WIRELESS DIAGNOSTIC SYSTEM WITH USE OF THE HARMONIC POLYNOMIAL BASE

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Summary
In this work were given the basics of the wireless diagnostic system which is the subject of patent application. This system is using the method of developing signals to Fourier series.

Keywords: wireless diagnostic system, sampling signal, Fourier series.

BEZPRZEWODOWY SYSTEM DIAGNOSTYCZNY
Z WYKORZYSTANIEM BAZ HARMONICZNYCH I WIELOMIANOWYCH

Streszczenie
W pracy zostały przedstawione założenia bezprzewodowego systemu diagnostycznego będącego przedmiotem zgłoszenia patentowego [1]. System ten wykorzystuje w nadajniku metodę rozwijania sygnałów w szereg Fouriera.

Słowa kluczowe: bezprzewodowe systemy diagnostyczne, próbkowanie sygnałów, szeregi Fouriera względem wielomianów ortogonalnych.

1. INTRODUCTION

The subject of this article is wireless diagnostic system being an alleged invention [1]. The sense of this patent is to spread the analog diagnostic signal – from converter, into the Fourier series due to relevant orthogonal basis and further transmission of the Fourier series components and their further processing.

Input signal (wireless diagnostic system) can be given by dismantling the electrical signal into the series according to relevant orthogonal basis (these series are called finite and infinite sampling series) on the transmission side and sending in channel information only about it's coefficient expansion and in receiver generate and sum them properly.

This system is used to wireless diagnosis of devices, mechanical machines and dangerous or inaccesible electric installations such as high voltage or high concentration of chemicals.

Mathematical basics of his system were given in these articles [2, 3, 4].

The most similar systems of data transfer are Bluetooth, IrDA and OFDM.

2. GENERAL SYSTEM DESCRIPTION

Data are delivered as non electric signal,which is turned with converter to electric. In next faze of converting, the signal is expanded into the Fourier series due to exact orthogonal basis, usually harmonic or into the series against orthogonal polynomial by Legendre, Czebyszew, Laguerre and Hermite. In radio channel are transmitted informations only about coefficient expansion of the signal. In the receiver according to received coefficients the components of the diagnostic signal are generated. These coefficients are next sum up with harmonic sampling kernels such as Dirichlet, Fejer or de la Valle Poussin kernels.

Harmonic basis will be used mostly to wireless diagnosis of devices using signals in forms of vibrations from different sources. These vibrations have harmonic pattern.

In case of diagnostic signals having non harmonic patterns - impulses, it's better to use polynomial kernels against Legendre, Czebyszew, Laguerre or Hermie polynomials, which allow to generale input signal having less coefficients in it's expansion, so it's possibile to get it's higher compression.

The radio system will be using OFDM modulation. It's more safe due to unwanted data capture in radio channel. In this channel will be transmitted infomations about signal expansion coefficients not about signal itself, so the capacity of data will be increased.

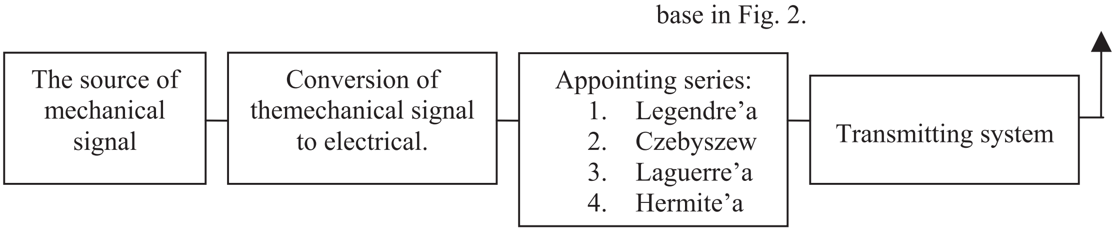
OFDM transmission technique allow to increase WLAN network discharge between dewices significantly. OFDM rely on single stream data coding in many carriers. In this system are used subcarriers in which are used BPSK, QPSK or QAM/64-QAM modulations. Maksimum speed of data transmission - 54 Mbit/s is achieved for 64-QAM (216 data bits per one OFDM symbol) modulation.

OFDM modulation is based on FDM but is used as digital modulation. Transmitted bit stream is spread to over twelve parallel streams. Available band is spread between couple of subchannels and every smaller stream is transmitted by one subchannel modulating it's carrier with use of simple modulation, for example PSK or QAM. Subcarriers are chosen in certain way, that every modulated stream is orthogonal against the others. This way gives opportunity to eliminate the co-channel disturbances. The alignment of channel is simplified because of usage of slower narrow band channels instead of one wide band channel. The basic rule of OFDM is to get along with different, sometimes hard environment of Chanel, for example With narrow band interferencje without any filters.

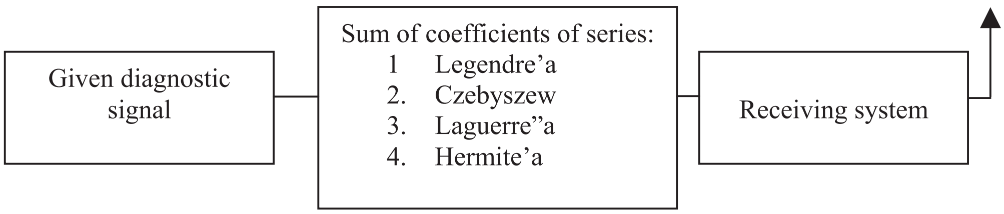
This solution allowed to build wireless diagnosis system without need to switch analog signal to digital. This system is immune for interferences of radio wave propagation for unwanted data capture and gives the allegiance of receivered signal with minimum of band occupancy.

Using of that system allow for immediate diagnosis based on valuation of unwanted components of diagnostic signal. This system exclude A/C and C/A converters. The basic idea of his project is decay od signal in the transmittor and to sum the components in receiver. Precision of mapping of signal in receiver is only up to amount of components granted in sum not up to parameters of transmission channel. In radio channel are transmitted the informations about the components of series. Thsis system can be used in other purposes and in the same way in receiver use informations from expansion into series in this receiver for example to indentification, diagnosis - telemedicine.

The block scheme of the system in case of polynomial base is in Fig. 1, in case of harmonic base in Fig. 2.

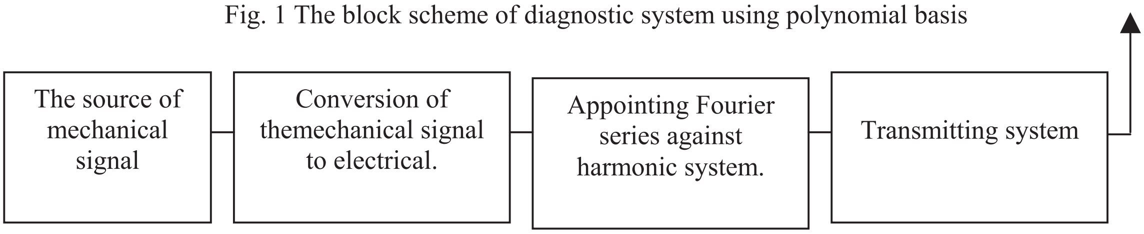


The block scheme – conversion of diagnostic signals in the transmitter

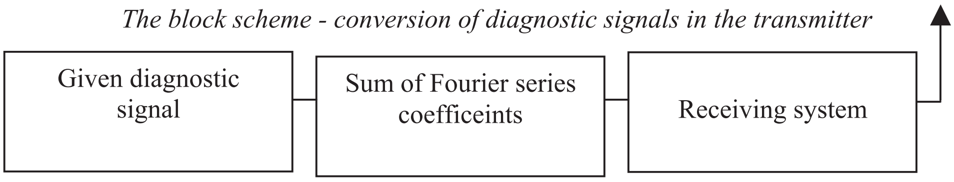


The block scheme of signal conversion in the receiver

Fig. 1 The block scheme of diagnostic system using polynomial basis



The block scheme - conversion of diagnostic signals in the transmitter



The block scheme of signal conversion in the receiver

Fig . 2 The block scheme of diagnostic system using harmonic basis

3. SIGNAL ANALYSE SYSTEMS BASED ON GENERALISED FOURIER SERIES

General block scheme of system used to define coefficeints of signal expansion into generalised Fourier series. Fig. 3.

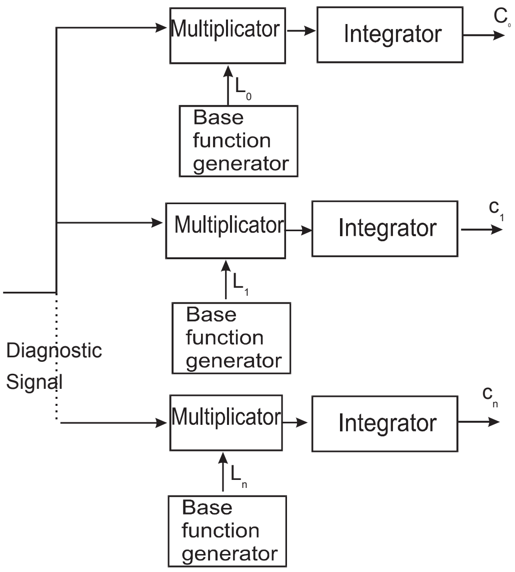


Fig. 3. Block scheme of system used to appoint Fourier coefficients of diagnostic signal

Basic elements of this system are base function genereators according to the expansion is effected.

Signal analyse – diagnosis, running in real-time.

Analysed diagnostic signal is multiplied by exact base functions and than integrated (integrating amplifier).

In the output of every integrating amplifier at the final moment of integration interval the continuous in time signal occure, which value is exact to responsive coefficient of generalized Fourier series.

On drawings 4, 5, 6, 7 are block schemes of basic function generators for eight first functions.

The base to build the electronic system generating particular basic functions are recurrence equations.

For Hermite polynomials this equation is :

$$H_{n+1}(x) = 2xH_n(x) - 2nH_{n-1}(x) \quad (1)$$

According to this equation dependings which define the eight first Hermite polynomials are :

$$\begin{aligned} H_0 &= 1 \\ H_1 &= 2x \\ H_2 &= 2(xH_1 - H_0) \\ H_3 &= 2(xH_2 - 2H_1) \\ H_4 &= 2(xH_3 - 3H_2) \\ H_5 &= 2(xH_4 - 4H_3) \\ H_6 &= 2(xH_5 - 5H_4) \\ H_7 &= 2(H_6 - 6H_5) \end{aligned} \quad (2)$$

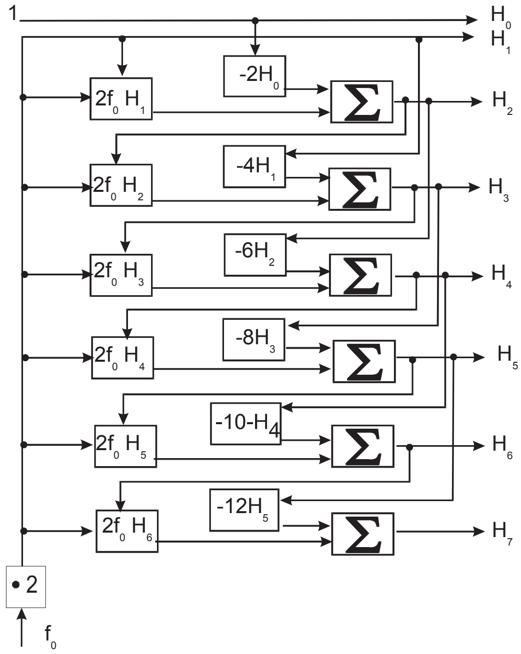


Fig. 4. Block scheme of generator of eight first Hermite polynomials

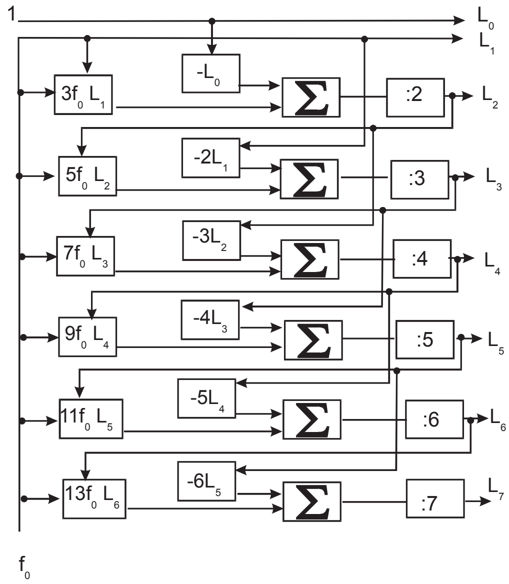


Fig. 5. Block scheme of eight first Legendre polynomials generator

For Legendre polynomials, recurrence equation is formed :

$$L_{n+1}(x) = \frac{1}{n+1}\left[(2n-1)xL_n(x) - L_{n-1}(x)\right] \quad (3)$$

From above equation, rules defining the eight firs Legendre polynomials are consequent :

$$
\begin{aligned}
L_0 &= 1\\
L_1 &= x\\
L_2 &= \frac{1}{2}\left(x3L_1 - L_0\right)\\
L_3 &= \frac{1}{3}\left(x5L_2 - 2L_1\right)\\
L_4 &= \frac{1}{4}\left(x7L_3 - 3L_2\right)\\
L_5 &= \frac{1}{5}\left(x9L_4 - 4L_3\right)\\
L_6 &= \frac{1}{6}\left(x11L_5 - 5L_4\right)\\
L_7 &= \frac{1}{7}\left(x13L_6 - 6L_5\right)
\end{aligned} \tag{4}
$$

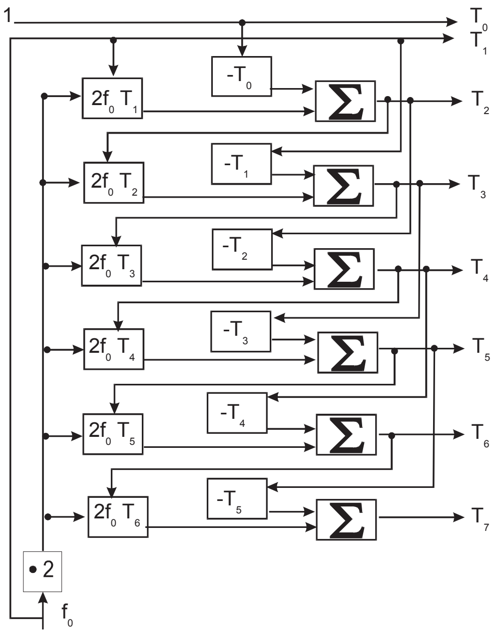


Fig. 6. Block scheme of eight first Czebyszew polynomials generator first type

For Czebyszew first type polynomials, recurrence equation is formed:

$$T_{n+1}(x) = 2xT_n(x) - T_{n-1}(x) \tag{5}$$

From above equation, rules defining the eight firs Czebyszew polynomials first type, are consequent:

$$
\begin{aligned}
T_0 &= 1\\
T_1 &= x\\
T_2 &= 2xT_1 - T_0\\
T_3 &= 2xT_2 - T_1\\
T_4 &= 2xT_3 - T_2\\
T_5 &= 2xT_4 - T_3\\
T_6 &= 2xT_5 - T_4\\
T_7 &= 2xT_6 - T_5
\end{aligned} \tag{6}
$$

For Laguerre polynomials, recurrence equation is formed:

$$L_{n+1}^{(a)}(x) = \frac{-(x - a - 2n - 1)}{n+1} L_n^{(a)}(x) - \frac{n+a}{n-1} L_{n-1}^{(a)}(x) \tag{7}$$

From above equation, rules defining the eight firs Laguerre polynomials are consequent:

$$
\begin{aligned}
La_0 &= 1\\
La_1 &= (a+1) - x\\
La_2 &= \frac{(a+3) - x}{2} La_1 - \frac{a+1}{2} La_0\\
La_3 &= \frac{(a+5) - x}{3} La_2 - \frac{a+2}{3} La_1\\
La_4 &= \frac{(a+7) - x}{4} La_3 - \frac{a+3}{4} La_2\\
La_5 &= \frac{(a+9) - x}{5} La_4 - \frac{a+4}{5} La_3\\
La_6 &= \frac{(a+11) - x}{6} La_5 - \frac{a+5}{6} La_4\\
La_7 &= \frac{(a+13) - x}{7} La_6 - \frac{a+6}{7} La_5
\end{aligned} \tag{8}
$$

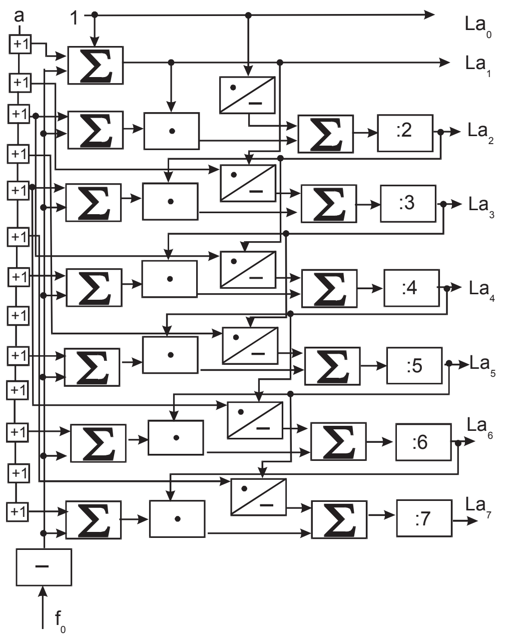


Fig. 7. Block scheme of eight first Laguerre polynomials generator

Markers are:

[•] multiplying system

[•/–] multiplying and reverse phase sys tem

[–] turning-out phase system

The *a* prameter is being increased by 1 and than transmitted to exact adder and to multiplying and reversing system. Some parameters (*a*+8; *a*+10, *a*+12) in eight first Laguerre polynomial generator are not in use. Basicly every non even value of coefficient $a+n$ is always used twice and even value once to generate polynomial of given order.

It's often to asume value $a=0$ because this parameter is gained by one. Only in case of fractional or irrational value of a parameter is important to grant it's value. In most cases a must be chosen experimentaly depending of analysed diagnostic signal.

4. SUMMARY

The most common solution in diagnostic technique is to change the analog signal (from converter) into digital the quickest way. Transmission of whole digital signal is made in radio channel. In the receiver of diagnostic signal is made it's analysis (usually digital signal processing).

In given solution decay of diagnostic signal into the series in the transmitter is being made. For that reason to receiver is getting information about malfunction (unwanted harmonic signal).

The reasons for designing wireless diagnostic system are:

- To build wireless diagnostic system without changing analog signal into digital.
- To ensure it's immunity for radio waves propagation decay.
- To ensure maximum immunity of system for unwanted data capture.
- To ensure maximum allegiance of received signal with minimum bundle interruption.
- To ensure the possibility of immediate diagnosis based on estimation of unwanted components of diagnostic signal (granting of the pattern spectrum of the machine).

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