Beam Signals Experiment Primmer

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(with material stolen from John Staples' talks and many words provided by Stefano De Santis)

Modulations on a Beam Pickup Signal

- On machine you use stripline or buttons beam pickups to determine beam position. These devices give one a short pulse signal the magnitude of which is proportional to the distance the beam is from the pickup device.
- If the beam that is passing by the pickup is moving up and down at some given frequency it is known as a betatron oscillation. (i.e betatron oscillation frequency)
- This shows up as a AM modulation on the signal at the pickup.

Synchrotron Oscillation

- If the time of arrival of a beam bunch also known a micropulse, is varying it known as synchrotron oscillation.
- This shows up on a beam pickup (more so on a button or cavity pickup) as an PM modulation.
- Telling the difference between this PM and AM on a real beam is very difficult [1. . Because Stefano says so]
- In theory, it can be done with a Vector spectrum analyzer because the phase of the FM sidebands is rotated 90d while AM sidebands are in phase with each other (Patent pending]

Where the problems lie

- For synchrotron oscillations the problem is with the RF or as we at JLAB FEL like to say it is always the drive laser (phase).
- For betatron oscillations the cause is normally a magnet stability or a lattice setup issue.
- There are times when induced betatron oscillations are useful.

Spectrum of a pulse train with phase (PM modulation)

- The frequency deviation is proportional to the harmonic number. However, the modulation index is the frequency deviation divided by the modulation frequency.

$$I(t) = e\sum_{n}\delta\big(t - nT_0 0 + \tau_X x cos(\omega_S)\big)$$

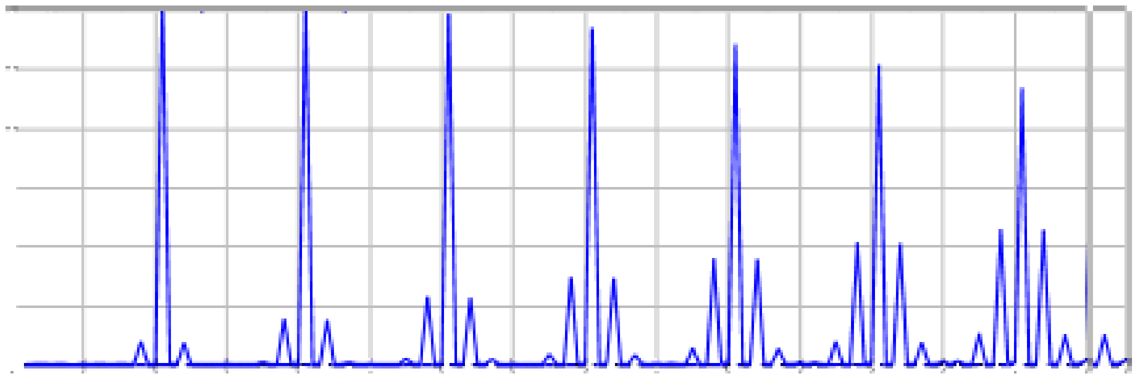
- Thus, the modulation index of each harmonic is proportional to the harmonic number.

Bessel functions continued

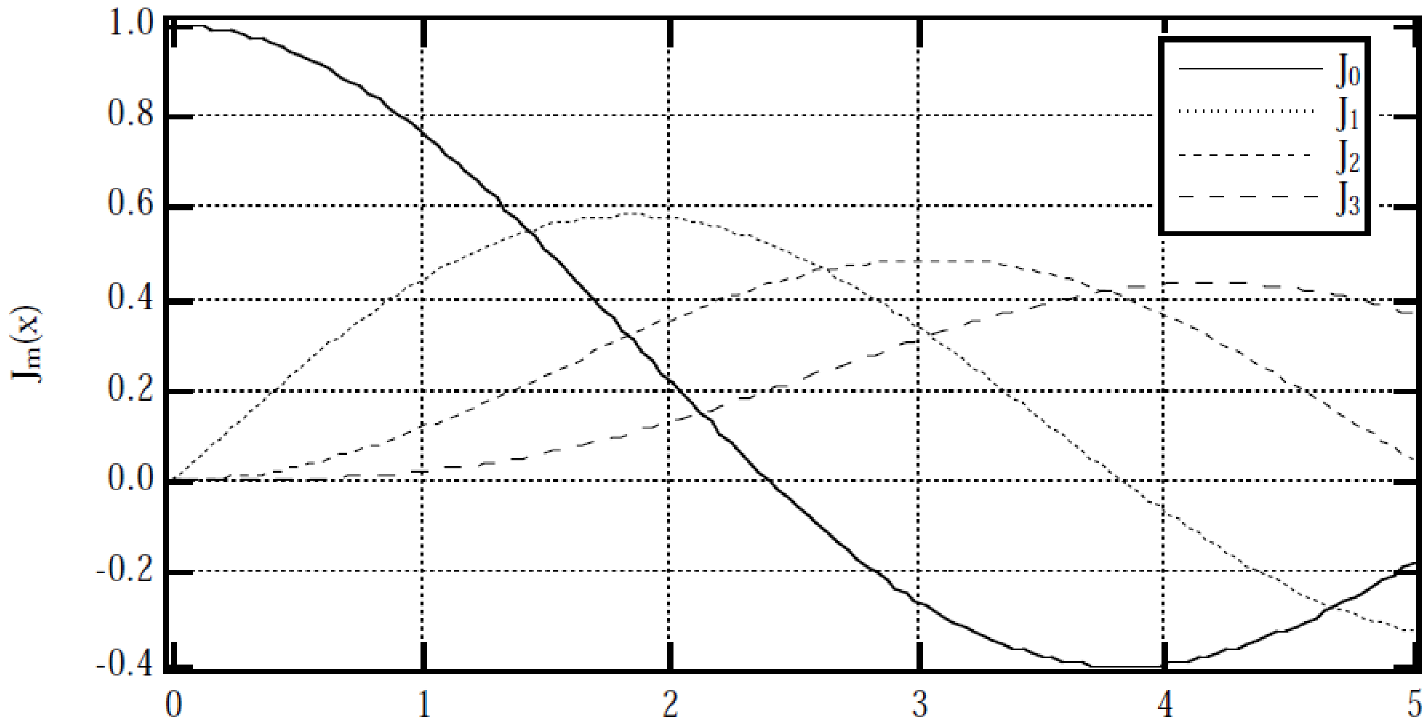
$$V(t) \sim \; J_0(m)\cos(\omega_c t) + J_1(m)\left[\sin(\omega_c + \omega_m)t + \sin(\omega_c - \omega_m)t\right] + J_2(m)\left[\cos(\omega_c + 2\omega_m)t + \cos(\omega_c - 2\omega_m)t\right] + J_3(m)\left[\sin(\omega_c + 3\omega_m)t + \sin(\omega_c - 3\omega_m)t\right] + J_4(m)\left[\cos(\omega_c + 4\omega_m)t + \cos(\omega_c - 4\omega_m)t\right] + \cdots$$

The sideband amplitudes grow as the Bessel function of the modulation index m. The sidebands retain the same separation from each carrier, but change amplitude.

Measuring the harmonics of the pulsed waveform, the amplitude and phase modulation amplitudes can be separately determined.



The comb function from an impluse response has added FM sidebands which are contained within the Bessel function envelopes



Bessel functions of order 0, 1, 2, and 3

Fundimental harmonics follow the m=0 Bessel functions while the first side band follow the m = 1 one Bessel function, the second follows the m = 2 sideband, etc.