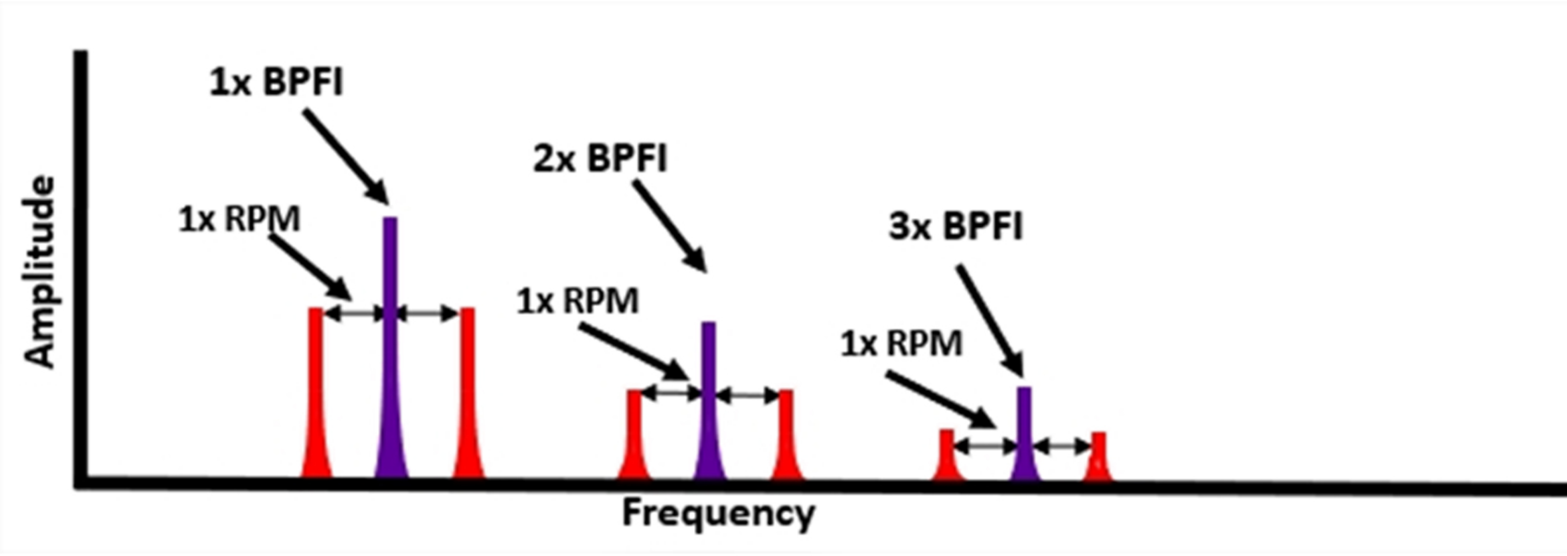
SIDEBANDS

Use of Sidebands to Aid Vibration Spectral Analysis



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Sidebands:

Use of Sidebands to Aid Vibration Spectral Analysis

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Introduction

When performing vibration analysis in rotating machinery, sidebands are a critical piece of the puzzle in determining certain types of faults. Often, sidebands can be a bit cumbersome to comprehend. If not properly understood, it means a lot of vibration data analysts miss out on the information that the presence of sidebands offers during the resolution of machinery health status.

What are Sidebands?

Imagine a perfect scenario where Gears mesh perfectly with no issues, no wear in the teeth, no shaft play, and no eccentricity problems, we would only have vibration activities at Gear Mesh Frequency (GMF). In reality this is not the case as there would be some imperfections. These can show up as sidebands alongside the GMF as the gears mate during operation. The GMF is the center Frequency and the other pairs of frequencies that show up due to worn or damaged teeth or shaft play are known as sidebands.

Sidebands are frequencies that are generated in the frequency domain because of the modulation of a Carrier signal by a Modulating signal. Modulation itself is usually the fluctuation (periodic change) in amplitude or in frequency of the Combined signal (Carrier plus Modulating signals) due to the influence of the modulating signal. The frequency of the Modulating signal is in most cases lower than that of the Carrier signal. The sidebands are formed in pairs as new frequencies above and below the Carrier Frequency. Simply put, sidebands are the way the FFT (Fast Fourier Transform) expresses the occurrence of modulation (as observed in the time domain) in the Frequency domain.

Consider another illustrative example that can be used to describe how sidebands present themselves. Imagine a discussion in a planning room about a Horse and a Horse rider in a Horse racing competition. On the actual day of racing, the executor of the plan decides that the Horse Rider should not show up directly but instead indirectly sends two representatives who show up at equal intervals. Representative A shows up 20minutes prior to the Horse and the other representative, B shows up 20minutes after the Horse. Both representatives A and B ride the Horse together and the spectators looking at this sort of appearance are only able to trace the originally intended Horse rider by the equal time interval (20mins) by which the representatives A and B showed up. This similar time interval of 20minutes is the only information available to identify the Modulating Frequency. In the frequency domain, the identity of the modulating frequency (Horse Rider) is only determined by the spacing interval between the Carrier frequency (Horse) and the Sidebands (Representatives). See below Table 1 (actors and connotations) and Figure 1.

Actor	*Connotation*
Planning Room	Time domain
Actual day of racing	Frequency domain
Executor of plan	FFT (Fast Fourier Transform)
Horse	Center Frequency (Carrier or Primary Frequency)
Horse Rider (identified by 20mins interval)	Modulating Frequency (identified by Spacing interval)
Representative A	Upper Sideband
Representative B	Lower Sideband
Spectators	Vibration data analysts

Table 1: Actors and Connotations in the two riders to one Horse illustrative example

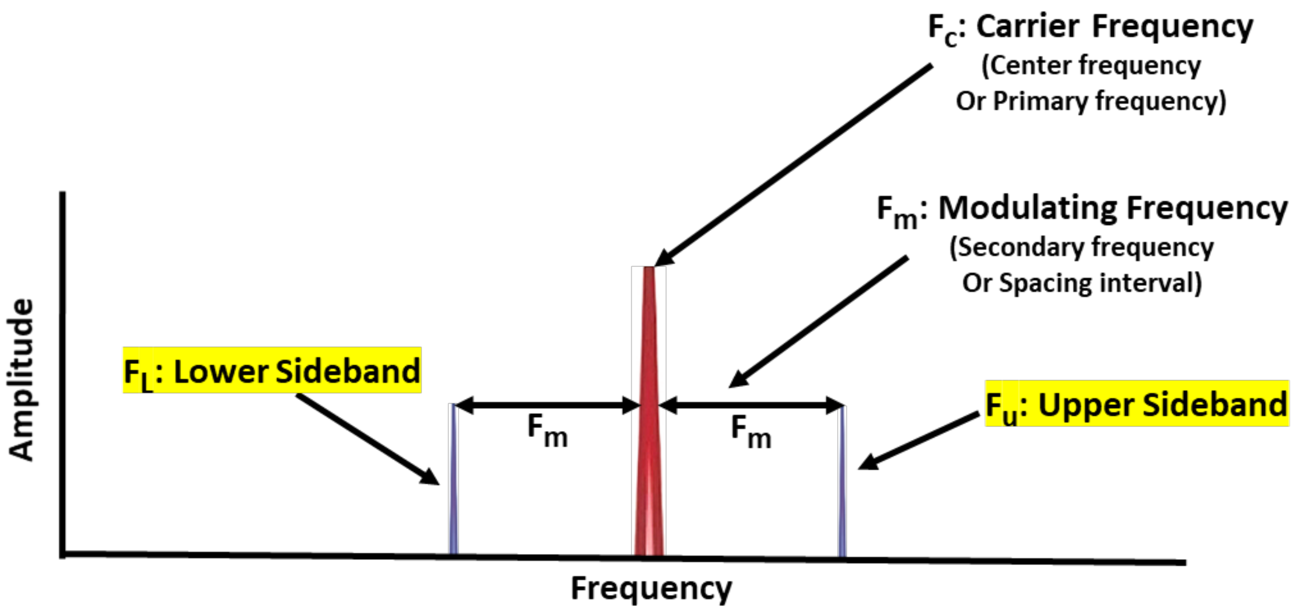

Figure 1: Sidebands formation around a Carrier frequency

Sidebands Formation

Sidebands are typically formed from two forms of modulation:

- Amplitude Modulation
- Frequency Modulation

Amplitude Modulation

This is the form of modulation that generates the most common cases of sidebands in vibration analysis. For this form of modulation, the Carrier signal and the modulating signal are somewhat superimposed to result in a new signal with varying amplitude but at a constant frequency. When this is passed though the FFT (Fast Fourier Transform) and viewed in the frequency domain, it typically shows the sidebands with varying amplitudes at constant frequency (see figure 2).

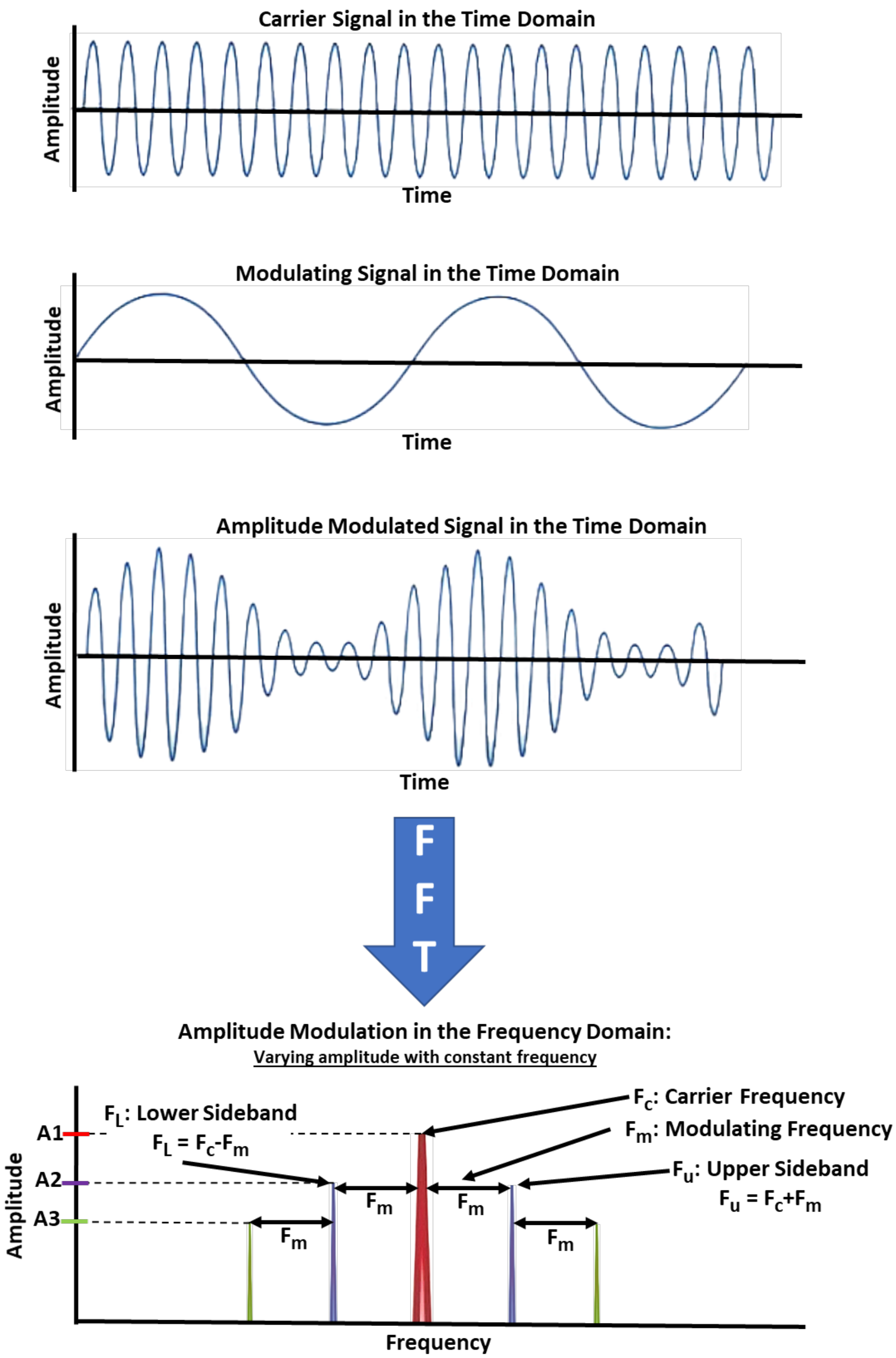

Figure 2: The process of amplitude modulation and the formation of sidebands

Frequency Modulation

In this case, the new signal formed because of merging the Carrier and the Modulating signals together has a constant amplitude but at varying frequency. Passing this through the FFT (Fast Fourier Transform) into the frequency domain gives the sideband peaks with varying frequency at a constant amplitude. This case of Frequency Modulation is not very common. See figure 3 below.

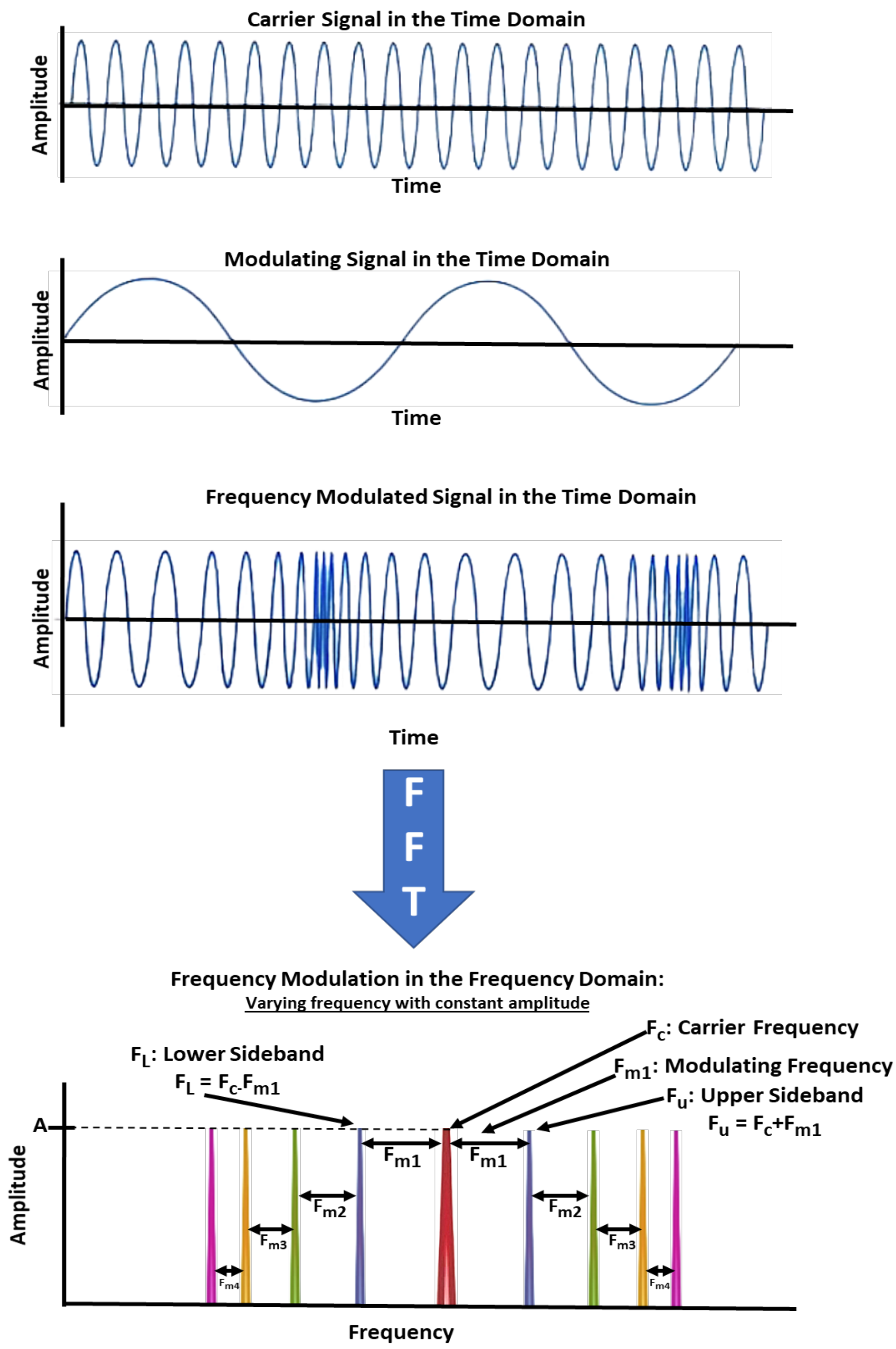

Figure 3: Frequency modulation process and the formation of sidebands

Important Features of Sidebands in Vibration Analysis

- Increase in their amplitude levels mostly indicate the presence of a machinery issue. (Note: They do not always show up for fun).
- Their presence even at very low amplitude levels can be significant during vibration data analysis.
- They are mostly equally spaced from the center frequency.
- They can occur around multiple harmonics of the center frequency.
- They can be formed around different center frequencies.
- They can occur in multiple pairs of more than one.
- They can have different amplitude levels relative to the center frequency (sometimes known as asymmetric sidebands).

Note: Sidebands are usually the lower and upper frequencies evenly spaced around the center frequency. The spacing or separation is the modulating frequency, and it is generally sometimes confused as the sidebands. For example, you will sometimes hear vibration analysts say, "there is a peak at 890Hz with sidebands of 30Hz". This means that the center frequency (Carrier signal) is 890Hz. The equal spacing or modulating frequency is 30Hz. This signifies that the Upper and Lower sidebands are (890+30 and 890-30) 920Hz and 860Hz respectively.

Fault Progression

If sidebands are present and do not change overtime, it means that there is no increase in the rate of deterioration. However, as a fault progresses, the amplitude levels of the sidebands will experience an increase. As things get even worse with the machine's health status, it is also possible to see multiple pairs of sidebands appear especially with amplitude modulation-type sidebands. With increased levels of deterioration, the carpet level (energy level) between the sidebands and the center frequency also tends to be increased. See figure 4 showing progressive deterioration from June through to August.

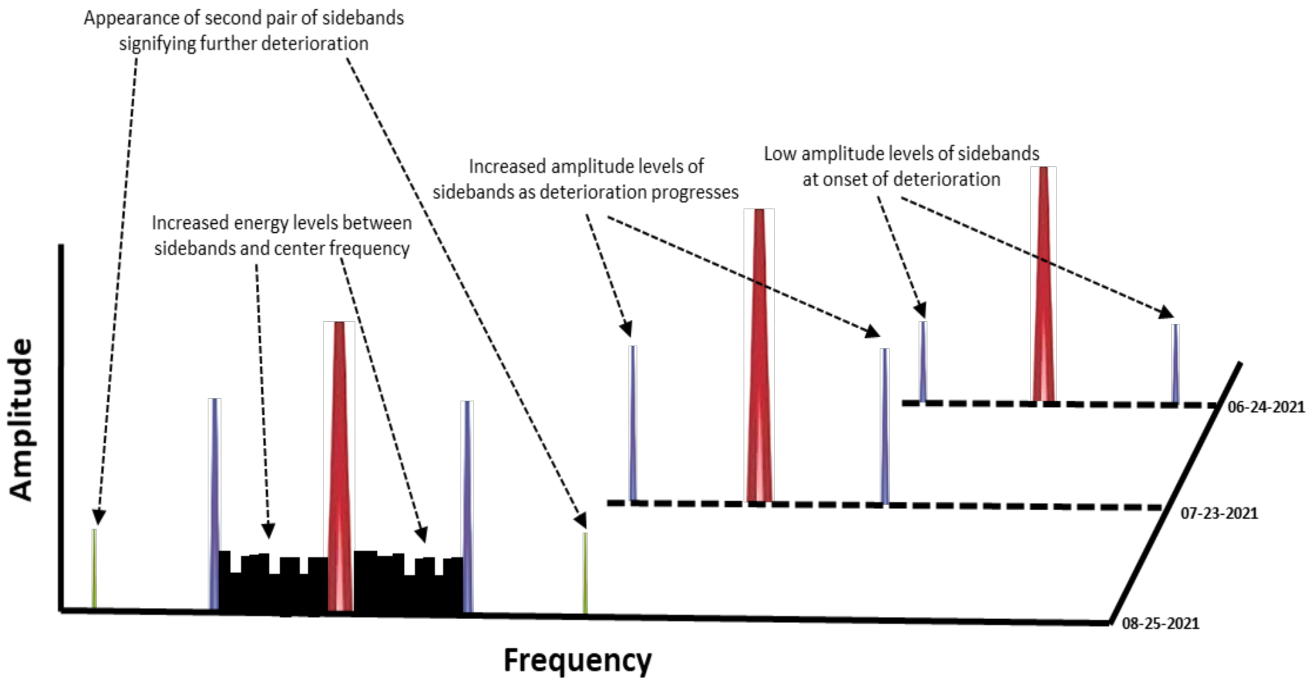

Figure 4: Fault progression highlighted in changes of sidebands activities over a given range of time.

Identification and Trending of Sidebands

Sidebands can sometime be difficult to identify from linear spectral plots. This is primarily due to their low amplitude levels, especially at the onset of a machinery fault. If vibration data analysis is carried out manually, it will be beneficial to view the spectra in the logarithmic display.

Some tools are capable of automatically detecting side bands (even with the tiniest of amplitude levels). In such cases there will be no need to manually scan through spectral plots overlays or historical waterfall plots to try and find sidebands. In other cases, the amplitude levels of these side bands can automatically be extracted and trended. This can be an important piece of information as the upward change in amplitude levels signifies an increased rate of deterioration. In other applications the progression in amplitude of multiples of sidebands and the energy levels between sideband peaks and the center frequency peak can also be trended. Threshold limits can also be applied to sideband peaks so that an alert notification is automatically sent by email to designated recipients if amplitude levels become higher than the set limits.

Brain Teasers: Check your Comprehension

Q1: Which one of the following is a form of modulation? (A): Amplitude (B): Mass (C): Force

Q2: A Vibration Analyst says that a set of data captured from a Forced Draft Fan contains a peak at 1790Hz with sidebands of 60Hz What are the Upper and Lower Sideband Levels (A): 1820Hz and 1760Hz (B): 1880Hz and 1700Hz (C): 1850Hz and 1730Hz

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