Bicoherence studies on LLO data

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- Offline analysis of bicoherence of 6hrs of data, July 12, 2002 using functions written in Matlab.
- Bicoherence shows low frequency noise being upconverted to around the power line harmonics(very strongly at 120Hz)
- Results suggest similar upconversion processes for these frequencies.

Definition of Bicoherence

$$B(k,l) =< X_k X_l X_m^* >$$

$$b(k,l) = \frac{B(k,l)}{\sqrt{|X_k X_l|^2 |X_m|^2}}$$

B=0 for signals spontaneously excited

B large for signals with m=k+l

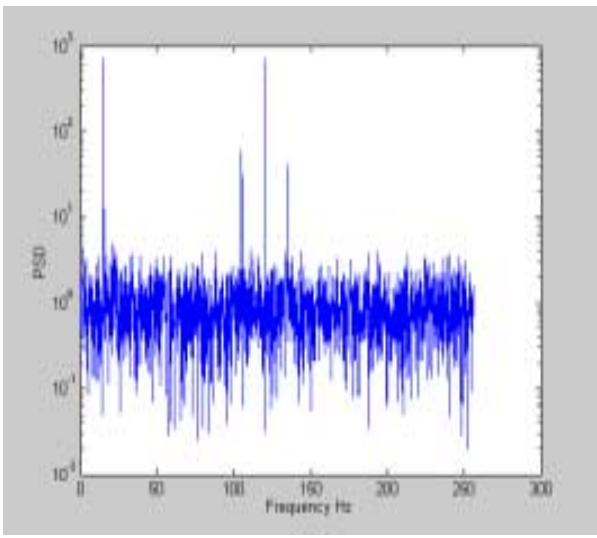
$$e^{i\phi_1} e^{i\phi_2} e^{-i(\phi_1+\phi_2)}$$

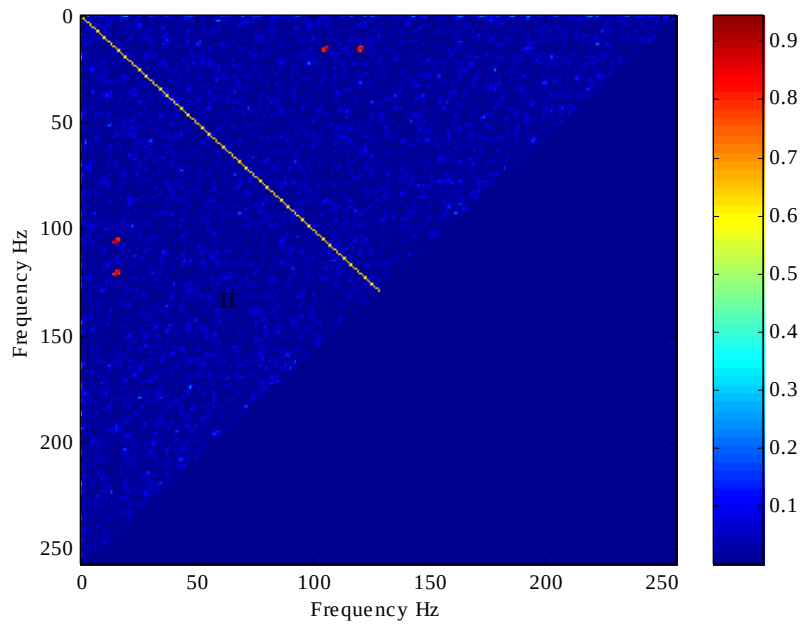
b normalised, $0 \le b \le 1$

Phase of b indicates degree of coupling

Y=y1 + y2 + y1*y2 +noise, 15Hz, 120Hz

15+120=135, 15+105=120



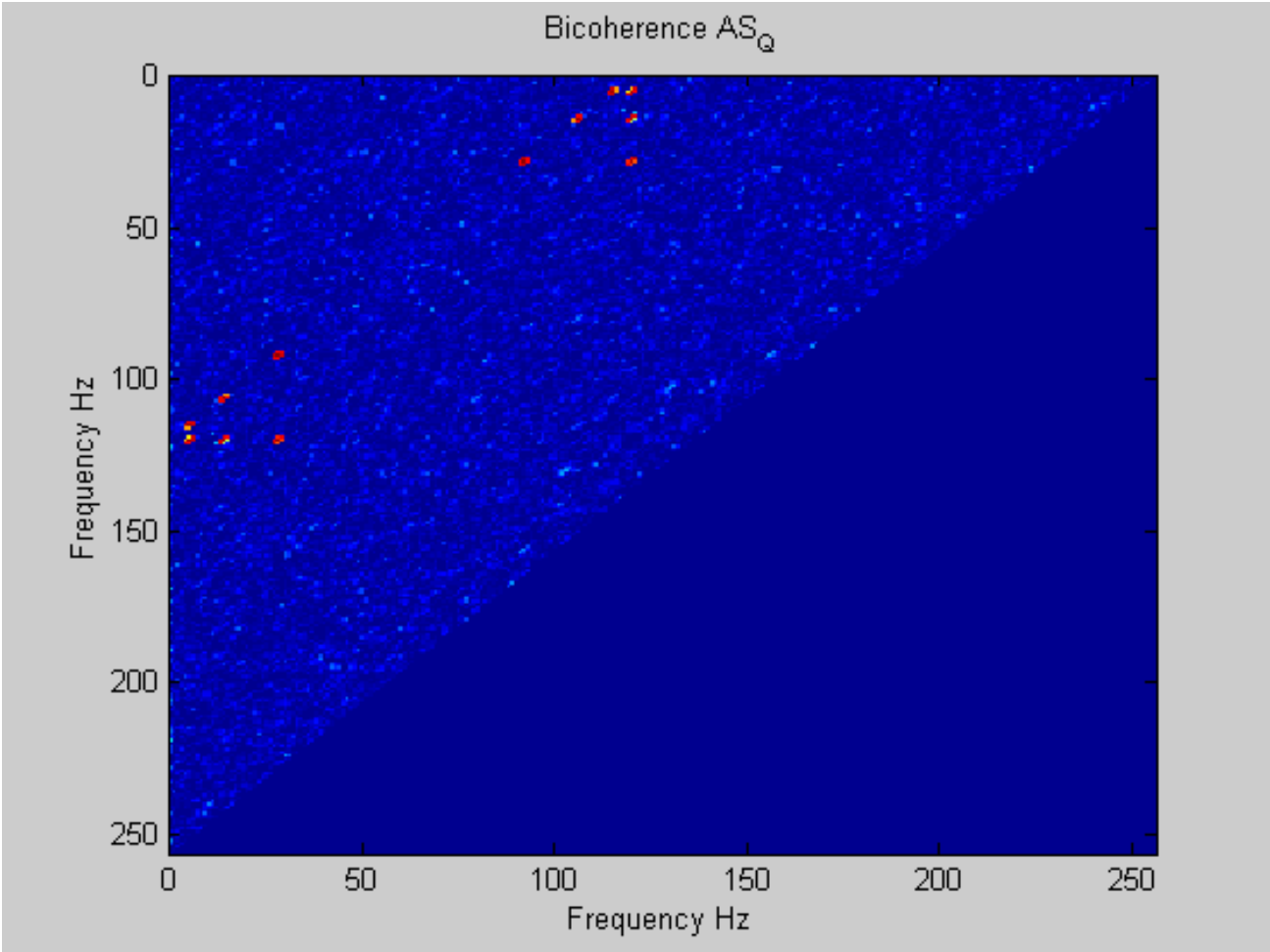


Simulation

Y=y1 + y2 + y1*y2 +noise
y1=5, 14, 27 Hz, y2=120 Hz

y1, y2 Phase coupled

Biphase $\arg(B(k,l)) = \arg(e^{i\phi_1} e^{i\phi_2} e^{-i(\phi_1+\phi_2)}) = 0$

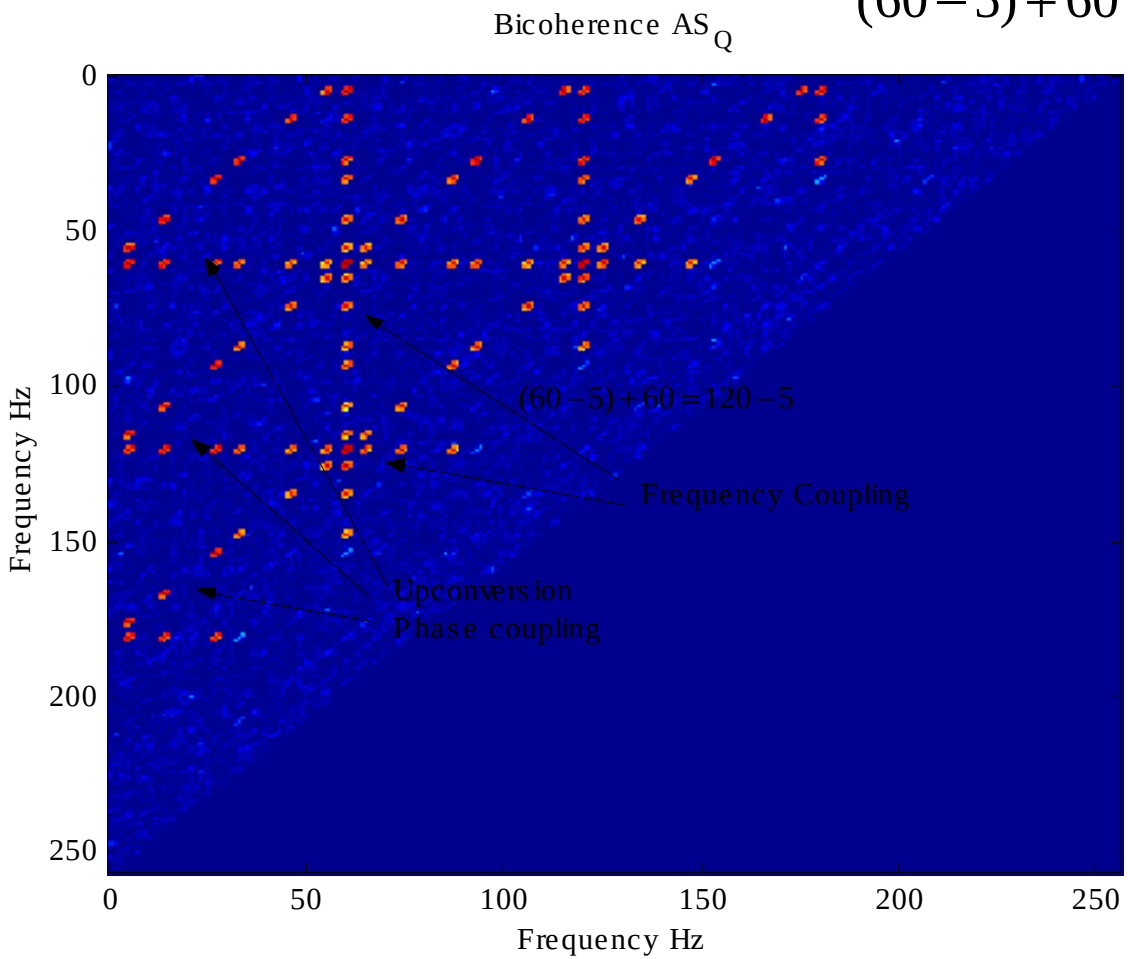


Simulation

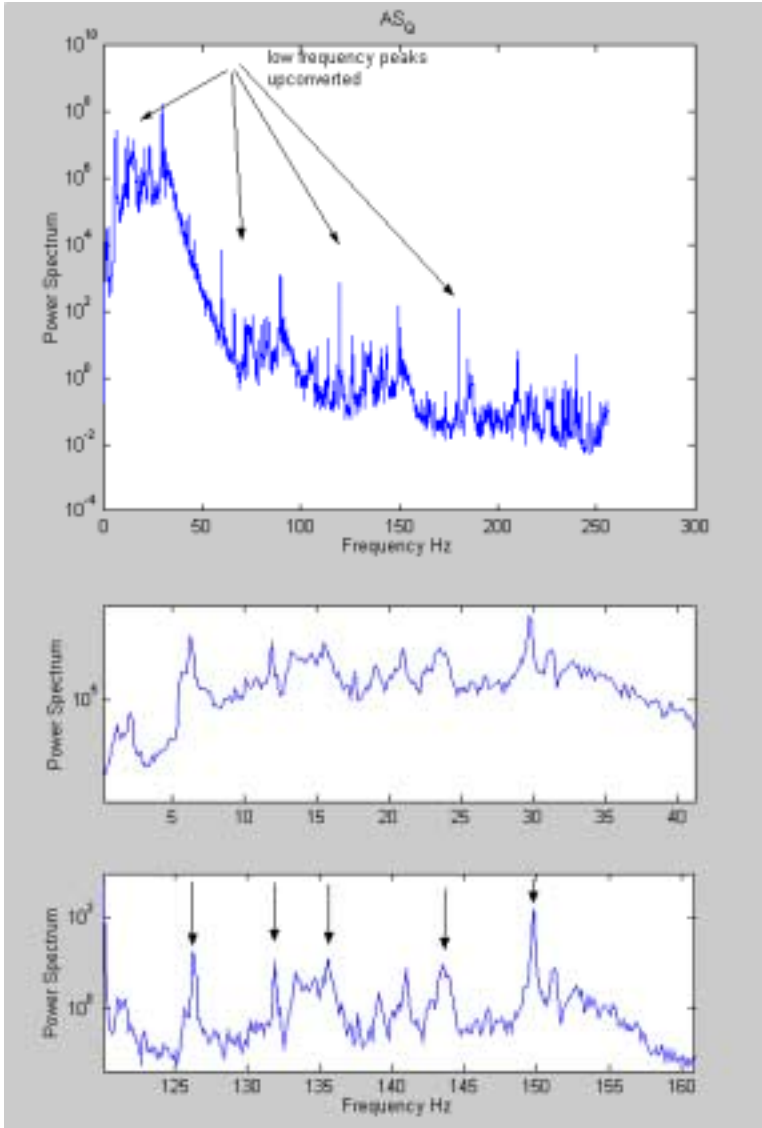
Y=y1 + y2 + y1*y2 +noise
y1=5, 14, 27 Hz,
y2=60, 120, 180Hz

Phase coupled ……..upconversion
Frequency coupled…more common, will exist if signals are in phase

$$(60-5)+60=120-5$$



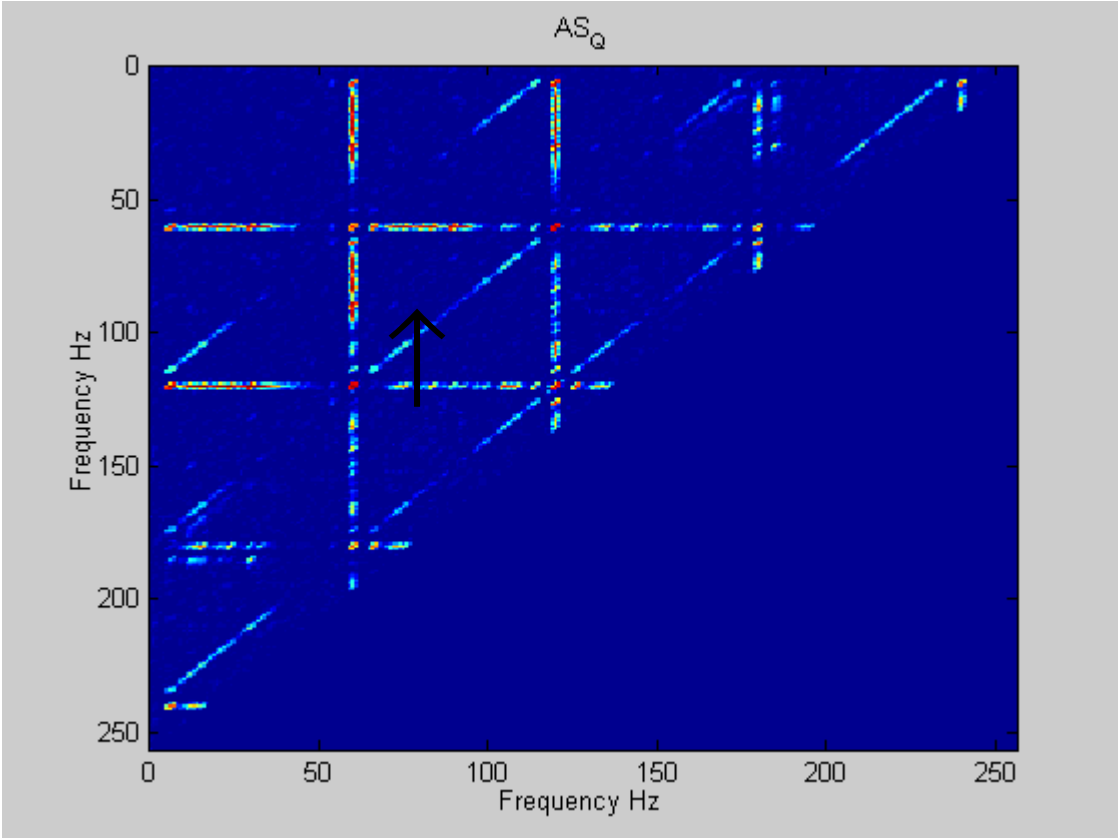
ASQ data power spectrum

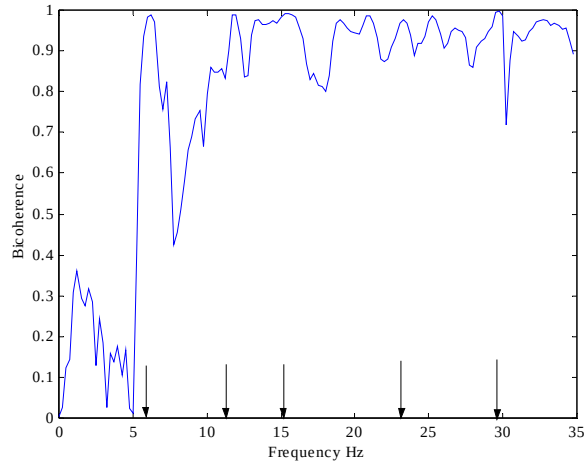


Prominent Peaks
1 Hz - MC side, pendular
6.3Hz - Stack mode
11.9Hz- ITM/ETM vertical bounce
15.4Hz- MC roll
23.3Hz- pump vibration
29.7Hz- pump vibration

Upconversion
Nonlinearity in electronics??,
Line harmonics modulate low frequency motion??…

ASQ Bicoherence





Bicoherence is close to unity for the low frequency peaks.

Low Frequency upconversion negative sidebands at 60Hz supressed by low frequency noise.

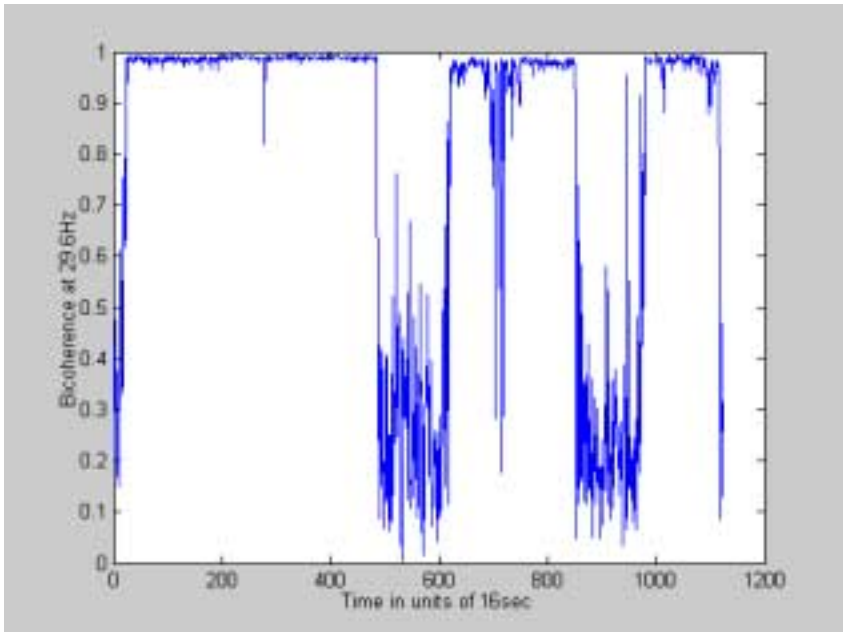
$$X_m = fX_k X_l + X_m^{noise}$$

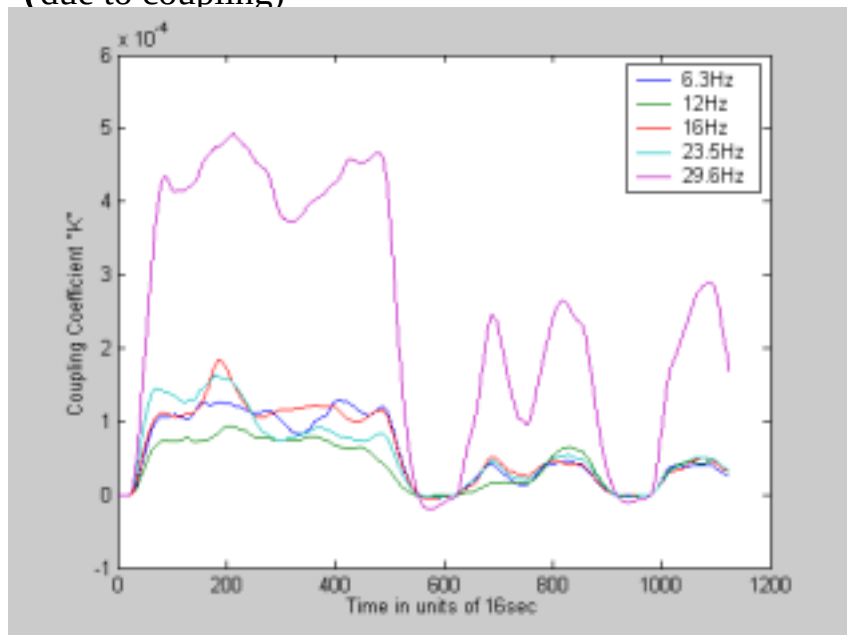
P(sidebands due to coupling)= $b^2 \times$ P(sidebands)

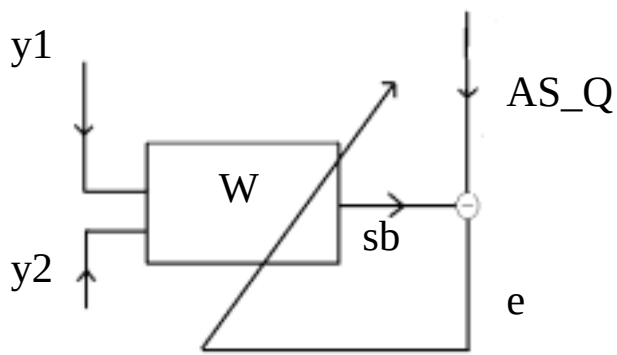
Tracking bilinear coupling

Simplified model:
Y=y1+y2+K(t)*y1*y2+noise.

K~P(sideband)/sqrt(P(120)*P(low freq peak))
(due to coupling)

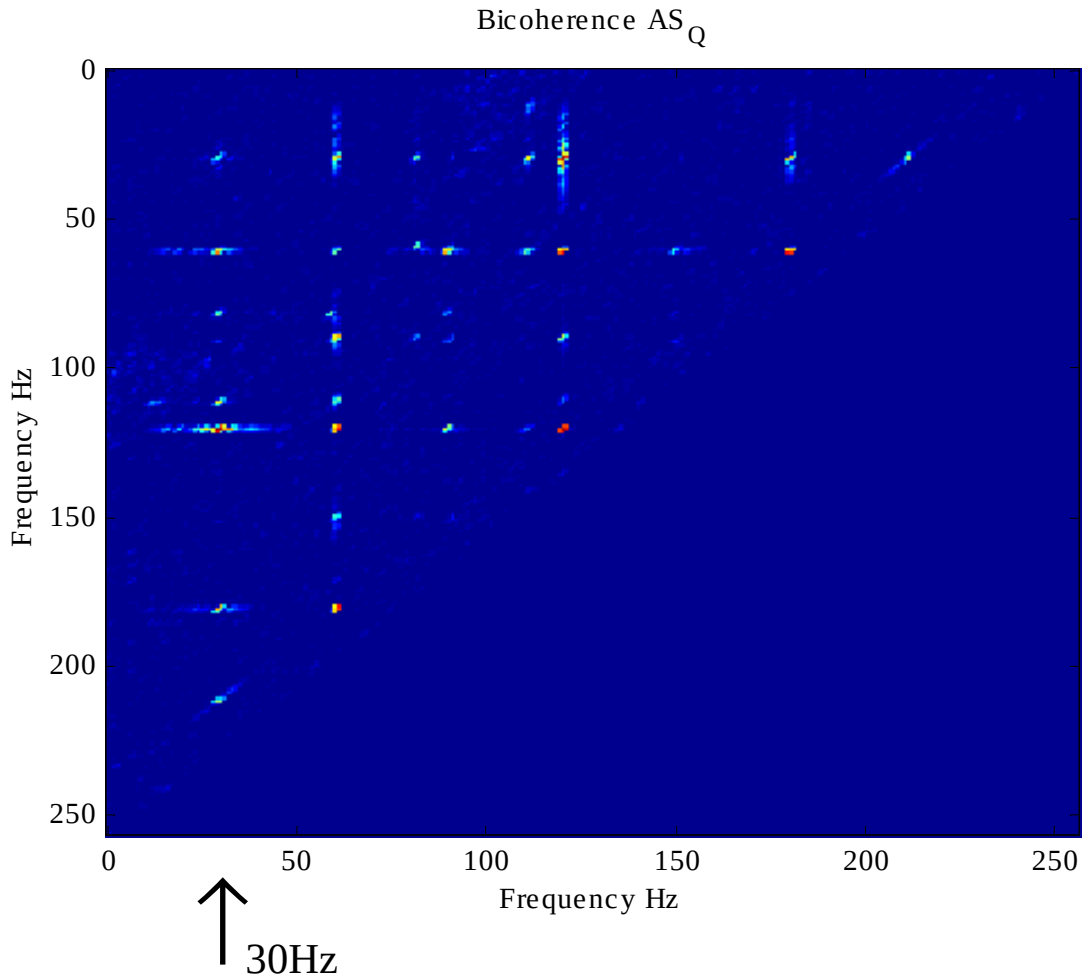






K shows similar trend in low frequency peaks.Individual differences should be examined in detail.
Adaptive scheme to estimate the sidebands obtain K(t), monitor for drifts or slow variation

Recent data taken shows reduced upconversion due to improvements in low frequency noise reduction.(upconversion varies in time)



Peak at ~30Hz most dominant.

Summary And Conclusions

- Bicoherence was useful in identifying bilinear coupling.
- Coupling seems to be similar for several frequencies although a more detailed analysis should be performed to look for individual variations.
- It might be interesting to explore nonlinear filters to track the coupling, more study needed to understand this.
- Online analysis using BicoMon, it would be useful to have an output where high regions of bicoherence are recorded, can be used to look for trends in coupling.
- Most recent data shows reduced upconversion, due to improvements made in low frequency noise, however analysis may be interesting for the future.