Windowing Effect on Electromagnetic Interference and Efficiency at Using Pulse Width Modulation Techniques

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Abstract— The PWM technique, which is used for voltage inverters of traction drives is analyzed. To decrease the higher harmonics level, various finite-impulse response (FIR) filters are considered. Obviously, that changes the efficiency of output signals. Therefore electromagnetic interferences and efficiencies are examined. The electromagnetic interferences and efficiencies are examined using numerical simulations.

1. INTRODUCTION

In power semiconductor voltage converters, semiconductor elements are used mainly in switching mode because of decreasing power loses. Today, a pulse-width modulation (PWM) is mainly used. This is switching voltage with very sharp edges, so production of higher harmonic frequencies is a result [1–7]. The PWM signal creating sinusoidal waveform is shown in Fig. 1.

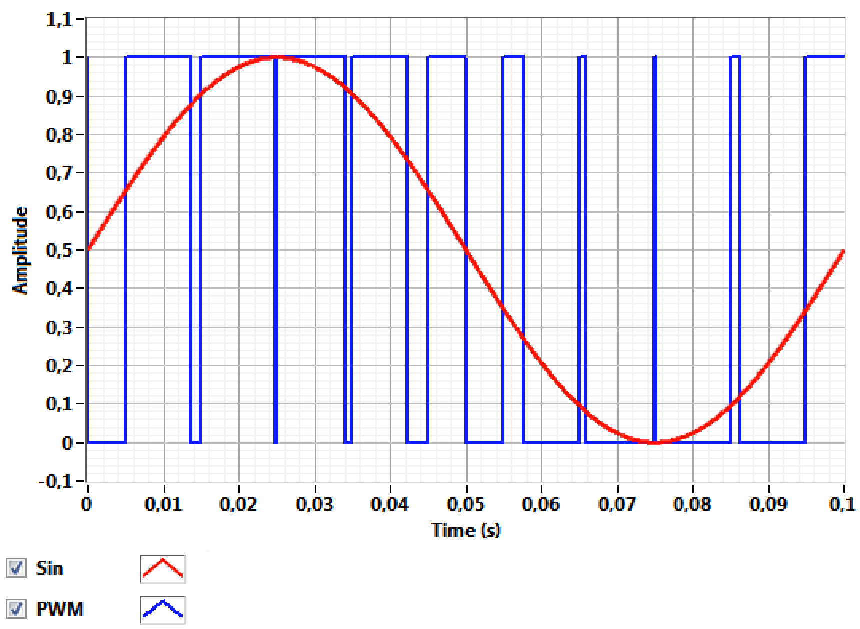

Figure 1: PWM signal.

In traction drives with high power, today mainly with induction motors or with permanent magnet synchronous motors, they are fed from voltage inverters. It is not possible to use another mode of semiconductor elements operation, so it is necessary to be engaged in research of those devices from the point of view of electromagnetic compatibility and from the point of view of decreasing electronic distortion. In power semiconductor voltage converters, semiconductor elements are used mainly in switching mode because of decreasing power loses.

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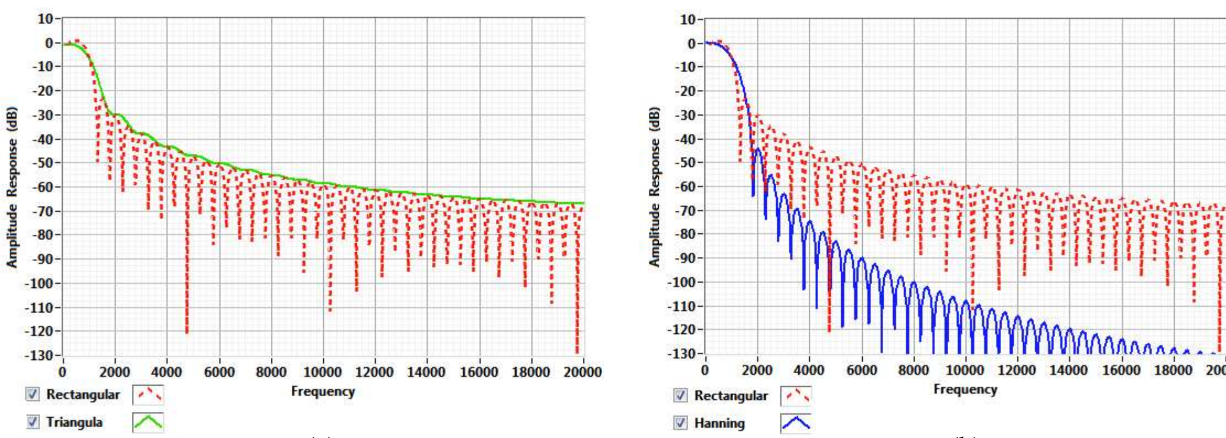
The paper analyzes the PWM techniques, which are used for voltage inverters of traction drives. To decrease the higher harmonics level, various finite-impulse response (FIR) filters are considered. Obviously, that changes the efficiency of output signals. Therefore electromagnetic interferences and efficiencies should be examined. The electromagnetic interferences and efficiencies are examined using numerical simulations.

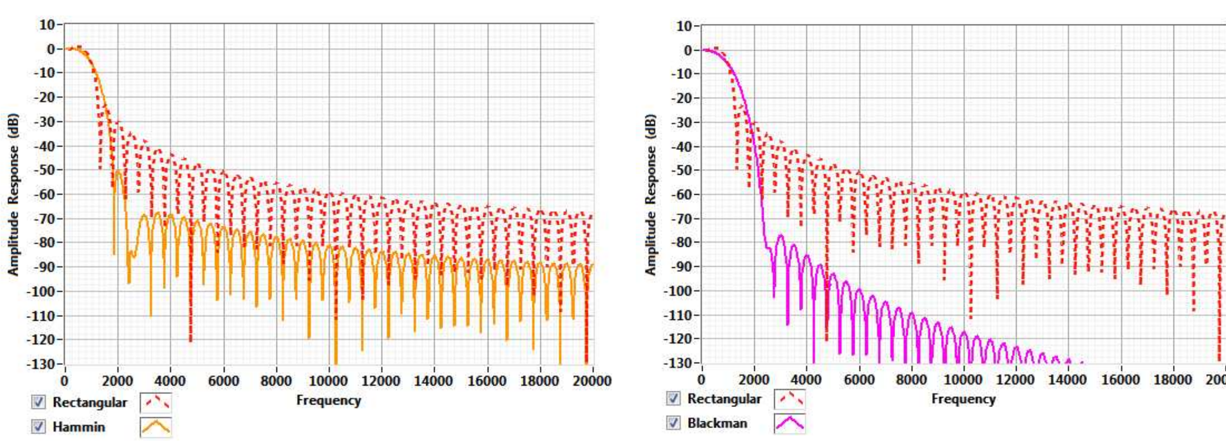
2. ELECTROMAGNETIC INTERFERENCES AND EFFICIENCIES

It is well known that windowing is one of the earliest techniques for designing the FIR filters [8]. The filter coefficients can be obtained in closed form without the need for solving complex optimization problems as in some other sophisticated FIR design techniques. Therefore, the design time is very short and the technique remains an attractive tool for FIR filter design. For a rectangular window, the maximum sidelobe amplitude is equal to approximately −13 dB relative to the maximum value, i.e., the sharp transition in the ideal response is converted into a gradual transition. To reduce the oscillations, i.e., higher harmonics, other window functions having spectra exhibiting smaller sidelobes should be used. The sidelobes of the rectangular window represent the high-frequency components and are due to the sharp transitions from one to zero at the edges of the window. Therefore, the amplitudes of these sidelobes can be reduced by replacing the sharp transitions by more gradual ones. The design of various low-pass FIR filters has been done using several windows. The rectangular (with −13 dB sidelobes), triangular (with −25 dB), Hanning (with −31 dB), Hamming (with −41 dB) and Blackman (with −57 dB) windows have been used. Their responses are shown in Figs. 2 and 3. They allows substantially decrease the electromagnetic interference. However, the design of FIR filters should be optimized considering several parameters such as sampling frequencies, cutoff frequencies and the order of the filter. The PWM signal shown in Fig. 1 was used as input of FIR filters as is shown in Figs. 4–8.



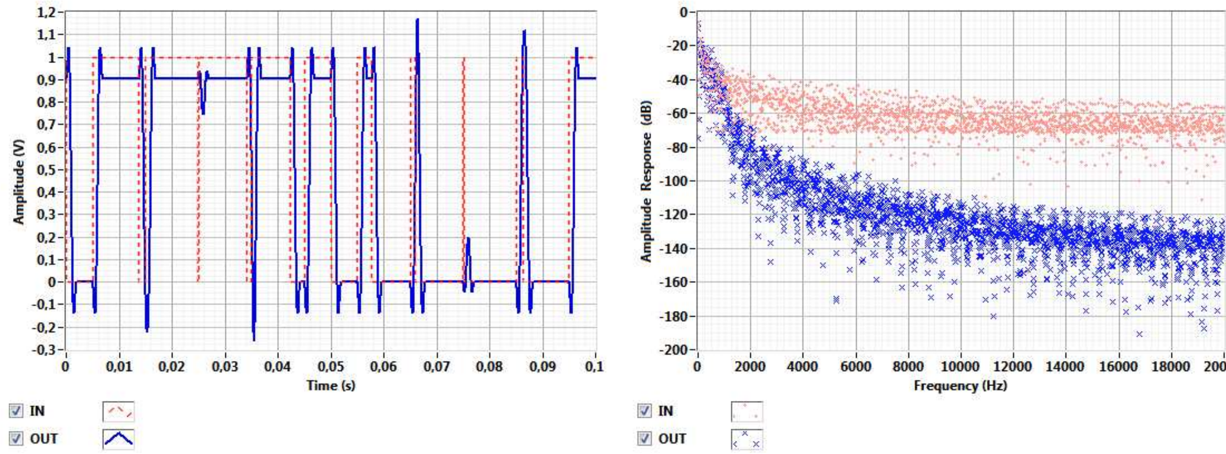
(a) (b)

Figure 2: Comparison of FIR low-pass filters for (a) rectangular and triangular, also known as Bartlett, and (b) rectangular and Hanning windows.



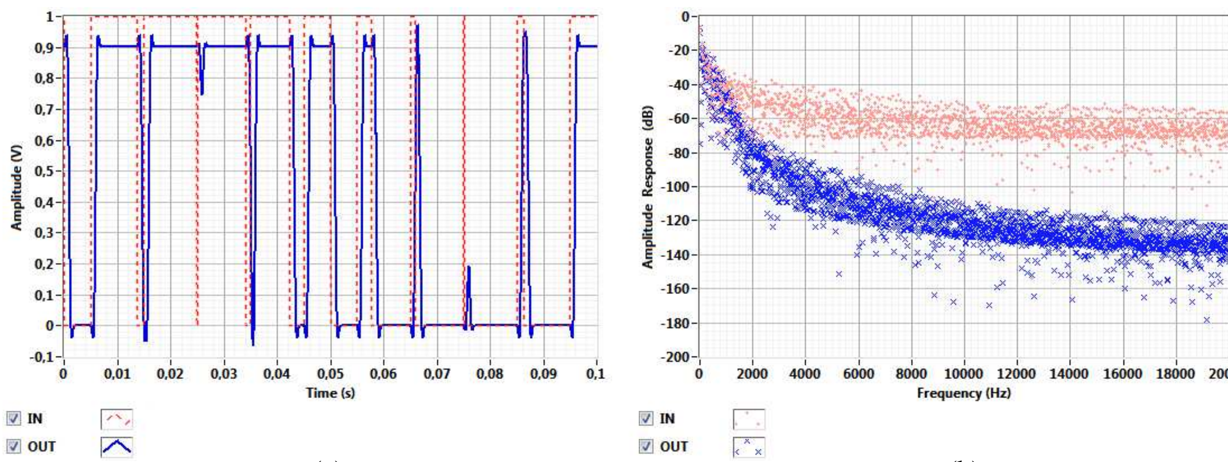
(a) (b)

Figure 3: Comparison of FIR low-pass filters for (a) rectangular and Hamming and (b) rectangular and Blackman windows.



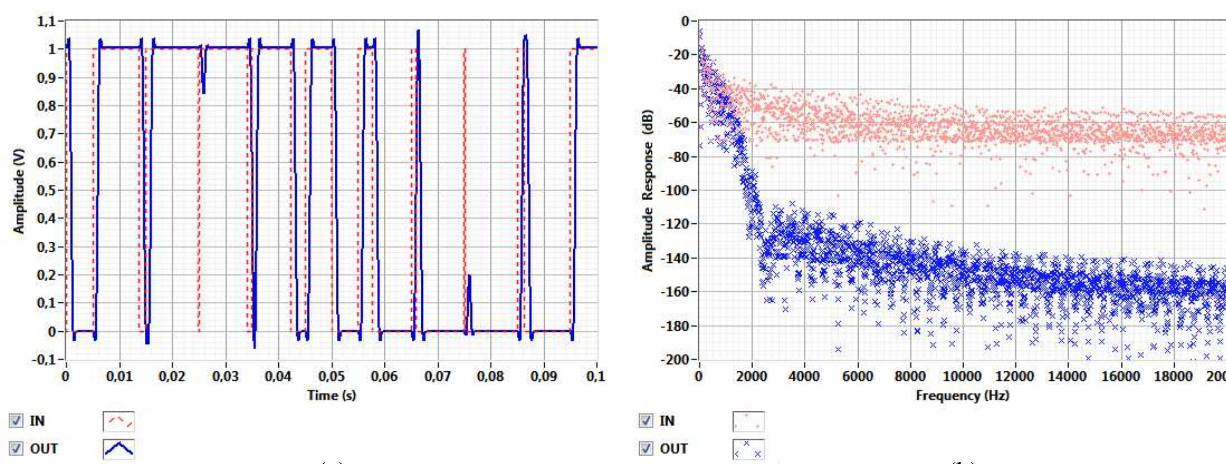
(a) (b)

Figure 4: Comparison of input and output of FIR low-pass filter for rectangular window. (a) Time domain, (b) frequency domain.



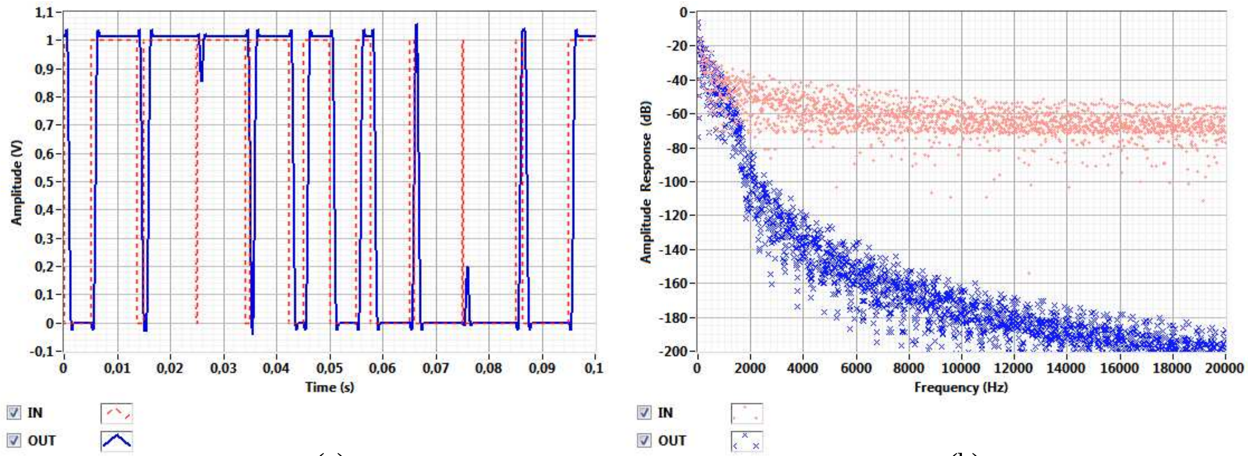
(a) (b)

Figure 5: Comparison of input and output of FIR low-pass filter for triangular, also known as Bartlett, window. (a) Time domain, (b) frequency domain.



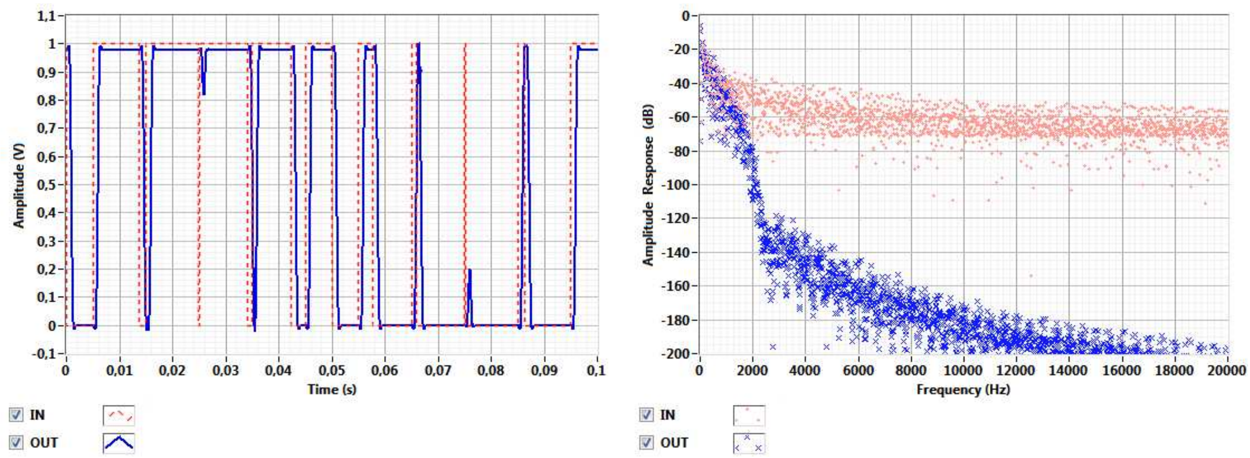
(a) (b)

Figure 6: Comparison of input and output of FIR low-pass filter for Hanning window. (a) Time domain, (b) frequency domain.



(a) (b)

Figure 7: Comparison of input and output of FIR low-pass filter for Hamming window. (a) Time domain, (b) frequency domain.



(a) (b)

Figure 8: Comparison of input and output of FIR low-pass filter for Blackman window. (a) Time domain, (b) frequency domain.

Table 1: RMS for FIR low-pass filter based on various windows.

Window	Rectangular	Triangular	Hanning	Hamming	Blackman
RMS	0.64371	0.63102	0.70557	0.70051	0.68106

To demonstrate the efficiency of various low-pass filters, Table 1 shows the comparison of RMS for FIR low-pass filter based on various windows.

3. CONCLUSIONS

The paper analyzes the PWM technique, which is used for voltage inverters of traction drives. To decrease the higher harmonics level, various finite-impulse response (FIR) filters are considered. Obviously, that changes the efficiency of output signals. Therefore electromagnetic interferences and efficiencies are examined. The electromagnetic interferences and efficiencies are analyzed using numerical simulations.

The comparison of input and output of FIR low-pass filters both for time and frequency domain clearly shows that frequency spectra could be substantially decreased using suitable designed FIR low-pass filters. Moreover, the output waveforms could be reasonable and efficiencies considering RMS are not substantially changed.

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