SYNCHRONISM AIDED RECOVERY OF PHASE MODULATION IN NON-STATIONARY SIGNAL – COMPARISON OF TWO METHODS

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Summary

The paper discusses an compares some properties and possibilities of two methods called PLL and OT in relation to PM demodulation of non-stationary machine VA signal due to repeatable operation mode of certain technical systems. Simulation experiment proved PLD efficiency. Case of OT needs synchronization with carrier cycle to get OT even better, but only if PM carrier signal is to recover, otherwise PM demodulation fails.

Keywords: synchronism, decimation, order analysis, demodulation.

WSPOMAGANIE SYNCHRONICZNE DEMODULACJI KĄTA DRGAŃ MASZYN W STANACH NIESTACJONARNYCH

Streszczenie

Porównywano skuteczność transformacji rzędów OT oraz procedury liniowej decymacji PLD we wspomaganiu asynchronicznej procedury demodulacji drgań maszyn cyklicznych w stanach niestacjonarnych. Badania symulacyjne wykazały zadawalającą skuteczność PLD i niekiedy nawet większą dla OT pod warunkiem synchronizacji cyklem nośnym, w praktyce diagnostycznej trudno dostępnym. Standardowa OT nie wykrywała PM.

Słowa kluczowe: synchronizm, decymacja, analiza rzędów, demodulacja.

1. TIME-SCALE TRANSFORMATION

Time scale in which:

- variability description becomes simpler,
- essential characteristics of informational variability are preserved,
- non-informational variability is reduced,

can facilitate diagnosing in variable operational conditions.

Local time scales are synchronized with marker event sequences determined by some characteristic $\psi(\Theta)$ of kinematics cycle, here by:

1. instantaneous cycle Θ;
2. short-term linear approximation of Θ;
3. carrier cycle Θ_C.

The above leads to known procedures formalizes as PLD and OT (see glossary)

Widely [2, 3, 7, 8] discussed, they don't need detailed presentation. The principle of TS conversion (see Fig. 1) shows the main difference between order transform and linear decimation.

2. DIFFICULTIES OF PM RECOVERY

A number of detailed researches [1, 2, 5] indicate the occurrence of angle modulation PM and its pulse version PPM as early as in the first stages of damage evolution.

However, if the case of unintended PM of machine vibrations several current methods of PMD, created and optimized for carrier signals of a specified form and constant frequency, turn out to be inefficient.

The problems originate from:

- non-informative carrier-frequency changes;
- inference rather than knowledge of modulation type and its parameters;
- inaccessibility of carrier signal
- unknown current form of the signal.

If and for what can they be overcome? One of the solution is to transfom original PM signal using local time scale synchronized with $\psi(\Theta)$.

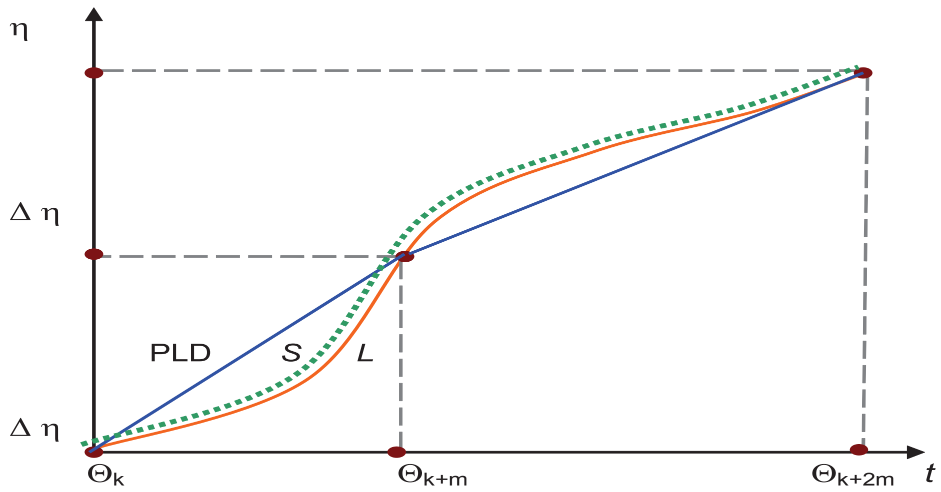

Fig. 1. PLD split instantaneous $\boldsymbol{L}(\Theta)$ into several line segments S with constant growth rate, while OT leads to 3rd order spline approximation of $\boldsymbol{L}$

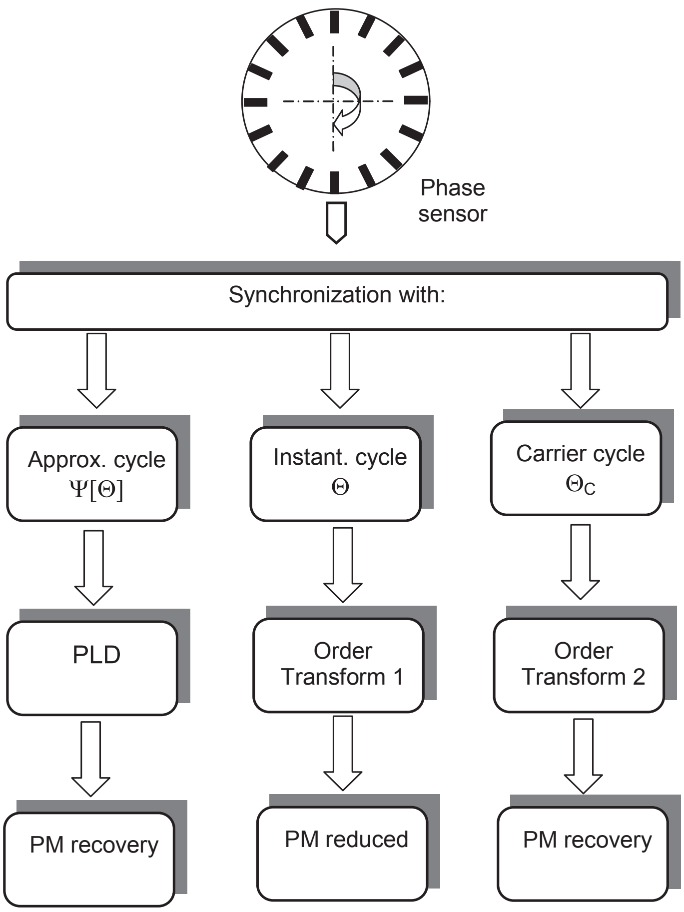

Fig. 2. Synchronization of time scale conversion in relation witch applied conversion procedure:
a) procedure of linear decimation PLD; b) order transform, standard version;
c)order transform synchronized with carrier cycle

3. SIMULATIONS

The efficiency of both methods has been tested using simulated PM signals and procedures disposed on Fig. 2.

OT has been synchronized with both carrier and instantaneous cycle. Some of conclusive results are shown below (Fig. 3 and 4) [8].

Corruption of of original PM spectra as well as efficiency of PM side-lobes recovery degree are there evident.

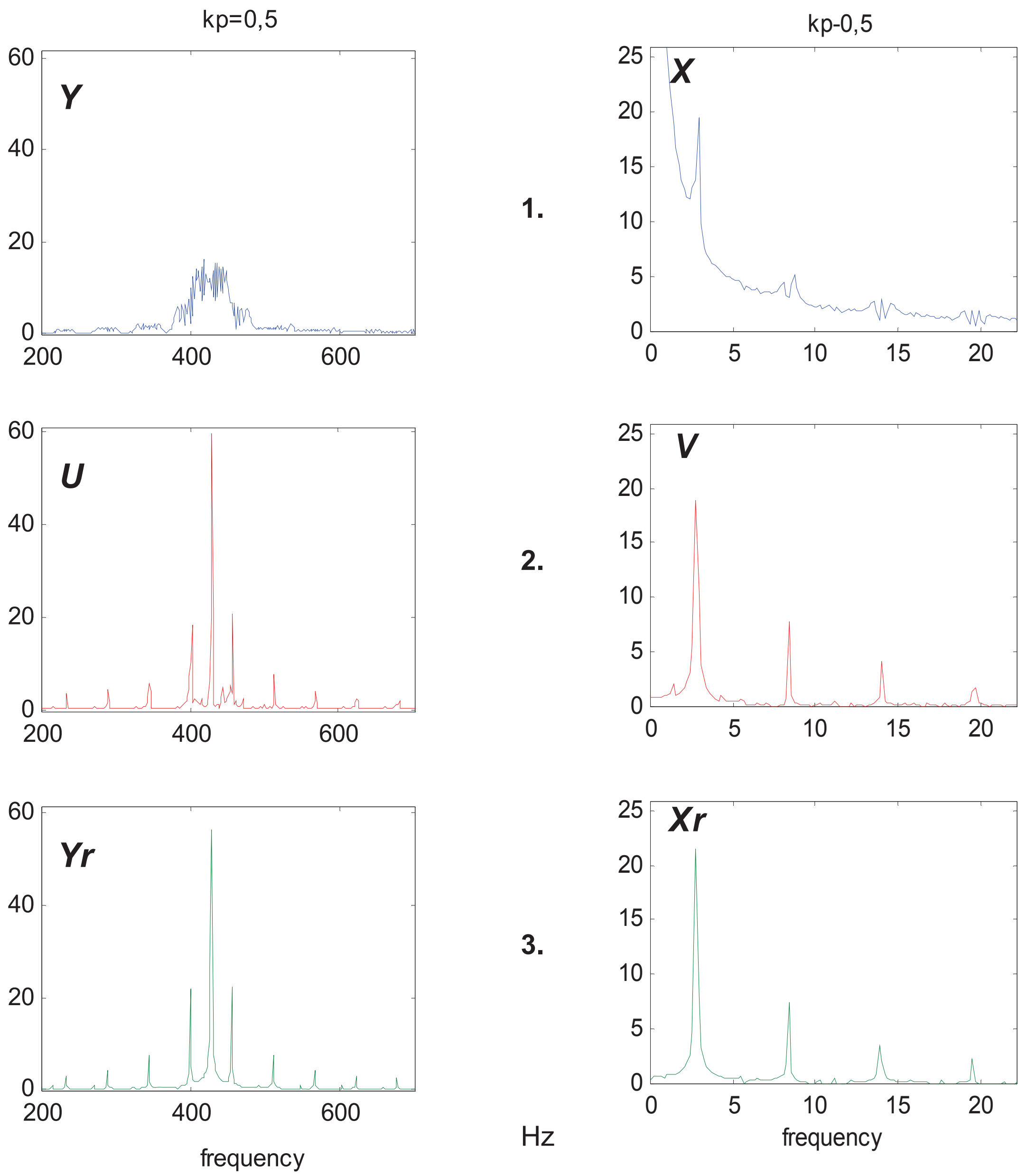

Fig. 3. Spectra of PM signal (A), and demodulation results (B).
1) real time signal; 2) after PLD transform; 3) real time reference signal, constant carrier frequency

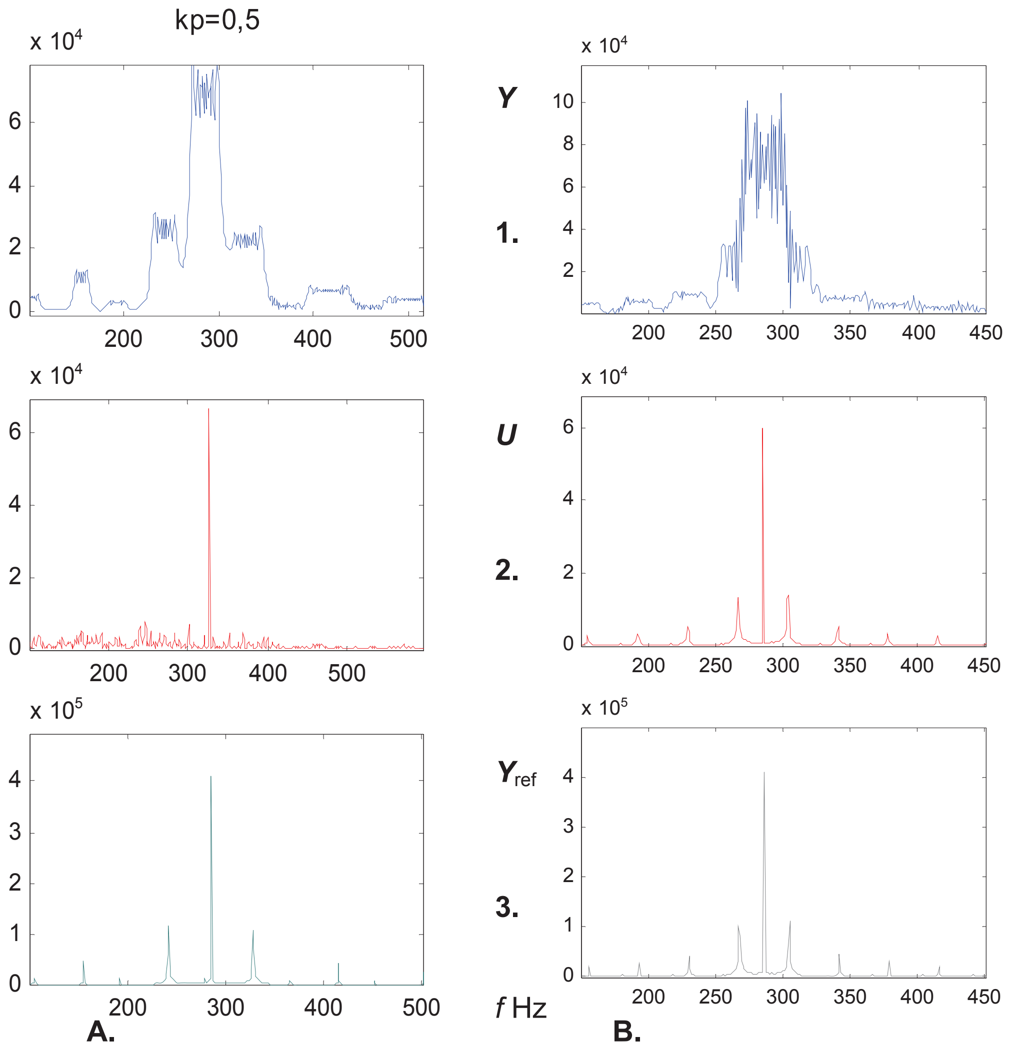

Fig. 4. Spectra of PM signal, side-lobes represent PM recovery.
A - order transform, standard version; B - order transform synchronized with carrier cycle
1) real time signal; 2) after time scale transform; 3) real time reference signal, constant carrier frequency

4. CONCLUSIONS

The results seems to confirm certain conclusions resulting from the model of machine signal PM modulation proposed once by author [4], Therefore:

- Both PLD and OT reduced leakage of FFT spectra.
- PLD offers generally lower FFT accuracy, but satisfactory in the case of monotonic carrier frequency trend; furthermore:
  - get DPM easy to synchronization
  - does not require the precise carrier cycle approximation;
  - does not require complex calculations;
  - is simple in on-line implementation.
- Order transform synchronized by signals with cycle closed to instantaneous cycle reduces PM effect (see Fig 4. A) [3].
- OT recover well PM spectral side-lobes, but only when synchronized with carrier cycle Θ_C, generally unknown in the case of real machine signal PM (see Fig 4. B).

5. REFERENCES

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Abbreviations & Symbols

DPR	–	dynamic residual process
MVS	–	machine vibration signal
OT	–	Order transform
PDI	–	Diagnostic identification procedure
PLD	–	Procedure of linear decimation
PM	–	Phase modulation
PMD	–	Phase demodulation procedure
TSC	–	Time scale conversion
$\psi(\Theta)$	–	synchronizing cycle characteristic
$\Delta\varphi$	–	angular step of synchronization
Θ	–	instantaneous cycle
Θ_C	–	carrier cycle
$\boldsymbol{y}$	–	original measured signal
$\boldsymbol{u}$	–	final signal after TSC
'η'	–	local time scale
't'	–	real time scale
$\boldsymbol{s}_F$	–	characteristic signal
T	–	Time width of observation window
η	–	PLD or OT time
z_k	–	referential event