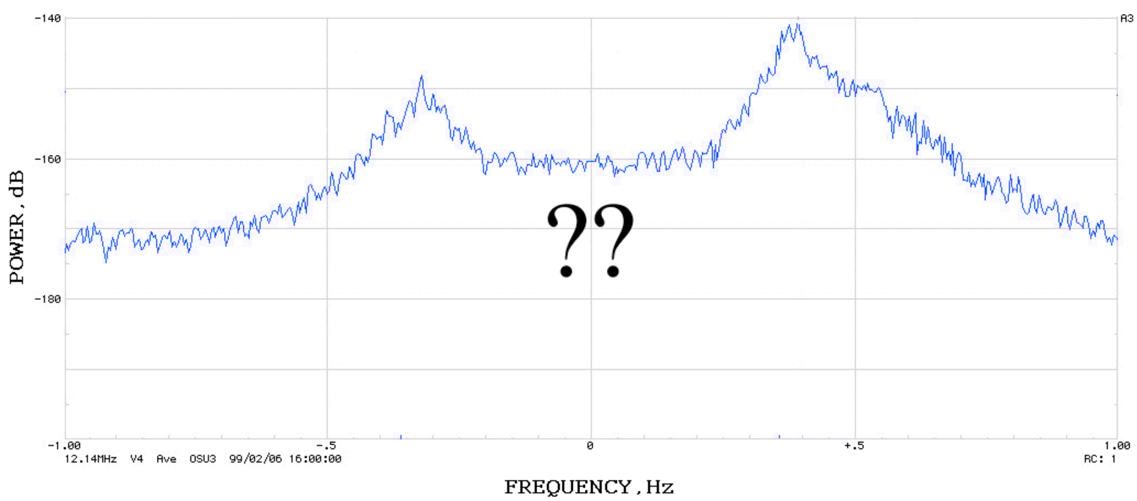


Fig. 5: An example of a saturated spectrum.. First-order spectrum cannot be isolated as it is merged with the higher-order echo.

(c) Setting the boundaries

To set the first-order region boundaries, we first apply a threshold to eliminate data that is considered too noisy, based on an estimation of noise in the wings of the spectrum (see Fig. 6). Then the local minima (which we call nulls) between the first- and second-order spectra are found, and used to define the first-order region from which the current information is derived. Before determining the null position, the spectrum is smoothed by applying a running mean to produce a more stable estimate. As a final check, the maximum current in the geographical location is estimated, and only the Doppler frequencies consistent with this estimate are accepted. We now describe these steps in detail, giving the associated setup parameters, which are set in the Header file in the setup files folder.

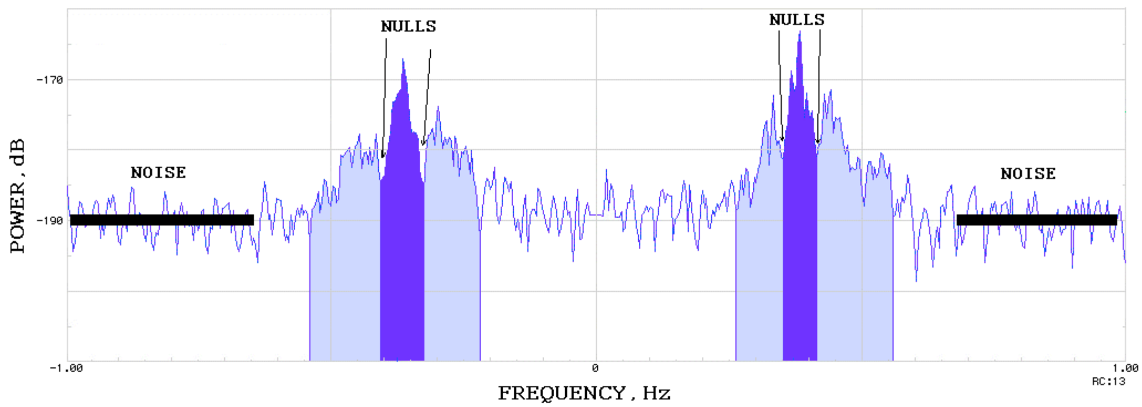


Fig. 6: Shows the first-order region (shaded dark) separated by 'nulls' from the second order structure (shaded light), and the noise level in the wings.

Steps 1-2 are applied to the entire monopole self-spectrum:

1. Thresholding for noise

A noise threshold is applied: the noise level in the wings of the spectrum is calculated and data eliminated that is below this noise level times a factor 'noisefact', (set in the header, line 15, parameter 2). For example, if 'noisefact' is set to 4, data will be accepted that is higher than 4 times the noise floor.

2. Smoothing the spectrum

To increase stability when finding the nulls between first- and second-order, a running mean is applied, smearing over 'nsm' points, ('nsm' is set in the 'Header' file line 11, parameter 2). Care must be taken in setting 'nsm', as too much smearing will destroy the null between first and second order, causing errors in setting the boundaries (see Fig. 7 for an example.) On the other hand, insufficient smearing may result in the minima being set within the first-order region.

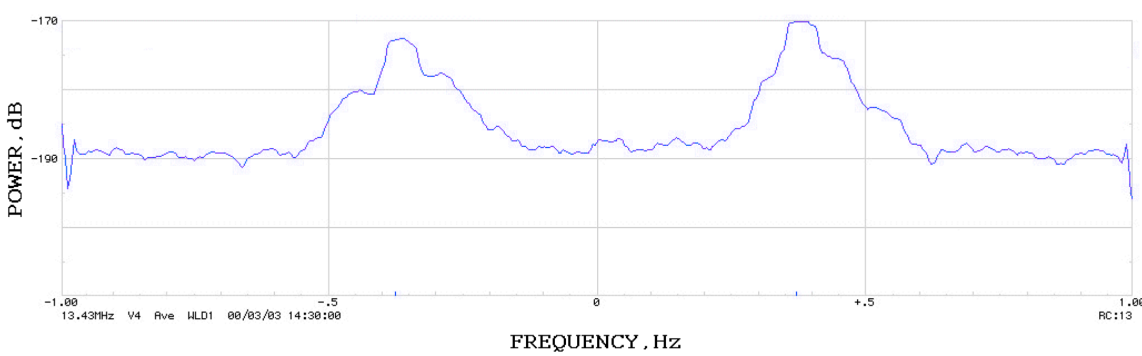


Figure 7: Demonstrates an overly-smoothed spectrum (the spectrum of Fig. 6 smeared over 6 points): Nulls between first and second order are smeared out on the positive Doppler side.

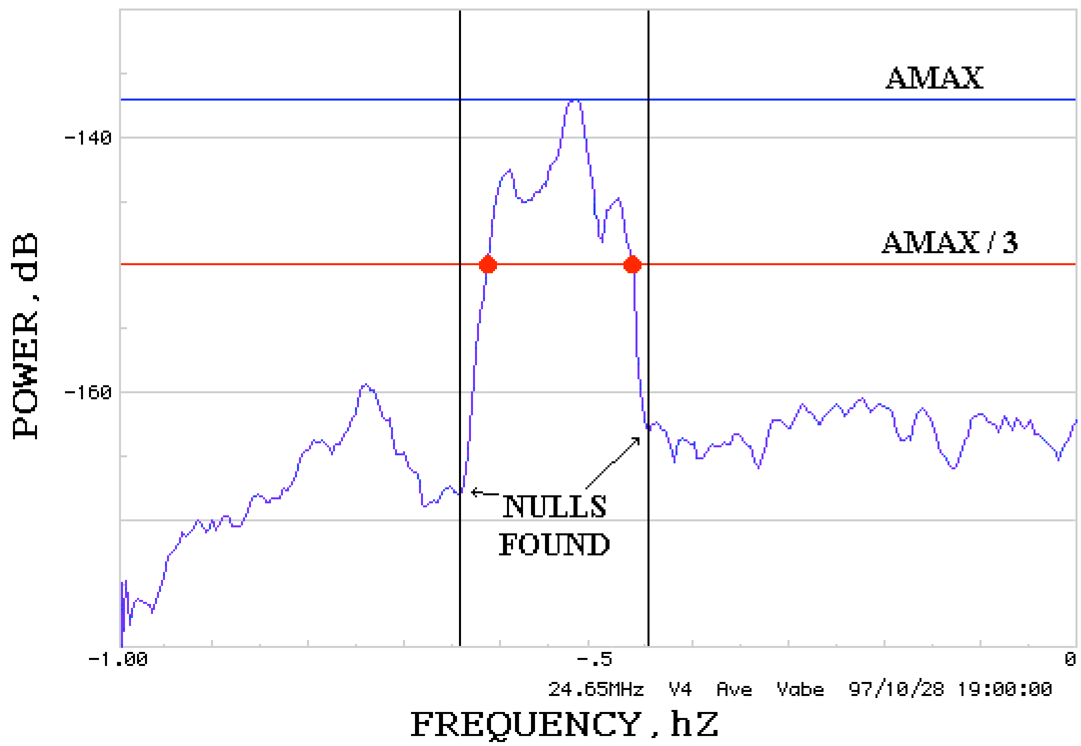
Steps 3-5 are applied separately for the +ve and -ve Doppler halves of the monopole self-spectrum.

3. Finding the nulls between the first- and second-order spectra

If there are no long waves on the water surface, as in a harbor, there will be no second-order structure. In this case, this step should be skipped by setting the parameter 'nsec' (line 12, parameter 2) to zero.

The first-order structure is usually separated from the second-order by well-defined minima, which we term 'nulls'. When locating these nulls, we don't want to search within the first-order region, which has its own local minima. So the search is begun on the periphery of the first-order region, at points defined using the following method: We find the point with the maximum power, amax, and the surrounding points with power amax/fdown ('Header' file line 15, parameter 1). These are indicated by the red dots in Fig. 8a for fdown=20. Starting the search for the nulls at these points results in acceptable null positions.

Care must be taken in setting 'fdown' to too small a value will result in the minimum is set within the first order region, as illustrated in Fig. 8b for fdown=3, meaning that good data is eliminated. However, if 'fdown' is chosen too large, the nulls may be missed altogether, and second-order data included in error, resulting in wild current vectors.


AMAX
AMAX / 3
-140
-160
POWER , dB
NULLS
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-1.00
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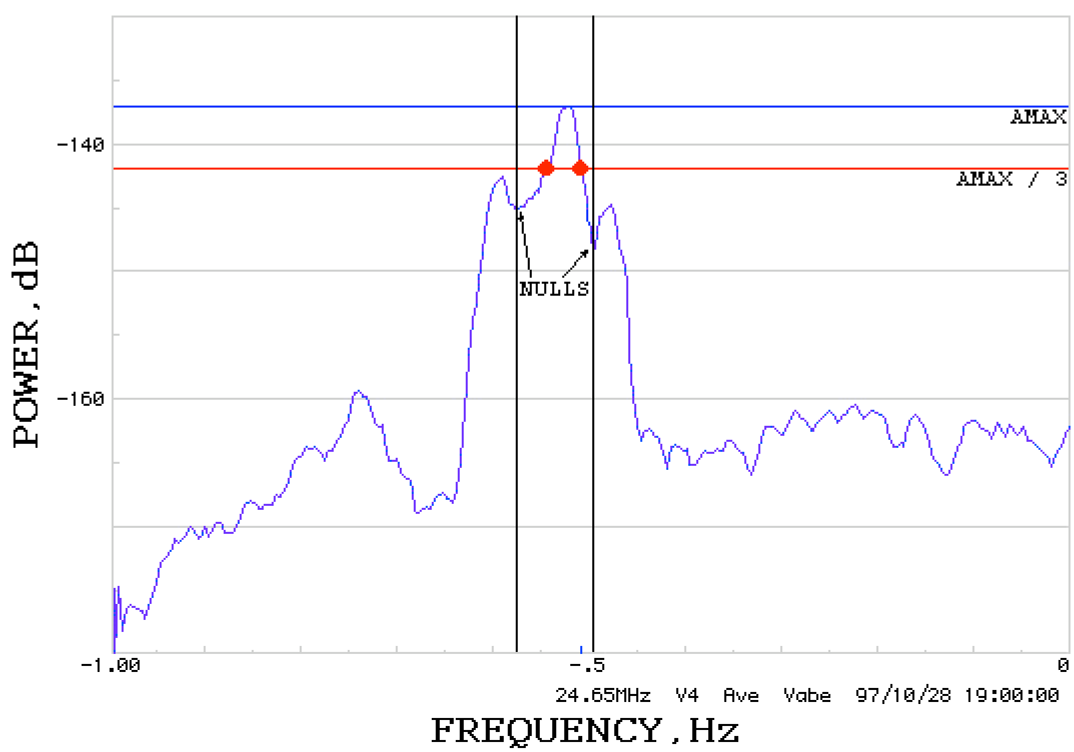
24.65MHz V4 Ave Vabe 97/10/28 19:00:00
FREQUENCY , hZ

Fig. 8a


AMAX
AMAX / 3
-140
-160
POWER , dB
NULLS
-1.00
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24.65MHz V4 Ave Vabe 97/10/28 19:00:00
FREQUENCY , Hz

Fig. 8b

Figure 8: Demonstrates the effect of different value of the parameter flim on finding the nulls between first- and second order (a) successfully) (b) unsuccessfully (see text)

4. Limiting the spectral range

We then eliminate spectral points that are too far below the peak energy, using the parameter flim ('Header' file line 12 parameter 1). Points are eliminated if:

Power in voltage-squared is less than (amax/flim)

5. Final frequency window

Finally we apply a frequency window, so the derived current speed will not exceed the value 'currmax' ('Header' file line 11, parameter 1), which is the maximum current estimated for the geographical location of the radar.