MTS PILOT TRACKING ALGORITHM FOR "WOW" DISTORTION ESTIMATION IN NTSC AUDIO RECORDINGS

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New algorithm for detection of the wow distortion characteristic basing on the MTS pilot tracking is introduced. By observing a variation of the pilot frequency, the depth of the parasitic modulation can be estimated. MTS is an audio coding system used in an NTSC television standard, thus the algorithm is applicable only in that type of recordings. It is based on a high-frequency bias tracking algorithm and further modified to minimize the influence of an acoustic-band audio signals which may interfere with the 15.734 kHz MTS pilot tone.

"Wow" distortion, Multichannel Television Sound, High Frequency Bias, pilot tracking

1. Introduction

„Wow" distortion (further referred to as the wow) is a pitch variation of a relatively low frequency (up to 6 Hz [5]) commonly found in gramophone or tape recordings. In most cases, it is caused by an irregular velocity of a tape shift, which can be caused by an unstable motor or unsymmetrical geometry of a carrier. Depth and character of such modulation is in most cases unknown and is hard to be evaluated or modelled accurately.

Pitch-variation curve (further referred to as the PVC) is a curve that tells about the depth of modulation at regular intervals. Such depth is measured as a nominal to actual frequency ratio, so the PVC value of 1 indicates a signal without distortion, PVC value of 0.5 is actual frequency two times lesser than the correct one and so on. One of methods of acquiring the PVC is to track modulation of some tone with a theoretically stable frequency that is assumed to be known. High-frequency bias in magnetic recordings (further referred to as the HFB), power-line hum or MTS (Multichannel Television Sound) pilot tone in NTSC signals are examples of such tones. The difference between them is a frequency of the used tone which implies specific approach and techniques of tracking. One of such examples is an algorithm for tracking the HFB constructed at the Multimedia Systems Department of Gdańsk University of Technology [2-4].

2. The MTS pilot and the HFB tracking algorithms

The aim of this work is to present an algorithm for tracking the MTS pilot tone in NTSC signals which is based on the mentioned algorithm for the HFB tracking.

The main differences between these two signals are:

- the MTS pilot tone is at 15.734 kHz which is inside acoustic band and can be masked by useful signals (in contradiction to the HFB which is high above 20 kHz),
- when copying NTSC recordings, a new pilot tone is added (in contradiction to magnetic tapes where the existing bias is overwritten) – such phenomenon is called 'the background pilot tone' later in this work,
- pilot tone has relatively low and unstable level (complete decays may occur as well).

Following techniques are used to determine the PVC in the HFB tracking algorithm (Fig.1). First, a part of a signal is taken for analysis, Hann windowing is applied to it and then FFT is performed to operate on frequency domain. Next, the entire acoustic band is removed, preemphasis and spectral expansion algorithms are applied and finally maximum of energy in spectrum is looked for. Parabolic interpolation helps to find fractional index of the bias frequency bin. Precision can be increased by applying other methods such as time-frequency reassignment [1]. More information on described algorithm can be found in several publications ([2-4]).

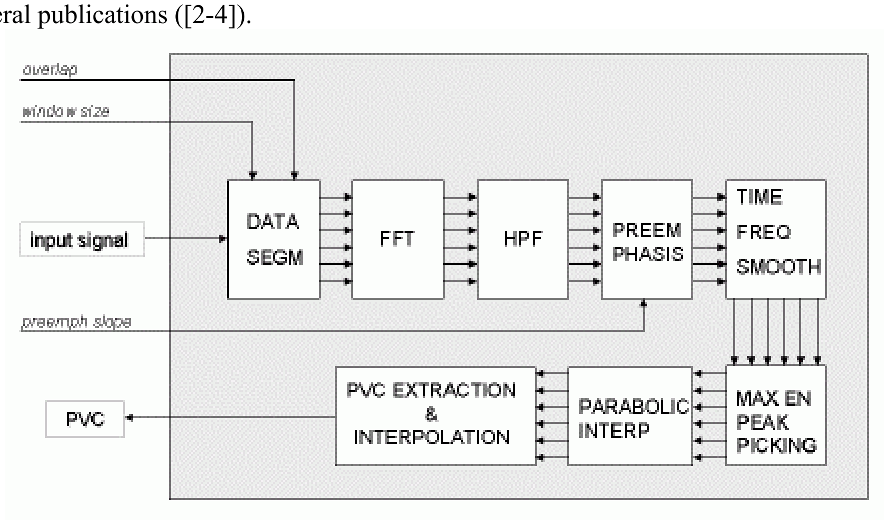

Figure 1: Block diagram of the HFB tracking algorithm [2]

3. The MTS tracking algorithm

In the original algorithm, a signal was filtered to remove spectral components up to 25 kHz (HPF block in Fig. 1). Then the preemphasis filter was applied and the whole spectrum was expanded (raised to 4^{th} power). First operation was to counterbalance decreasing of energy towards high frequencies and the latter was to bring forth the HFB tone against a background of a spectral noise. Also the time- and frequency-domain smoothing (both 3^{rd} order) were applied. This had an effect of blurring the whole spectrogram which was helpful because of noise reduction and a better frequency estimation.

The MTS tracking algorithm is presented in Fig. 2. It works in two phases (loops) – the first one is very similar to the HFB tracking algorithm, while the latter is more complex. In the first phase, the only modification made to the HFB tracking functions was to lower the cutoff frequency to 14 kHz because of the obvious importance of the frequencies around 15.7 kHz. It is assumed that the beginning of a record under analysis is free of the wow distortion, so the only peak existing above the cutoff frequency is the pilot tone. Parabolic interpolation is used to estimate the pilot tone frequency more precisely. Acoustic signals above 16 kHz that could have possibly interfered, have energy that can be disregarded.

Additionally, the center of a gravity (CoG) within the nominal pilot tone frequency neighborhood (15734 ± 250 Hz) is sought. It is used later to eliminate background pilot tone signal and to correct a potential inexactness of a signal's pitch.

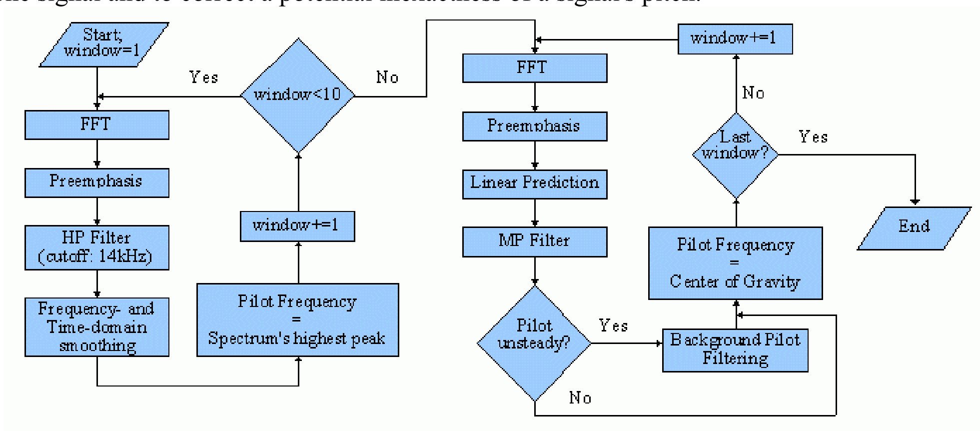

Figure 2: Block diagram of the MTS tracking algorithm

After 10 steps the algorithm starts to work differently, though (second phase). Following pilot tone frequency is estimated basing on 3 previous frequencies and using second order linear prediction. Then the band taken under analysis is limited to 7,5% of the estimated frequency to the bottom and 10% to the top. Margins are not statically assigned, so that if the pilot tone goes towards low frequencies (due to deep modulation), they are still narrow enough to reduce influence of a 'useful' yet unwanted spectral components. These components always interfere from the lower frequencies and have more energy (energy of a spectrum towards higher frequencies is seldom increasing) – that's the reason for making bottom margin narrower than the top one. Next, simple weighting function is created, where the element of the predicted frequency has the weight = 1, border elements has the weight = 0 and weights of elements between center and borders are linearly approximated and raised to the second power.

When the predicted frequency is up to 1 kHz from the nominal pilot tone, a very narrow (200 Hz bandwidth) filter is applied at the actual pilot tone frequency to eliminate the background pilot tone. It is done to avoid following the wrong pilot and altering tracking the right one. This filtering is applied, however, only if the pilot tone was recently unstable, so that the algorithm does not filter the correct pilot tone which is stable at the right frequency. Steadiness is stated, when a frequency of the pilot tone had not differed more than 250 Hz from the nominal pilot frequency in previous 10 steps.

Finally, the pilot tone frequency for the current step is calculated as the CoG of such narrowed spectrum. Choosing the CoG instead of just a maximum of spectrum reduces accidental jumps to nearby strong interfering signals that are making pilot tone harder to find in next steps (due to prediction basing on a false sample). Such accidental jumps are also limited by checking if a difference between the last and current frequency is not greater than 800 Hz. Last frequency is taken otherwise.

4. Experiment and results

The MTS tracking algorithm was created basing on a wow-distorted audio sample of the length of 143 [s]. As seen in its spectrogram (Fig. 3), there are three fragments with oscillating FM distortion (around 20-30, 45-65 and hardly seen due to lowered pilot tone level at 80-90) and one with deep aperiodical modulation (starting around 115 with peak at around 120 and lasting almost until the end of the sample). A background pilot tone is noticeable in the whole length of a clip. The mentioned varying level of a pilot tone is also easy to see (it goes up after 11 and down again after 82). Unstable level resulted in difficulties in finding the correct pilot tone (the background one has actually higher level than the distorted one as seen in Fig. 4). 2nd and 3rd region was hard to track properly due to rapid changes of the level of modulation in a neighborhood of the background pilot tone. The problem with the last region was to avoid interfering with an audio spectral part of the signal. An impulse-type high-energy useful audio content introduced a danger of losing the track which was minimized by a varying band of the MP filter, narrower from the bottom.

The results of a pilot tracking are shown in Fig. 5. It presents spectrogram with marked MTS pilot track. Optimal selection of various parameters has led to satisfactory results, where the pilot tone was found and properly followed.

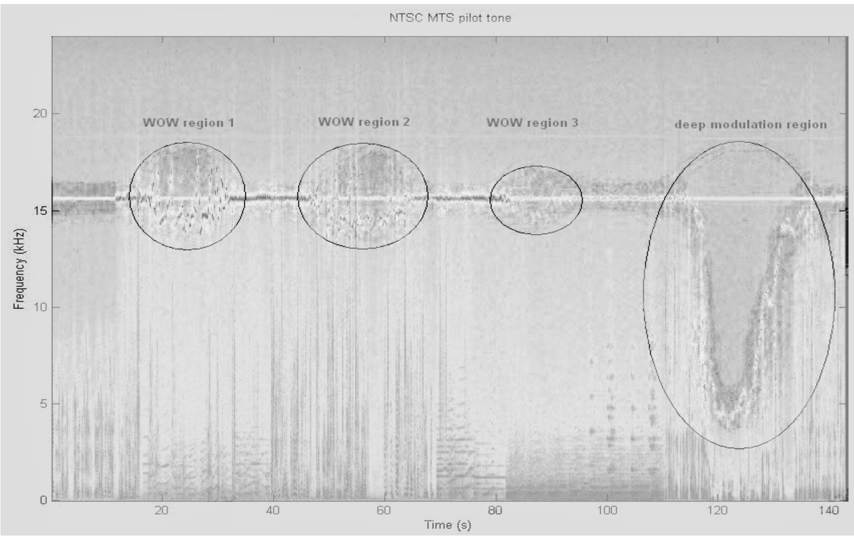

Figure 3: Wow-distorted audio sample spectrogram

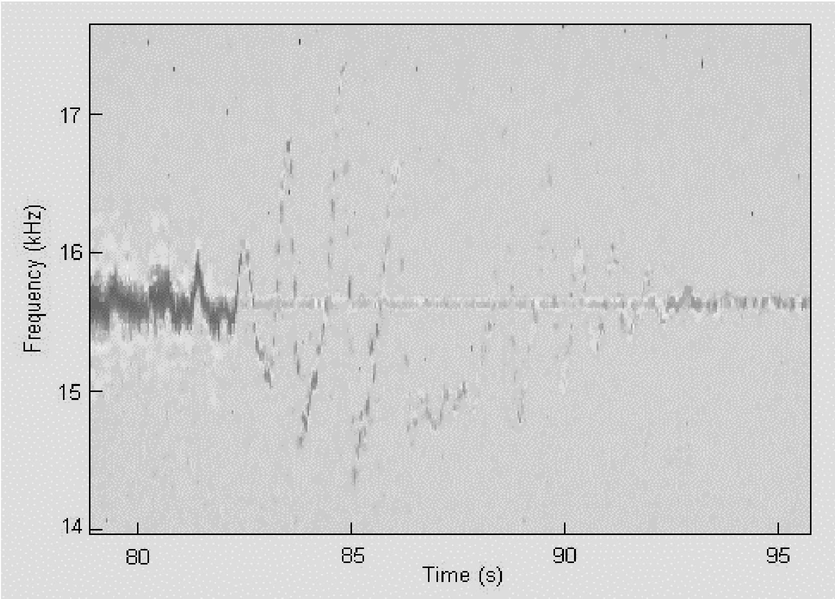

Figure 4: Zoom of a wow region 3 of Fig. 3

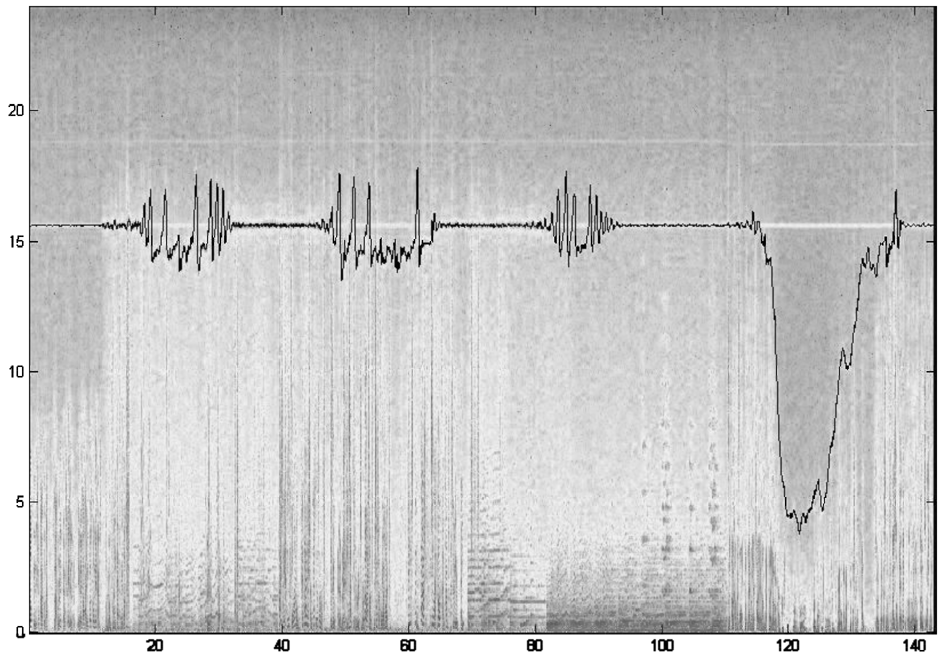

Figure 5: Wow-distorted audio sample spectrogram with tracked MTS pilot tone

5. Disadvantages and possible modifications

The weakest point of the presented algorithm is its iterativeness with a backward dependence. It means that it has no means to verify confidence of the signal being followed. Simple confidence value could be added in future – e.g. based on the spectral level of the estimated pilot tone frequency. If it would be too low in a certain number of steps, the algorithm could try to find a pilot tone by searching for a high peak starting from the upper frequencies and moving downwards. Distinguishing the background pilot tone from the actual one would be problematic, though.

Another simple concept of a confidence value bases on tracking the MTS pilot tone from both sides of a distorted sample (forwards and backwards). Significant differences in the estimated pilot tone track would mark regions of uncertainty.

The fact that the algorithm was tested on small variety of NTSC signals due to lack of sufficient examples of distorted audio samples is another weak point. Artificial NTSC samples could not be forged, because MTS pilot tone itself was problematic to model due to its rudimentary documentation.

Further improvements in precision of determined frequency could be made. Basing on the computed track of the pilot tone, the additional algorithm could try to find the real frequency in the close neighborhood. It was not introduced directly because of a needed stability of the algorithm (following the pilot tone track). Future correction of the pilot frequency will not lead to an “error propagation” because the track will be fixed.

6. Acknowledgment

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