Estimation of harmonic parameters of linearly frequency modulated signals using analysis by synthesis approach

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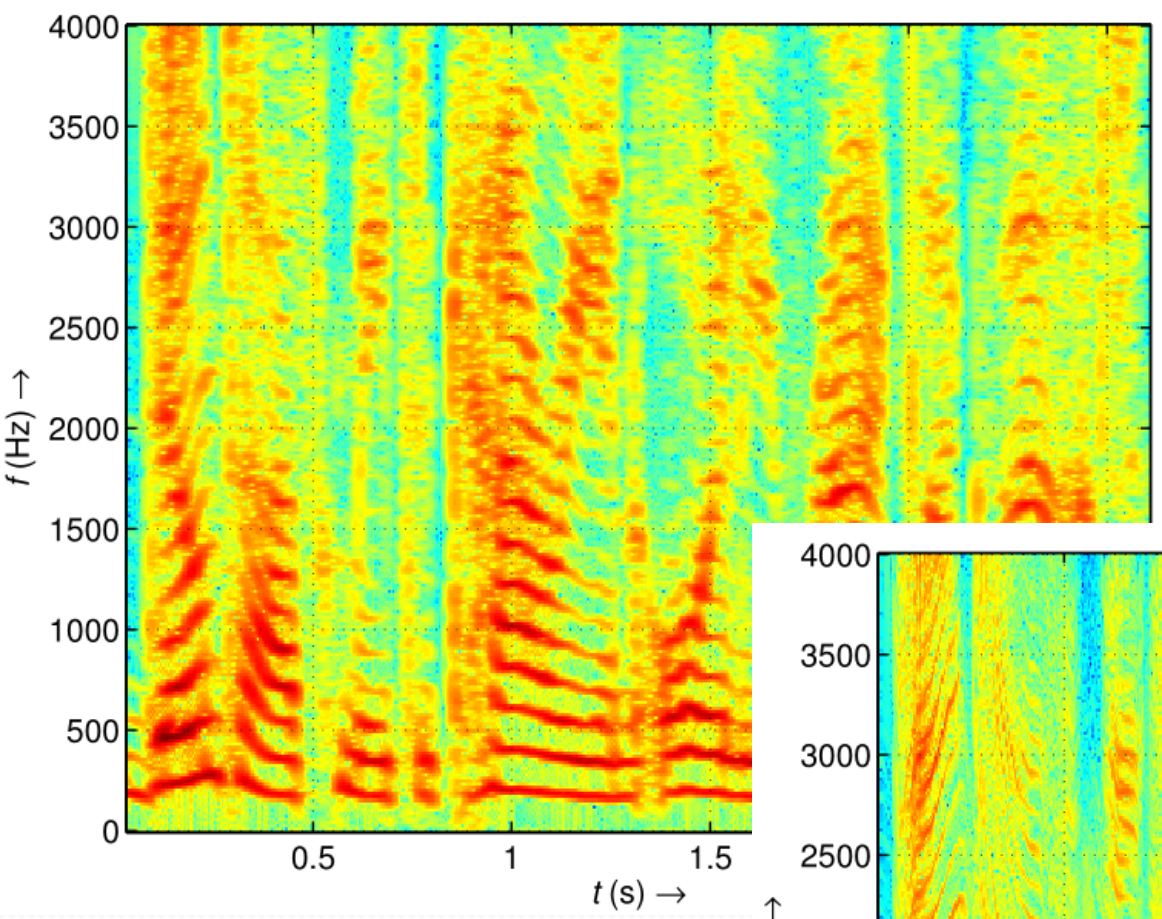
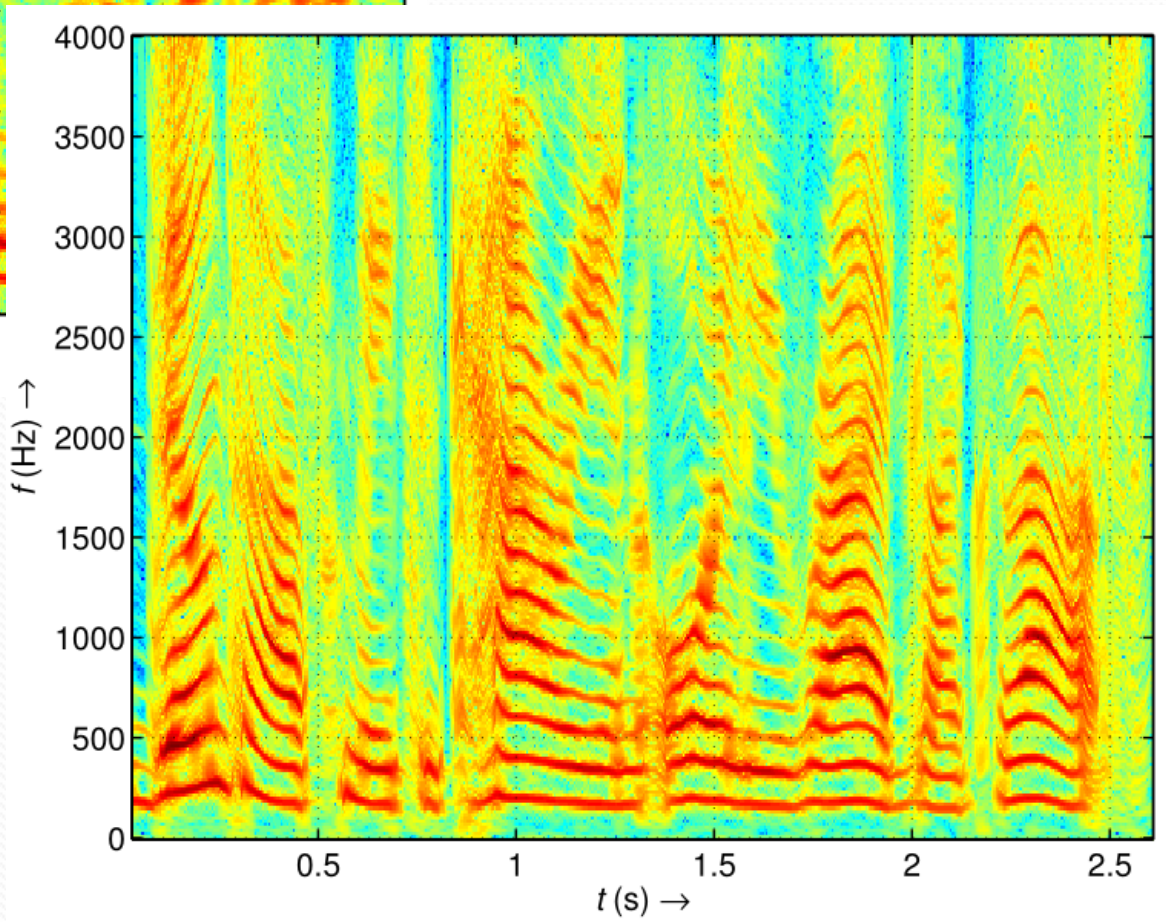
INVESTMENTS IN EDUCATION DEVELOPMENT

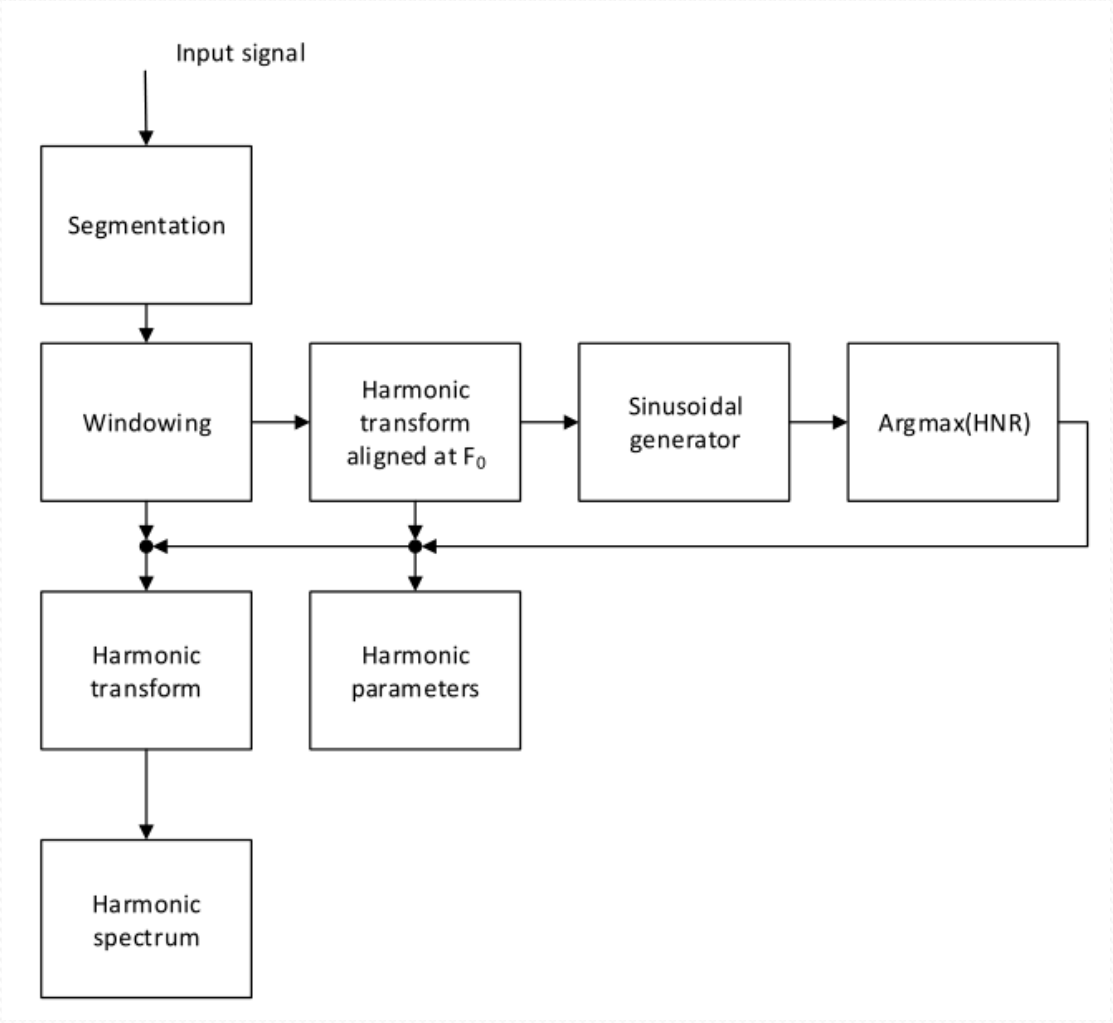
Content

- Harmonic transform at fs = 8 kHz
- Analysis-by-synthesis algorithm
- Analysed signals at 44.1 kHz
  - Viola, Soprano, Vibrato
- Conclusion


4000
3500
3000
2500
2000
1500
1000
500
0
f (Hz) →
0.5
1
1.5
t (s) →


4000
3500
3000
2500
2000
1500
1000
500
0
f (Hz) →
0.5
1
1.5
2
2.5
t (s) →

The algorithm



The algorithm

- For selected ranges of fo and Δfo/fc:
- 1. HT aligned at fo - O(kN)

$$S(k) = \sum_{n=0}^{N-1} s(n)\alpha'(n)\mathrm{e}^{-j\frac{2\pi k f_r}{F_s}\alpha(n)}$$

- 2. Harmonic parameters from S(k)

$$\begin{aligned} A_k &= \sqrt{\Re S(k)^2 + \Im S(k)^2}, \\ \varphi_k(0) &= -\arctan\left(\frac{\Im S(k)^2}{\Re S(k)^2}\right), \end{aligned}$$

- 3. Estimation of harmonic signal

$$\hat{h}(n) = \sum_{k=1}^{K} A_k \cos(k\varphi(n) + \varphi_k(0)),$$

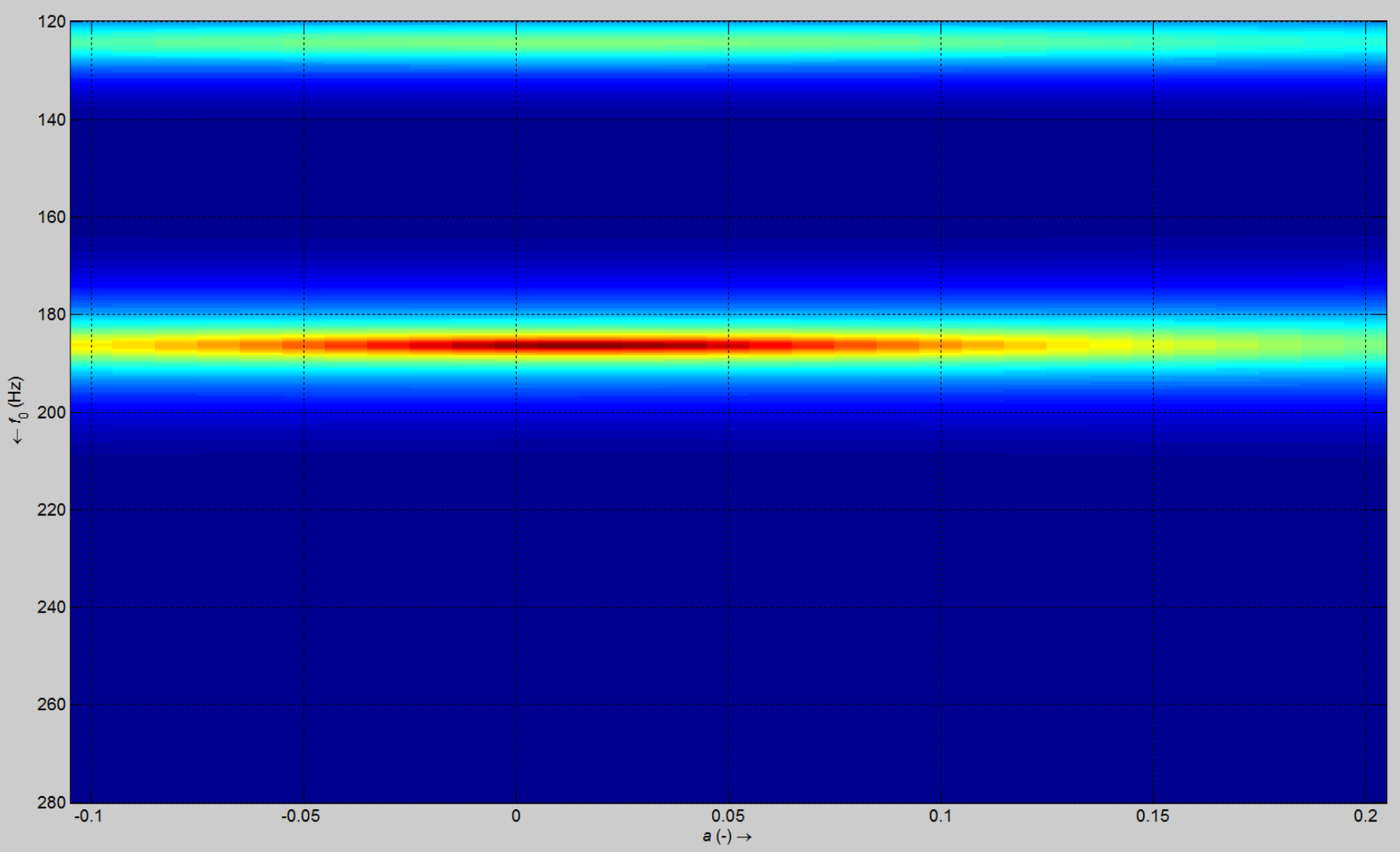
- 4. Estimation of noise signal

$$\hat{r}(n) = s(n) - \hat{h}(n)$$

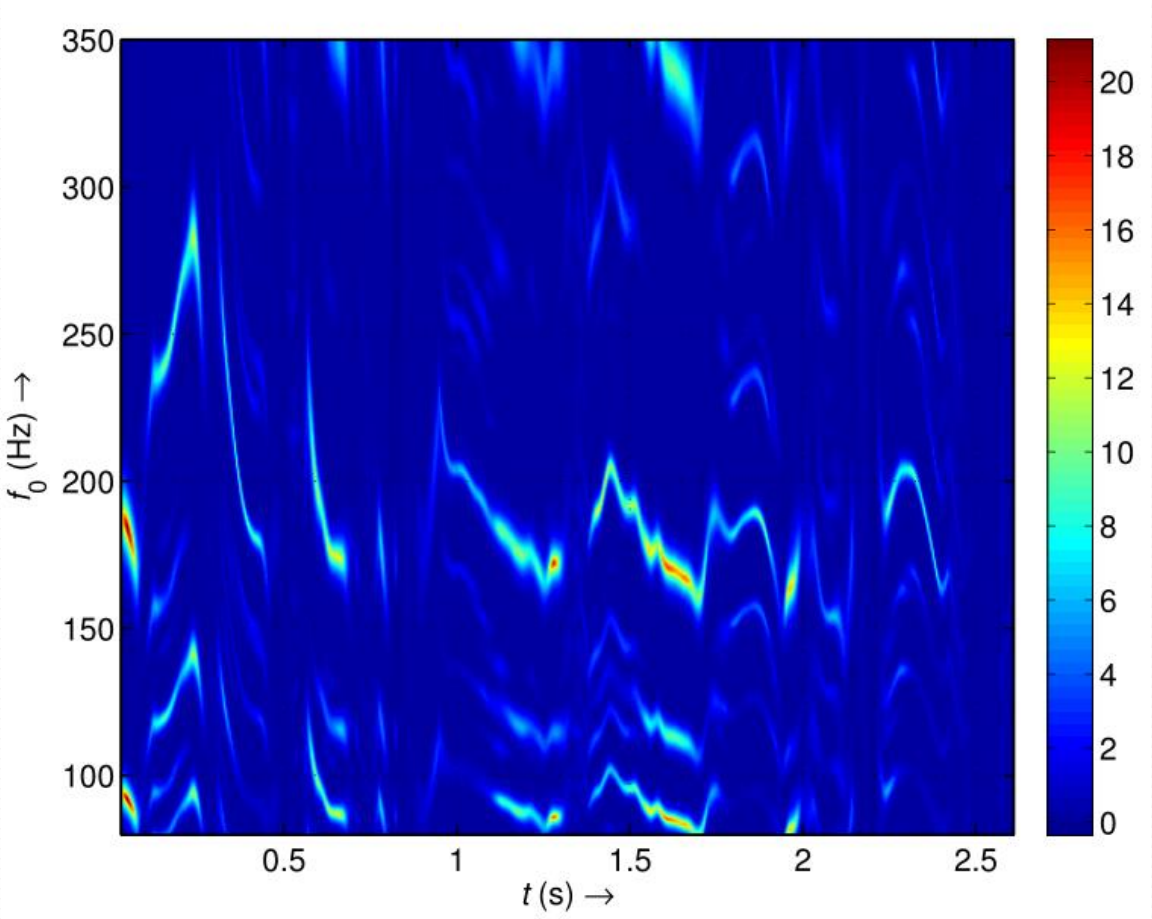
- 5. Harmonic to noise ratio

$$HNR = 10\log\frac{E_{\hat{\mathrm{h}}}}{E_{\mathrm{n}}},$$

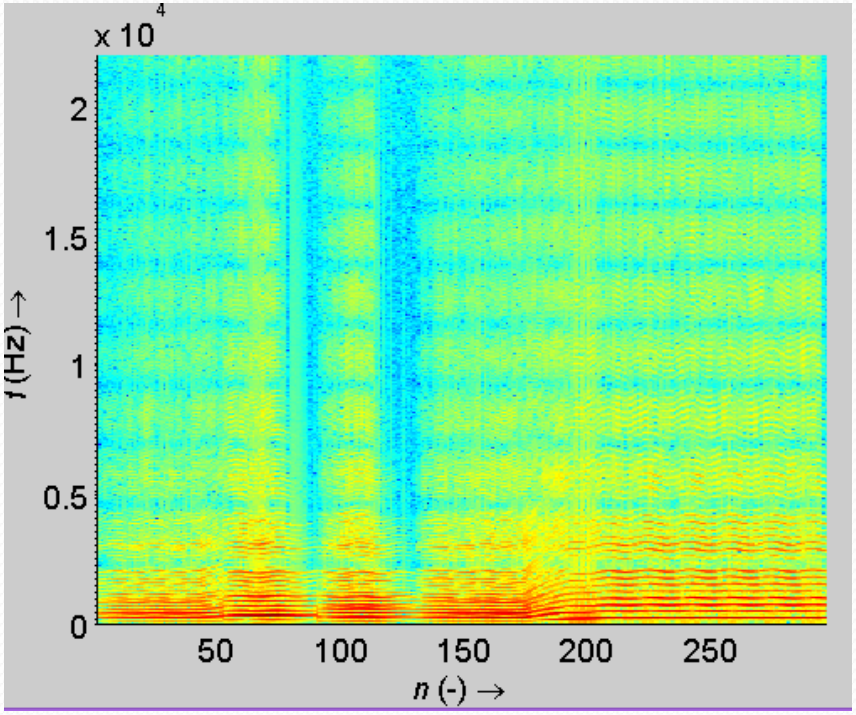
HNR(f0,Δf0/fc)

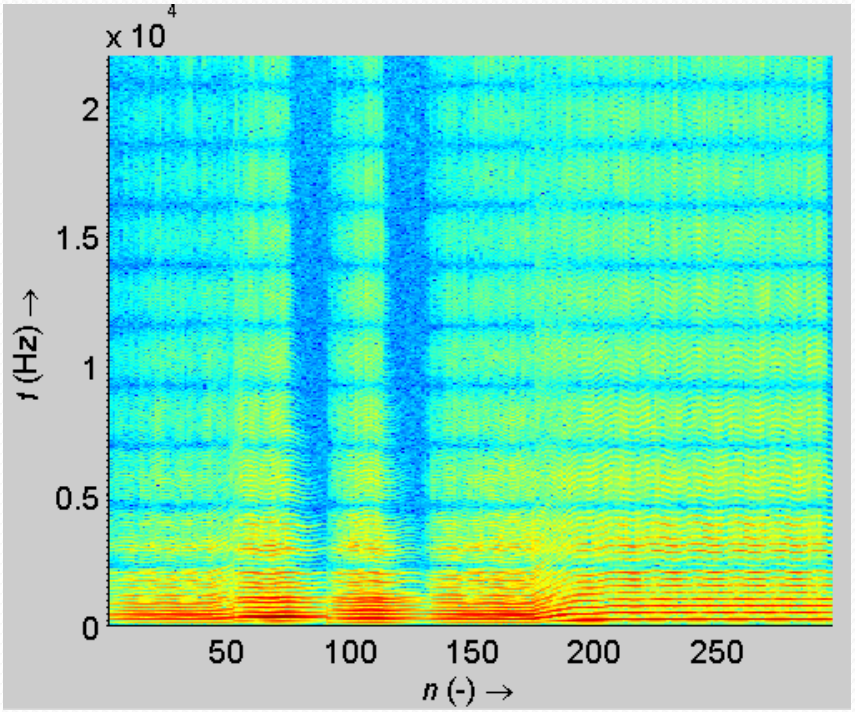


HNR

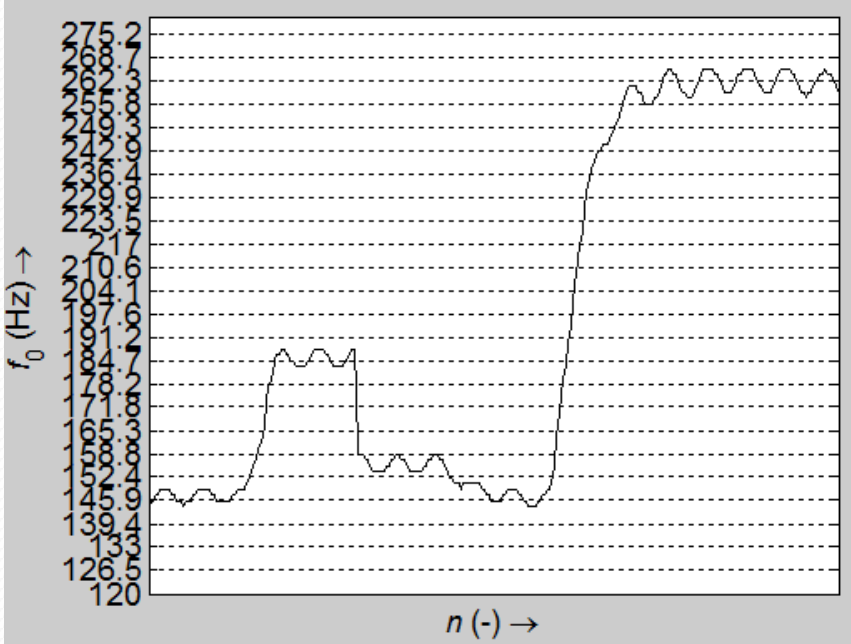


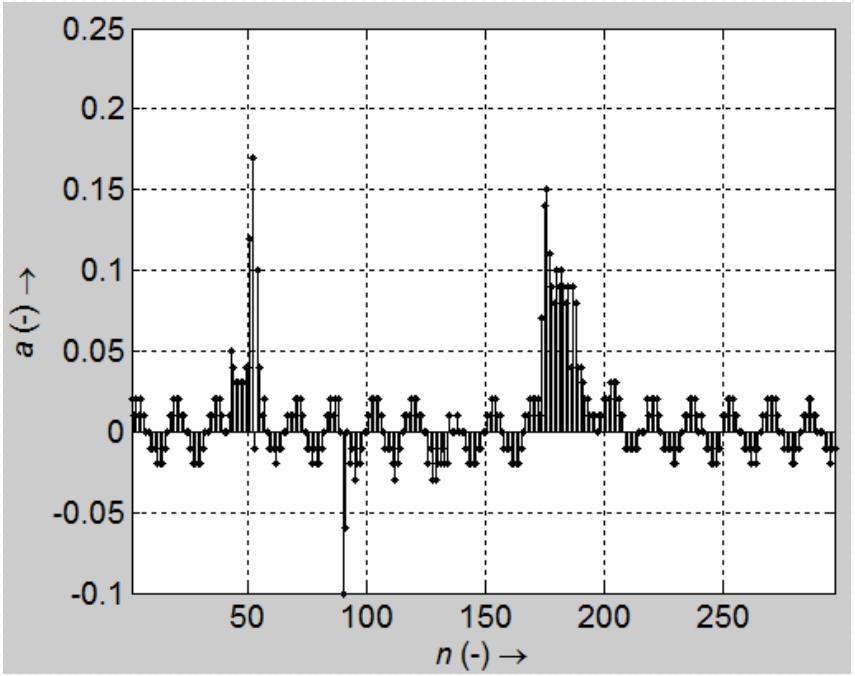
Viola - STFT vs. STHT



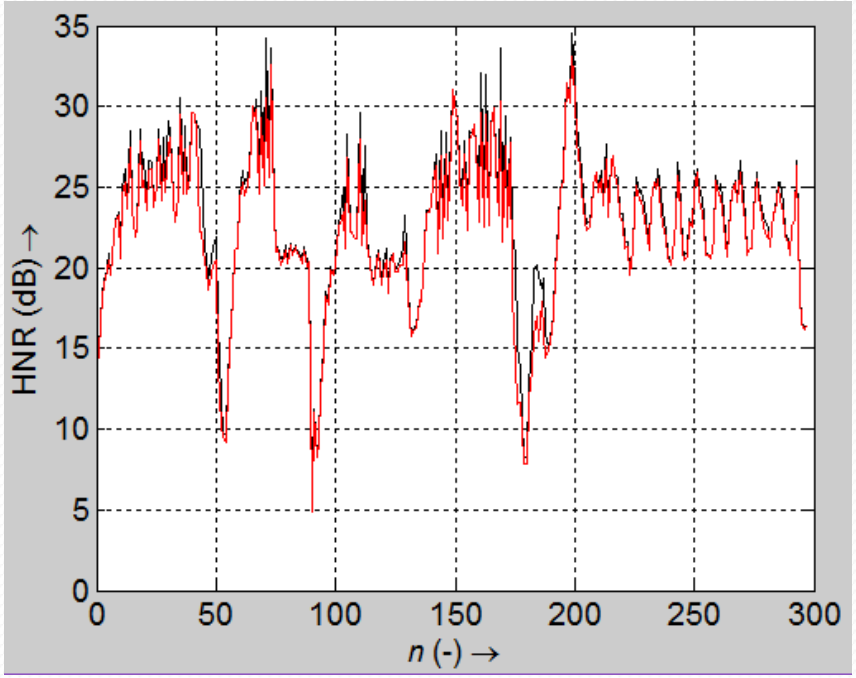


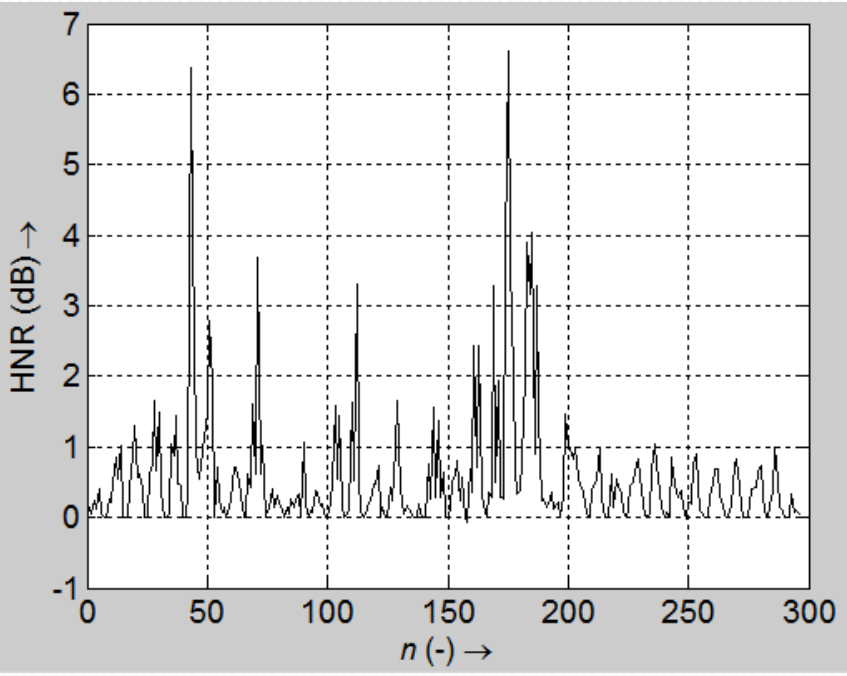
Viola – f0, Δf0/fc



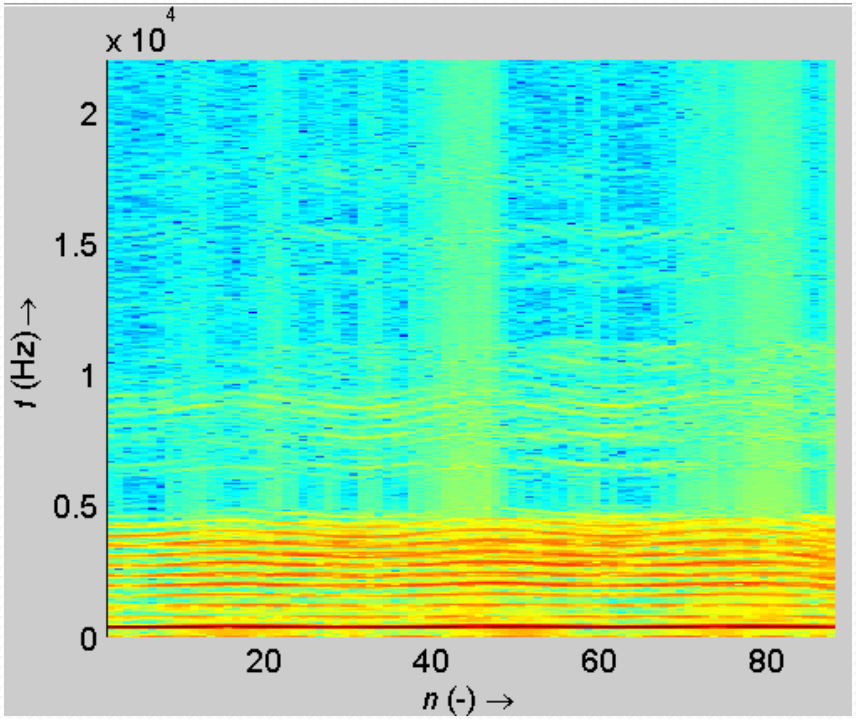


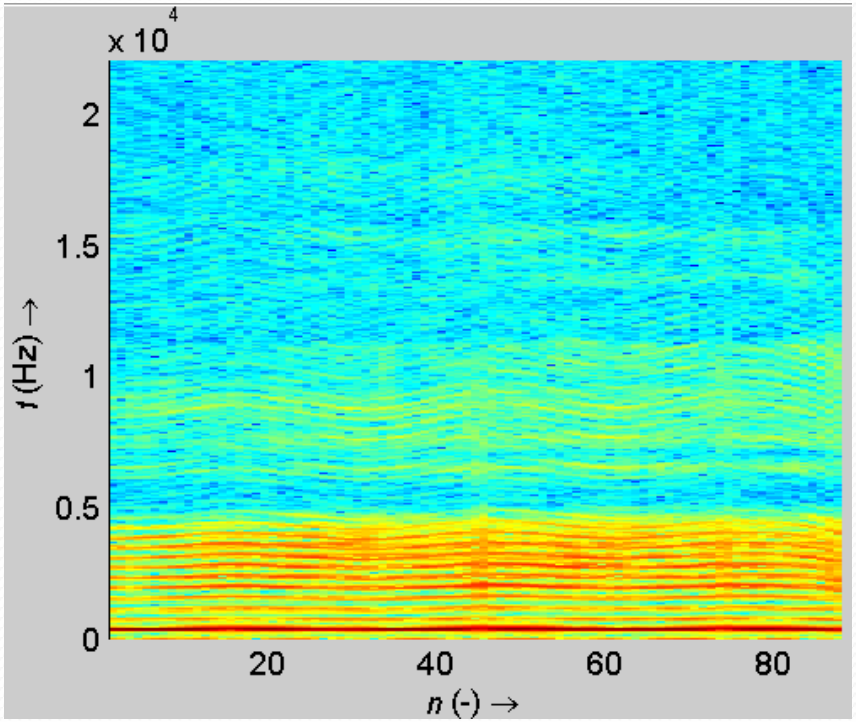
Viola – HNR


HNR (dB) →
n (-) →
0
5
10
15
20
25
30
35
0
50
100
150
200
250
300

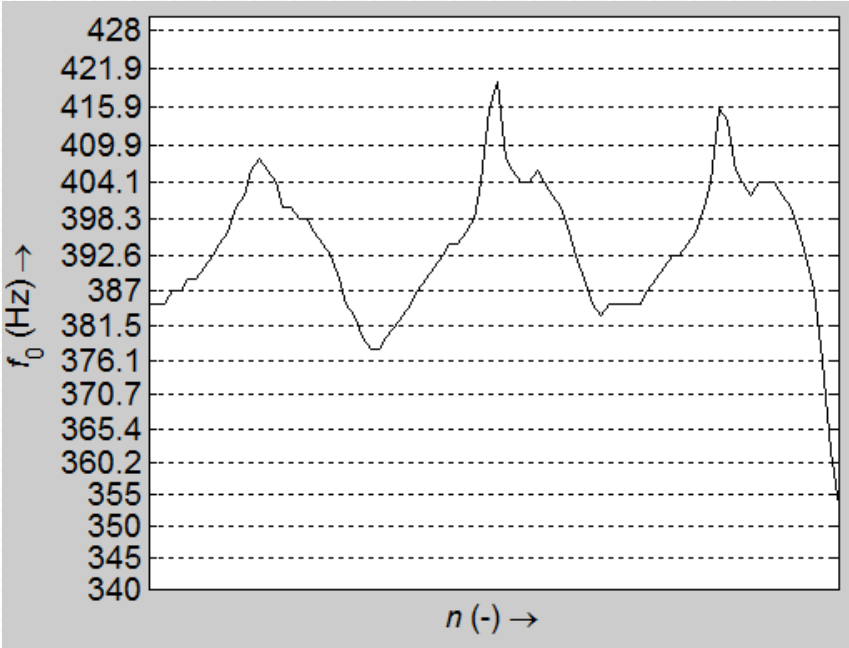

HNR (dB) →
n (-) →
-1
0
1
2
3
4
5
6
7
0
50
100
150
200
250
300

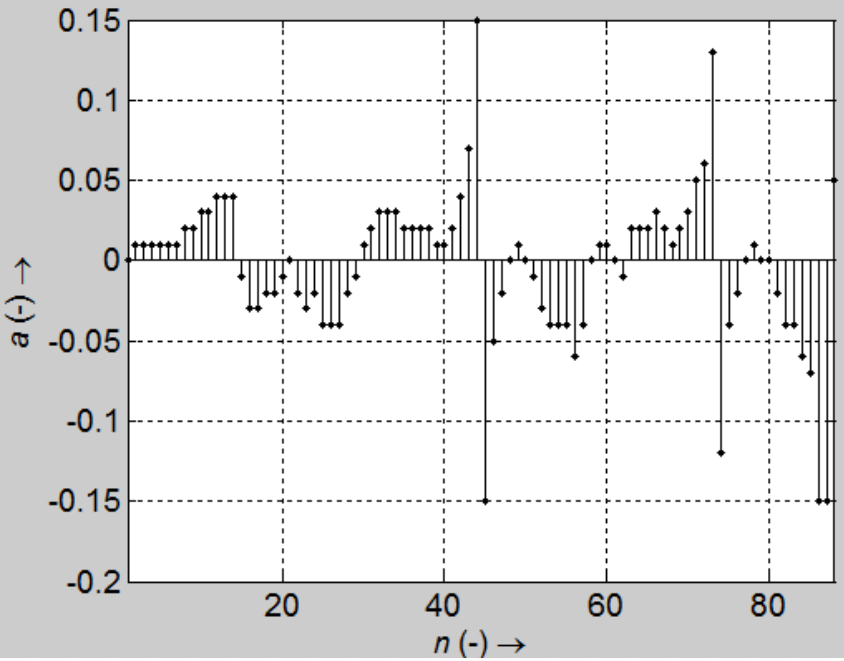
Soprano – STFT vs. STHT



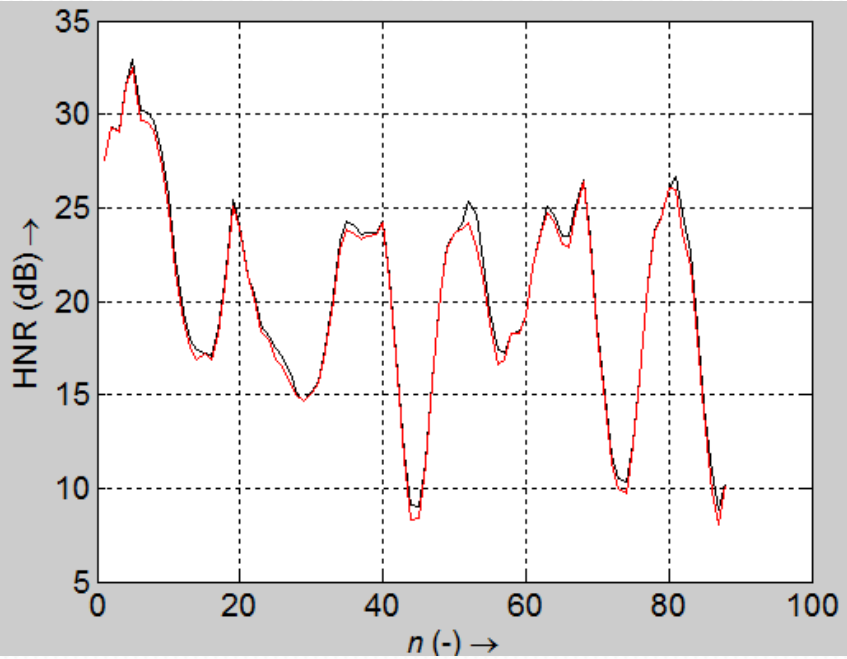


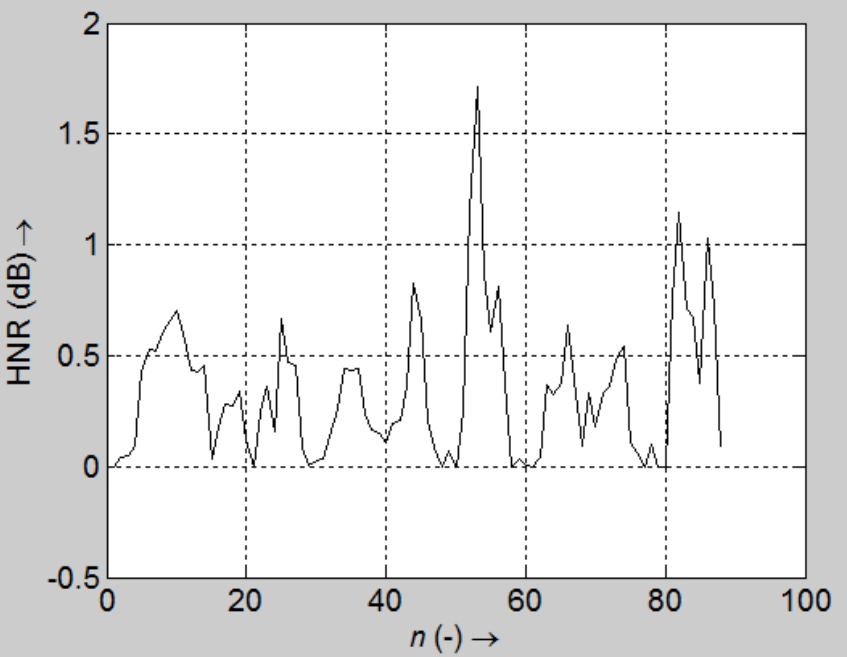
Soprano – f0, Δf0/fc



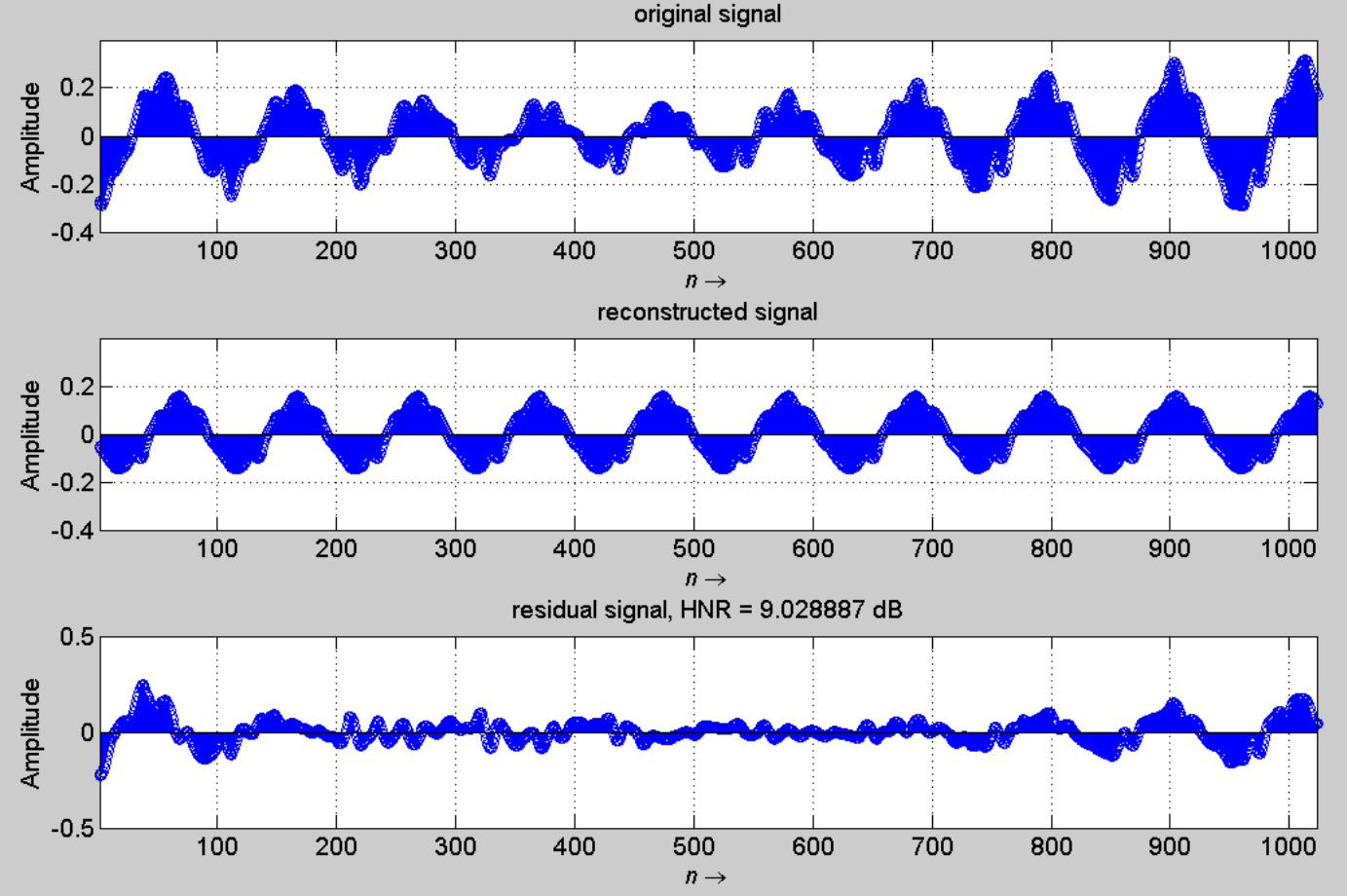


Soprano - HNR

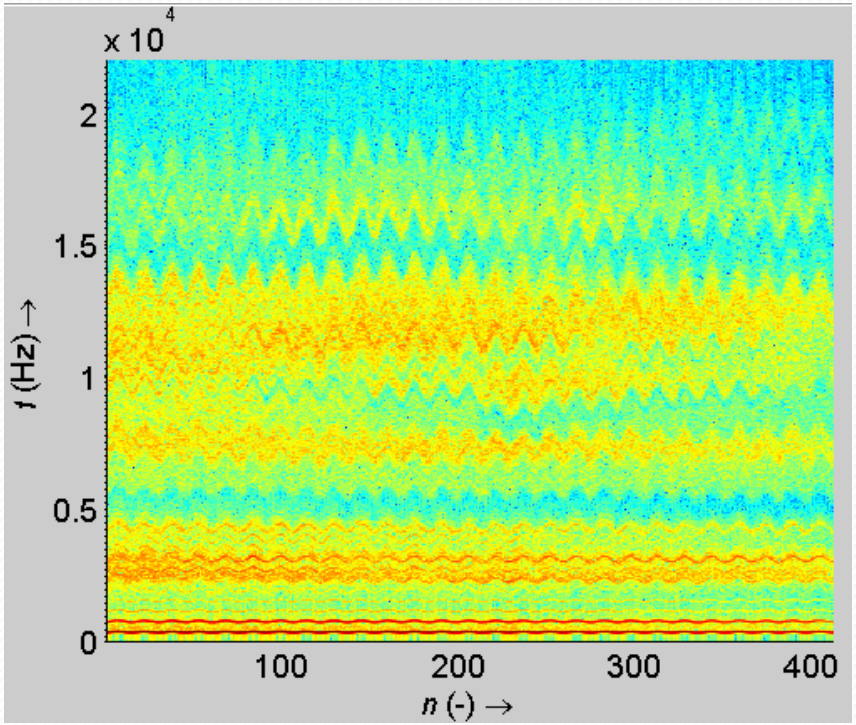

35
30
25
20
15
10
5
HNR (dB) →
0
20
40
60
80
100
n (-) →

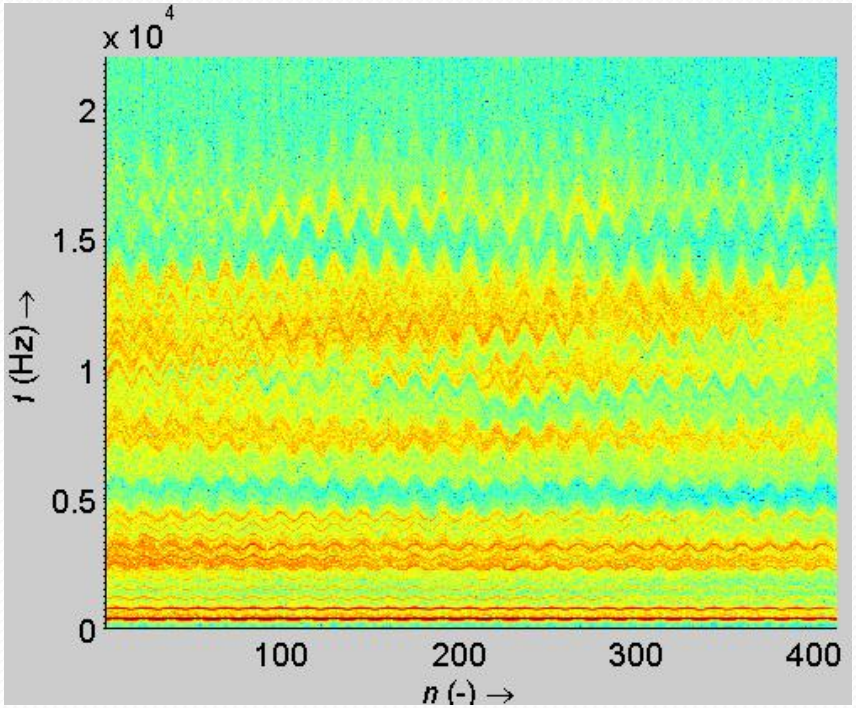

2
1.5
1
0.5
0
-0.5
HNR (dB) →
0
20
40
60
80
100
n (-) →

Soprano – AM

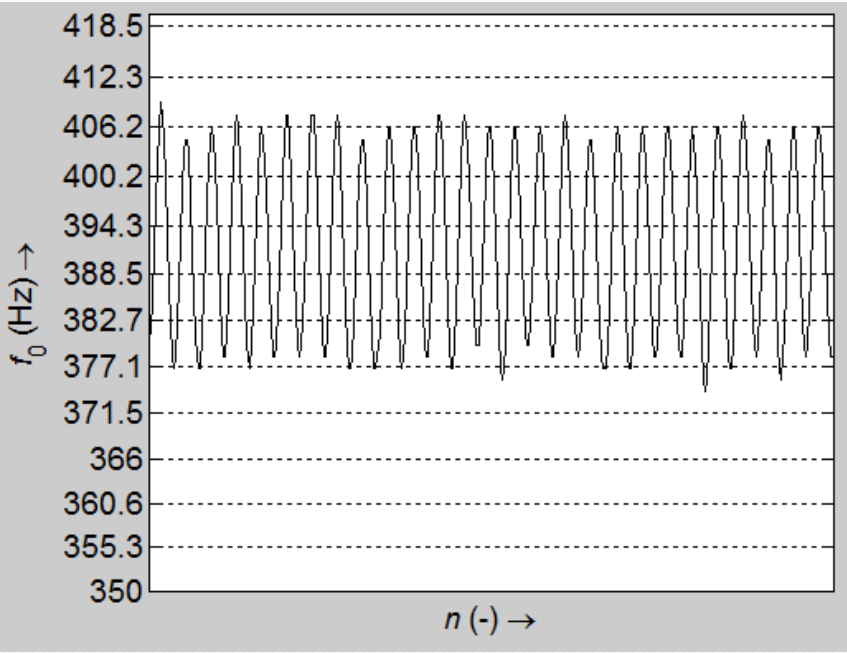

original signal
Amplitude
0.2
0
-0.2
-0.4
100
200
300
400
500
600
700
800
900
1000
n →
reconstructed signal
Amplitude
0.2
0
-0.2
-0.4
100
200
300
400
500
600
700
800
900
1000
n →
residual signal, HNR = 9.028887 dB
Amplitude
0.5
0
-0.5
100
200
300
400
500
600
700
800
900
1000
n →

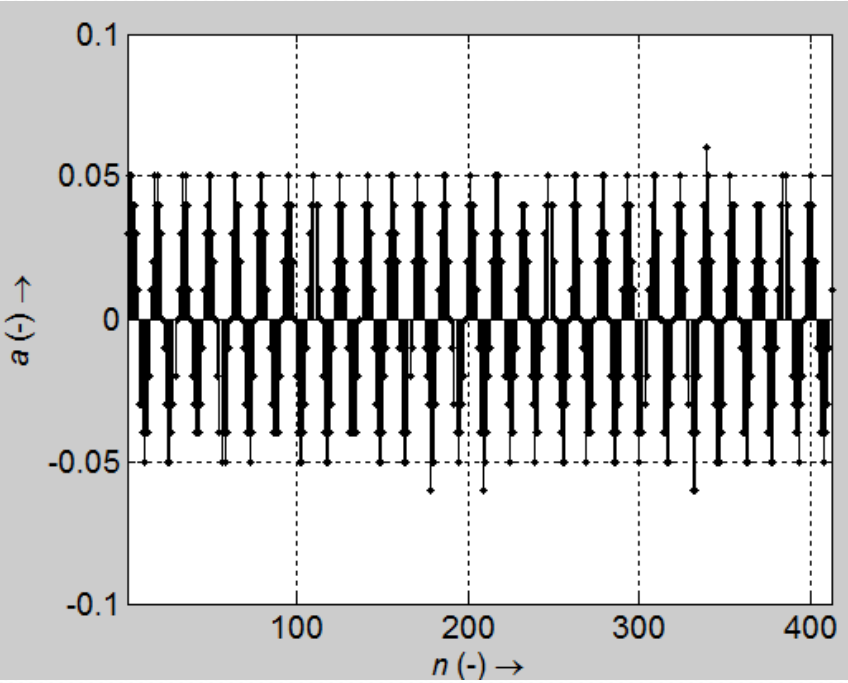
Vibrato – STFT vs. STHT



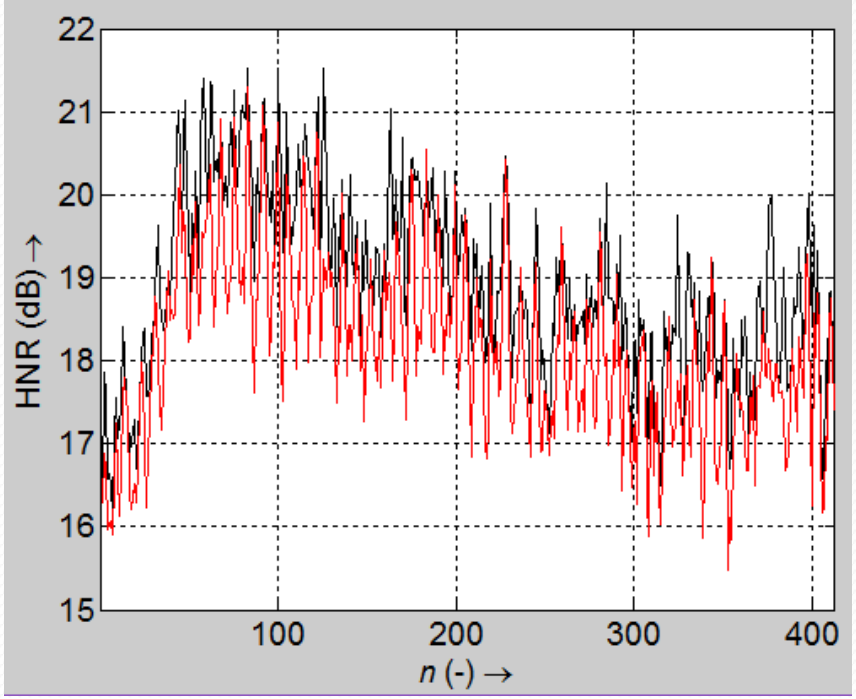


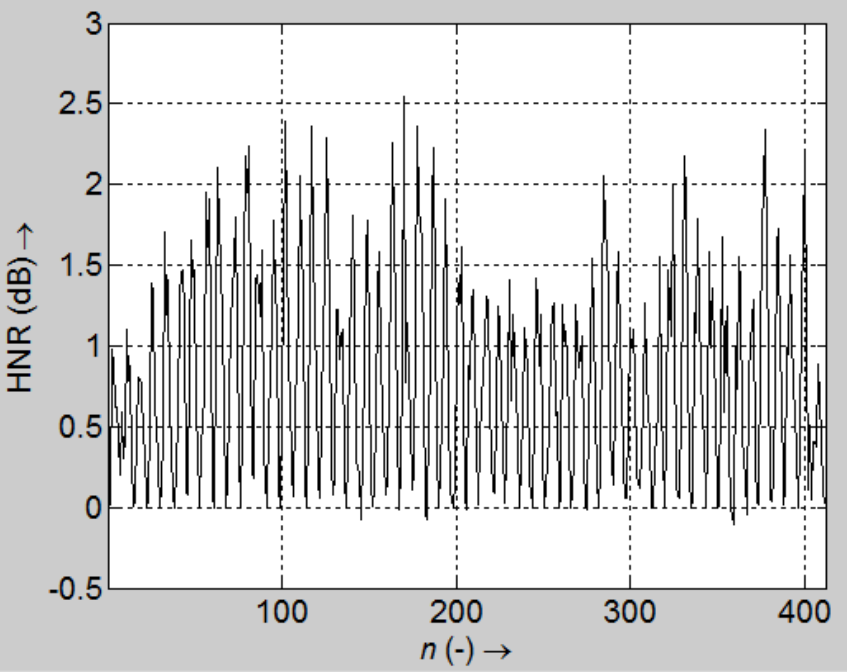
Vibrato – f0, Δf0/fc





Vibrato – HNR


22
21
20
19
18
17
16
15
HNR (dB) →
100
200
300
400
n (-) →


3
2.5
2
1.5
1
0.5
0
-0.5
HNR (dB) →
100
200
300
400
n (-) →

Conclusion

- Increase in HNR for FM modulated audio signals
- The increase of HNR increases with FM.
- Low energy of harmonics in high frequencies for 44.1 kHz
- Therefore the increase in HNR with HT is low
- Sensitivity to AM

Thank you for attention.