

# F-K Filter

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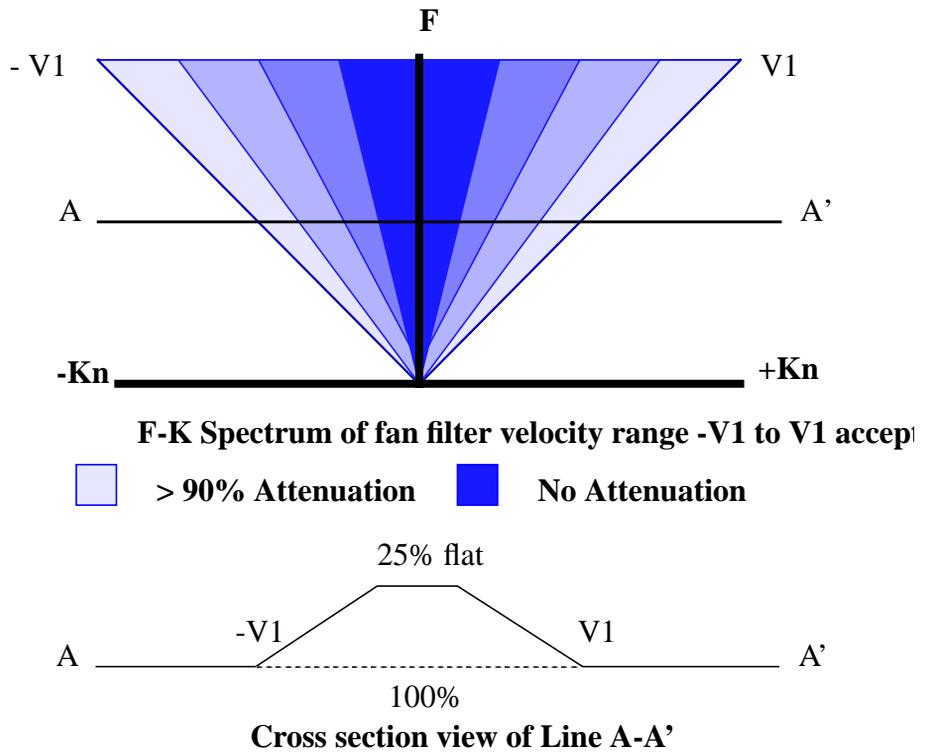
**F-K filter** works with **F-K Analysis** to apply F-K filters in batch mode to a large volume of traces.

## Theory

The ProMAX® processing system applies a frequency-wave (F-K) filter to data which is internally converted to the F-K domain. The data is converted from time and space (T-X) sampled traces to the F-K domain by a two-dimensional Fourier Transform. Once the F-K filter is applied, the data is converted back to the T-X domain by the inverse Fourier Transform. Trace mutes, such as first break suppression mutes, can be reapplied automatically after F-K filtering.

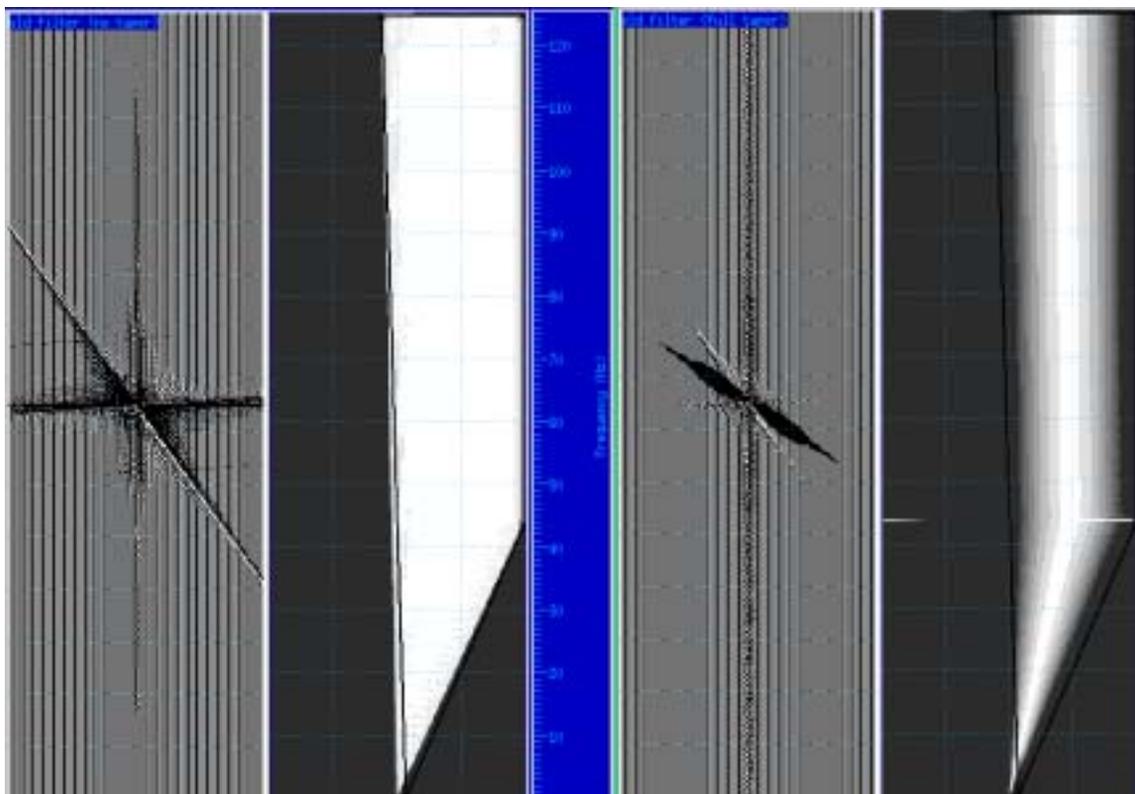
### Conventional vs. ProMAX® F-K Filters

A conventional method for controlling impulse responses of an F-K filter is to apply a taper to the filter in F-K space. These filters are typically a linear ramp or a cosine taper within the keep zone of the velocity filter. The values in the center of the keep zone are scaled by 100% and the values at the velocity cut lines are scaled by 0%. The filter is usually not scaled to absolute zero; the F-K plane is placed on an amplitude pedestal to prevent hard zeros.



#### Old Style F-K Plane Tapering

In the same manner that abrupt amplitude discontinuities in T-X space, such as high amplitude spikes, transform over the entire F-K plane, amplitude discontinuities in the F-K plane transform over the entire T-X space upon inverse transform. The intent of the taper is to prevent abrupt amplitude discontinuities in the F-K plane. This method has been used in the past to help control the spatial extent of the F-K filter impulse response in the T-X domain.



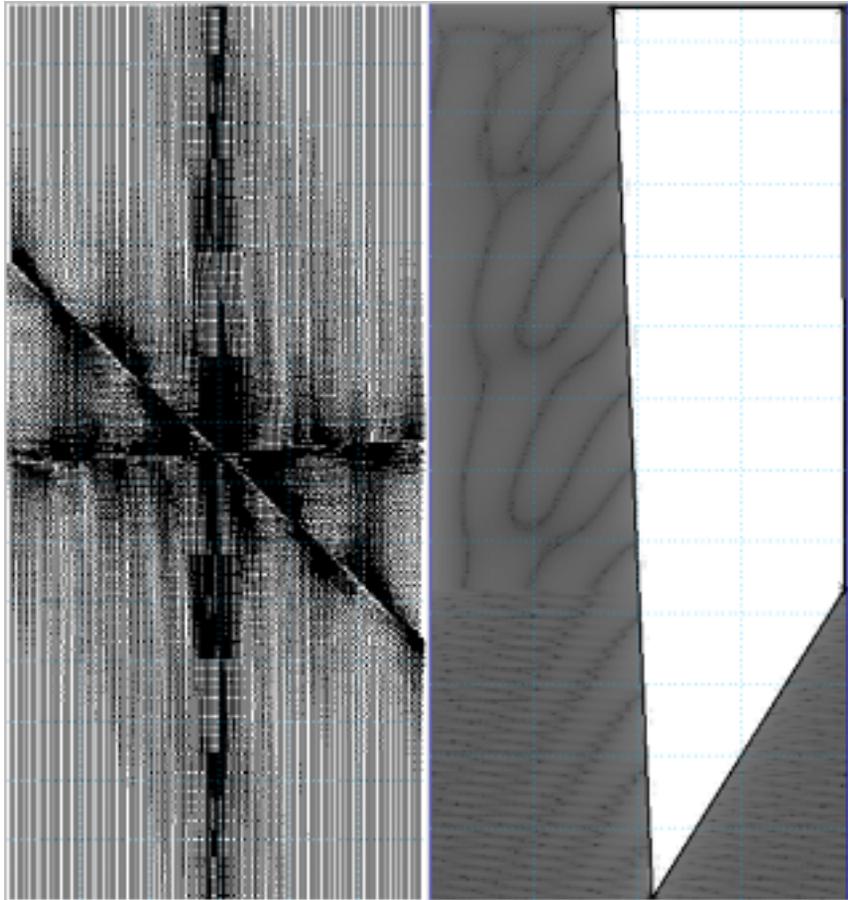
No F-K Plane taper ----- Full F-K Plane Taper

As shown above, the F-K plane taper is fairly successful at limiting the impulse response. However, the problem of this technique is the keep zone of the filter actually results in a region of additional attenuation over the ramp zone. This generally leads to overspecifying the keep zone so that the desired range of velocities remains at full amplitude.

### ProMAX® F-K Filter

The F-K filter used in the ProMAX® processing system takes a different approach to control the spatial extent of the impulse response in the T-X domain. ProMAX® F-K filters are designed by explicitly specifying the limits of the impulse response in the T-X domain and then converting this to a *mask* of F-K coordinate scalars. This mask can then be overlaid on the F-K transform of a seismic record. Our filters are designed by using Green's Theorem to compute an exact T-X filter for a given keep or reject region of the F-K plane. This T-X filter is then spatially and temporally tapered and transformed to the F-K domain with a 2-dimensional FFT to create the mask.

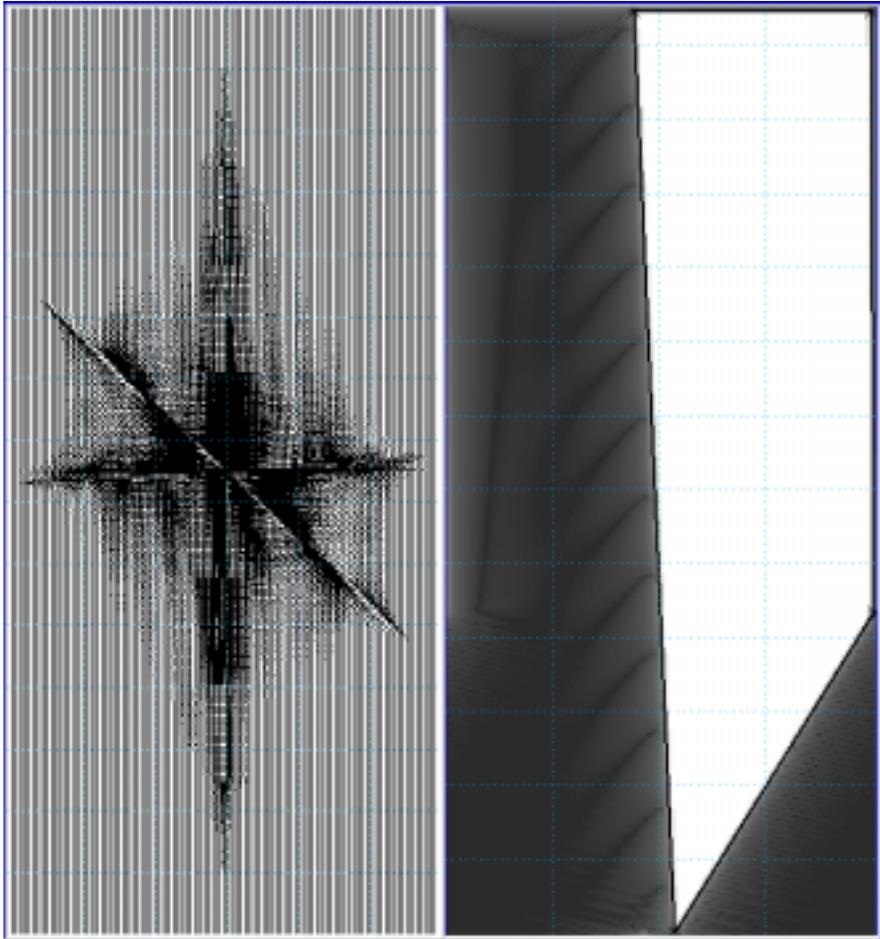
In this technique, a pass or reject range is specified in the F-K plane. Because there is no tapering of this filter in the F-K plane, that is  $\text{keep}=1$  and  $\text{reject}=0$ , the impulse response of this filter tends to spread over the entire T-X plane. This filter is computed for a specific extent in the T-X domain, thus limiting the allowed T-X extent of the impulse.



ProMAX® F-K Filter - Full Spatial and Time Aperture - no taper

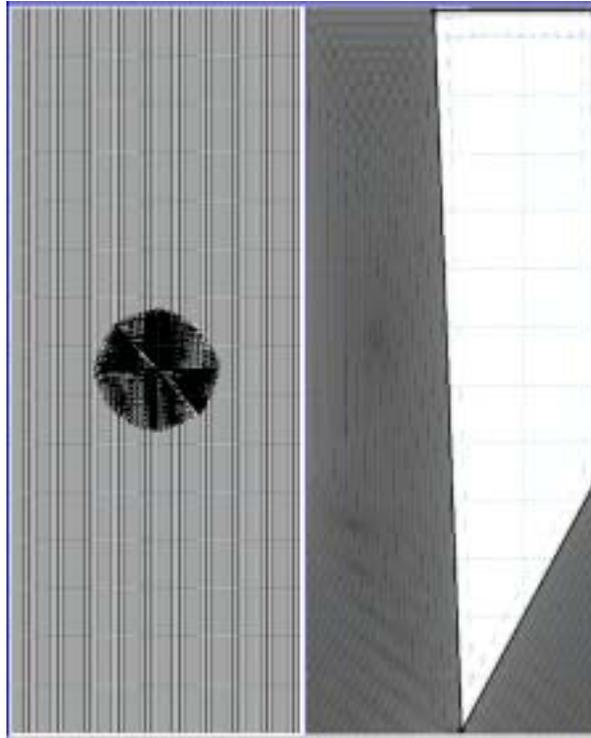
In the above diagram, the impulse response is generated from the specified keep and kill zones. Note that after the F-K filter mask is generated, the keep zone is full on instead of varying from full on to full off.

In the following diagram the effect of applying a 100% taper over all time and all space to this impulse is shown. Note the impulse has less spatial and time extent.



ProMAX® F-K Filter - Full Spatial and Time Aperture - full taper

The ProMAX® F-K filter explicitly limits the number of traces and time samples any input sample can affect. The parameters specify the spatial and temporal limits of the filter and how the amplitudes of the impulse response are tapered. Typical parameters are: extents are limited to 50 traces and 500 ms with a 90% flat taper.



ProMAX® F-K Filter - 500 ms. x 50 trace and 90% flat taper

When the spatial and temporal extents of the filter decrease, the percent flat should probably decrease. The highest amplitudes of the impulse are near the origin of the impulse. The smaller the extents of the filter, the larger the amplitudes. Thus the need for the longer tapers.

For large spatial and temporal extents of the filter, the taper length becomes less important because the amplitudes tend to fall off naturally as the distance from the impulse increases. For short spatial and temporal extents of the filter, the taper has a large effect on the dB separation between the keep and kill zones. For smaller extents, use smaller% flats (or more tapering) to increase the separation between the keep and kill zones.

## Usage

Three options are available for designing the F-K filters: **fan filter**, **power exponent**, and **arbitrary polygon**.

The **fan filters** are specified by frequency and velocity limits. You have the option of entering an unlimited number of frequency-velocity zones to filter within the F-K domain. If the

fan regions are allowed to extend beyond the Nyquist wavenumber (K-nyquist), only one fan filter can be specified. Velocity fan filter specifications are converted to polygons inside the program.

The **power exponent** option transforms the data to the F-K domain, raises all of the values to a given power, and then transforms the data back to the T-X domain. This procedure has the effect of enhancing the continuity of the data. As with all such techniques, it should be used with care and moderation. A power of 1.2 to 1.5 is recommended.

The **arbitrary polygon** option specifies a filter as a polygonal region of the F-K plane. Parameters for such polygonal regions are input as text F-K pairs, but using **F-K Analysis** is much easier. If using the text input option, be sure that polygons do not overlap.

Filters determined by polygons can vary spatially along the line. If polygons vary, F-K filters are interpolated from one location to the next. Filter polygons are not interpolated, but the computed F-K filter masks, designed at each location, are interpolated. This interpolation computes a different mask for each input ensemble by linearly interpolating the surrounding masks on a per F-K sample basis.

Filters used in the fan or polygon options are designed as T-X domain filters. These filters can be designed for a specific size and then windowed using elliptical Hanning tapers. The smaller the T-X filter, the less attenuation and smoother the response of the resulting F-K filter. Remember, the larger the filter, the longer the required execution time. T-X data is padded with zeros, half the filter size in each direction prior to transformation to F-K to prevent wraparound of amplitudes. Windowing the T-X filter results in a smoother F-K response with some reduction in attenuation. **F-K Analysis** should be used to optimize filter size and windowing parameters.

Filters are designed as either **Pass** or **Reject** filters in the F-K plane. Pass filters gives little attenuation of the data within the specified polygon or fan, while strongly attenuating the data outside of this region. A reject filter strongly attenuates the data in the specified region, while leaving the data outside this region relatively unaffected.

We recommend applying gain corrections before applying F-K filter to the data. If the data have highly variable amplitudes,

the highest amplitudes will dominate the F-K spectrum. Filtering will cause artifacts of these high amplitudes to be spread to other regions of the data in T-X. It is possible to compress amplitudes before F-K filter and decompress afterwards by using **AGC** before F-K filter and saving the scalars to the trace headers, then removing the AGC scalars after F-K filter. The actual picking of the polygon is done interactively with **F-K Analysis**.

## Parameters

### ***TYPE of F-K filter***

Select one of three types of filters to be applied in F-K space:

- **Fan Filters** filters pie slice(s) in the F-K domain.
- **Power Exponent** raises the F-K domain to a fixed power.
- **Arbitrary Polygon** filters an arbitrary polygon in F-K space.

### ***Units of pie slice parameterization***

This appears if **Fan Filters** to **Type of F-K filter**. Select units of either **Velocity** or **Ms per trace**. The default for Fan Filter parameters change depending on this option.

### ***Distance between input traces***

This appears if **Fan Filters** or **Arbitrary Polygon** to **Type of F-K filter**. Enter **0.0** to automatically calculate the trace spacing. Input ensembles must be shot, receiver, or CDP ordered. The trace spacing is calculated by:

[[current fold/shot fold] x shot interval] for CDP and receiver ordered ensembles

the receiver interval for shot ordered ensembles

the CDP interval for stack data

Otherwise, enter the actual trace spacing.

### ***Panel width in traces***

Enter the number of traces to process at one time. Enter the number of traces per ensemble for prestack data. The minimum allowable number of traces in a panel is 5.

### ***Test the filter impulse response?***

This appears if **Fan Filters** or **Arbitrary Polygon** to **Type of F-K filter**. Select **Yes** to output the result of applying the F-K filter to a spike. This result shows the impulse response of the filter which you have designed. Select **No**, the default, to output the result of the application of the filter to the data.

### ***Percent flat for time ramping***

This appears if **No** to **Test the filter impulse response**. Enter the percent flat for time ramping. A value of **100.0** means that no ramp is applied. A value of **90.0** will result in a ramp on each end of each trace equivalent to 5% of the maximum time length of the traces.

The shallow and deep ends of each trace can be tapered before the T-F transform in order to minimize the FFT edge effects. The process attempts to remove the effect of this ramp after the F-K filtering and inverse transform. High amplitudes may result on output along the first and last time samples since the ramping is removed after filtering.

### ***Percent flat for offset ramping***

This appears if **No** to **Test the filter impulse response**. Enter the percent flat for offset ramping. A value of **100.0** means that no ramp is applied. A value of **90.0** will result in a ramp on each end of the data equivalent to 5% of the input panel width value.

The edge traces can be tapered before the K-space transform in order to minimize the FFT edge effects. The process attempts to remove the effect of this ramp after the F-K filtering and inverse transform. High amplitudes may result on output along the first and last traces since the ramping is removed after filtering.

### ***Get polygon mute file from the database?***

This appears if **Arbitrary Polygon** to **Type of F-K filter**. Select **Yes** to get a polygon mute parameter file from the database. Select **No** to specify an arbitrary polygon manually.

### **Select mute parameter file**

This appears if **Yes** to **Get polygon mute file from the Database**. Select a polygon mute parameter file from the list of parameter files.

Polygon mute parameters are specified at primary key locations and the filters are linearly interpolated between these locations.

### **Specify arbitrary polygon**

This appears if **No** to **Get polygon mute file from the Database**. Enter the polygon corners as F-K pairs in the following format:

$$\text{KEY: Frequency1-} \frac{K_1}{K_{\text{Nyquist}}}, \text{Frequency2-} \frac{K_2}{K_{\text{Nyquist}}},$$

$$\text{Frequency3-} \frac{K_3}{K_{\text{Nyquist}}}, \text{Frequency4,} \frac{K_4}{K_{\text{Nyquist}}} /$$

EXAMPLE: 1:10-0.0, 20-0.4, 30-1.0,50-1.0,10-0.0 /

Remember that the values must loop form a complete polygon. Frequencies are input in units of Hz, while wavenumber (K) values are input as fractions of K-nyquist.

### **Mode of F-K filter operation**

This appears if **Fan Filters** or **Arbitrary Polygon** to **Type of F-K filter**. The choices are:

- **Reject** attenuates the specified F-K region(s).
- **Accept** passes the specified F-K region(s), attenuates elsewhere.

### **Percent flat for F-K filter windowing**

This appears if **Fan Filters** or **Arbitrary Polygon** to **Type of F-K filter**. The T-X filter used to design the F-K filter may be windowed to give a smoother response which will result in fewer artifacts on the output data. This may be at the expense of some attenuation in selected regions of the filter. This windowing is implemented by an elliptical Hanning taper window applied to the T-X filter. This filter will be a full Hanning taper if a value of **0.0** is used, or may only apply to

the outside edge of the filter if a value of **90.0** is used. A value of **100.0** results in no tapering of the filter.

### ***Time length of F-K filter (ms)***

This appears if **Fan Filters** or **Arbitrary Polygon** to **Type of F-K filter**. Enter the time length of the desired T-X filter in ms to use in designing the F-K filter. A longer T-X filter will result in greater attenuation of noise, but will give a longer execution time. The filter will have a maximum time length equal to the maximum time of the input data, even if specified longer.

### ***Spatial extent of F-K filter (traces)***

This appears if **Fan Filters** or **Arbitrary Polygon** to **Type of F-K filter**. Enter the number of X-samples (traces) of the desired T-X filter to use in designing the F-K filter. A longer T-X filter will result in greater attenuation of noise, but will give a longer execution time. The filter will have a maximum number of traces equal to the number of traces of input data, even if specified larger.

### ***Power to raise F-K space to***

This appears if **Power Exponent** to **Type of F-K filter**. Enter a power to raise the F-K transform values, and then inverse transform. If the power is greater than 1.0, the output traces could have noticeably larger amplitudes than the input traces.

### ***Reapply T-X trace mute after filter***

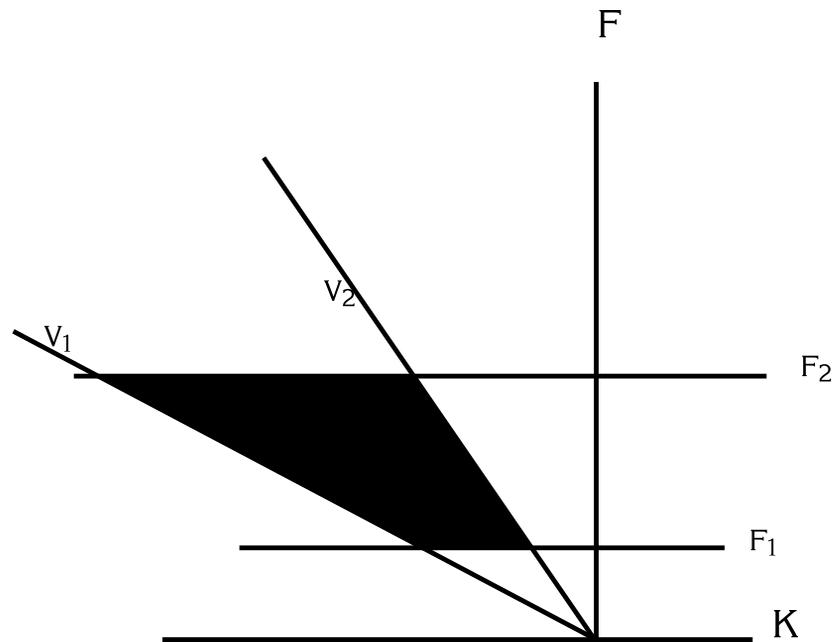
Select **Yes** to automatically reapply previously applied trace mutes after F-K filtering. Select **No** to leave the data as it is output from the F-K filter.

### ***Fan filter parameters***

This appears if **Fan Filters** to **Type of F-K filter**. Enter the settings for the F-K filter slices. The velocities can be positive or negative. You can specify a slice which spans from a negative velocity to a positive velocity. That is, the filter can include the zero wavenumber axis. However, problems can occur if one of the velocities in the fan is very low. For example, a value less than 500 ft/s. Any number of fans or slices can be entered.

This parameter can also be entered in units of ms/trace dip depending on the **Units of pie slice parameterization**. In this case the slices are specified in the following format:

dip1, dip2, freq1, freq2 / dip1, dip2, freq1, freq2 /



### ***Wrap fan in K-space past Nyquist?***

This appears if **Fan Filters** to **Type of F-K filter**. Select **No** to not wrap in K-space past K-Nyquist, the spatial aliasing wavenumber. This prevents the fans crossing or overlapping which gives either double response or no response in the in the overlap areas due to the integration around the polygons.

The default **Yes** wraps past the spatial Nyquist. If Yes, only a single fan or slice may be specified and this fan cannot include  $K=0$ . If more than one fan is specified or a single fan that includes  $K=0$  is specified, this option is automatically set to NO regardless of the menu input value.

### ***Percent K-space restricted for fan***

This appears if **Fan Filters** to **Type of F-K filter**. Enter a percentage of the K-space Nyquist, or aliasing value. The F-K velocity filtering is restricted to this limit in order to prevent spreading at higher frequencies. The effect of this restriction is to give a corridor region with parallel sides at a velocity which is the harmonic mean of  $V1$  and  $V2$ .

### ***Time filter padding in percent***

This appears if **Power Exponent** to **Type of F-K filter**. Enter a percentage of the trace length. This value calculates the number of zero-valued samples to add to each trace before the F-K transform. For normal data, with gain corrections applied, a value of 25% is suitable. If the data is poorly gain corrected and still shows significant amplitude variation with time, a value of 100% might be more appropriate. Adding more samples will increase the computation time.

### ***Space filter padding in percent***

This appears if **Power Exponent** to **Type of F-K filter**. Enter the percentage of zero padding for the FFT in the spatial domain. For normal data with gain corrections applied, a value of 25% is suitable. If the data is poorly gain corrected, a value of 100% might be more appropriate. Adding more samples will increase the computation time for this process.

### ***Percentage of K-space to keep around K=0***

This appears if **Fan Filters** or **Arbitrary Polygon** to **Type of F-K filter**. Enter the percentage of K-space to leave unfiltered in a corridor around  $K=0$ .

**Caution:** This parameter is not incorporated in the design of the T-X filter. It is applied to the F-K filter before application. Therefore, the effective T-X filter may extend beyond the trace and time boundaries.

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