Designing Hand-Held Vibration Measuring Device for Industrial Machines

[a]Nguyen Thi Dieu Linh[*], [b]Hoang Manh Kha,[c]Le Anh Tuan,[d]Tran Ngoc Duc

[a,b,c]*Hanoi University of Industry, Vietnam,*

[d]*Namdinh University of Technology Eduction*

[a]*nguyenlinh79.haui@gmail.com, (https://orcid.org/0000-0001-8596-392X)*

[b]*hmkha2506@gmail.com;*

[c]*anhtuandt04k2@gmail.com*

[d]*tranngocducnute@gmail.com*

Abstract

Evaluating the quality of industrial machines, the vibration meter is used to measure the machine's actual vibration. The two most important parameters describing machine vibration, amplitude and frequency, are the key factors for determining the cause of vibrations. Spectral analysis of the vibration signal will give information about the vibration level and determine which part of the machine leads to the observed vibration signal. This paper presents a self-made machine vibration measuring device with a simple structure, compact size, high accuracy with a reasonable price. The device can display the value of the measured vibration signals in real-time and analyze the spectral by computer to produce the required parameters.

Keywords

Vibration meter

Spectrum analysis

MATLAB

STM32F407

1. Introduction

In factories, most of the machines operate in unexpected situations due totheincorrectlink and balance, resulting in higher load-bearing on loaded parts,which increases the impact force and abrasion of the critical components. Therefore, the machine might operate inefficiently, generate heat, andlead to malfunction,interrupting the production. Random vibration will increase the wear and damage the mechanical parts of the machinery. This will cause a substantialadverse effect on the manufacturing business.

Regularly controlling mechanical parts' vibrations will help detect damage and, consequently, prevent damage from machine breakdown, proactively plan maintenance, and promptly replace parts to bring economic benefits. Developing a predictable maintenance schedule according to key factors such as measured vibration helps reduce production disruptions and makes maintenance more efficient. This increases product quality and productivity. When vibration measurements are taken and plotted the results periodically, it would show progress or deterioration of a particular machine.

---

[*] Corresponding author
Nguyen ThiDieuLinh
Email: nguyenlinh79.haui@gmail.com

The vibration measurement on the market today are very diverse and plentiful. Some of them need to be connected to the computer during the analysis of machine vibration leading to the reduction of work safetyand reducing work efficiency. A device can directly measure and analyze the local vibration signals is essential. It will help maintenance work more efficiently.

Vibration measuring types of equipment for industrial machines have been designed with the requirement of compact size, easy to use, low cost, and high accuracy. This paper presents how to design a hand–held vibration device that can directly measure and analyze the local vibration signals, easy to use, low cost, and high accuracy.

The paper is organized as follows: The regular vibration measuring system's standard structure is presented in Section 2. In Section 3, the procedure to develop the hardware and software design is described in details. The experimental results and discussions are given in Section 4 to demonstrate the proposed self-made vibration device. Finally, the paper is concluded in Section 5

2. Structure of Vibration Measuring System

A vibration measuring system has five main components, including sensor, signal processing amplifier (matching sensor), filtering, averaging wave detection (averaging wave detection), and display and storage processing (output device).
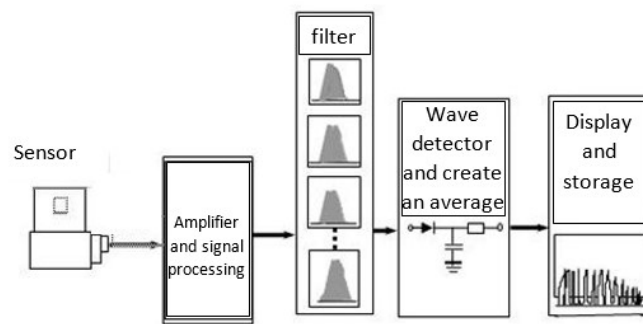
Figure 1:Vibration measuring system Block diagram

The signal obtained from the sensor will be put in to amplifier and signal processing. The signal after processing is filtered, wave detected and averaged to display and storage.

The vibration monitoring of industrial machines is divided into three different levels: low-frequency vibration, medium frequency vibration, and high-frequency vibration.Vibration monitoring with low vibration frequency requires displacement measurement; Vibration monitoring with medium vibration frequency shall measure the velocity; Vibration monitoring with high vibration frequency shall perform accelerometer measurement.

Industrial machines such as compressors, crushers, pumps, agitators, centrifuges, electric fans... all are high vibration frequencies. Therefore, the hand-held vibration measuring device performs measures the acceleration values to monitor the vibration signal.

3. Hand-Held Vibration Measuring Device

3.1. Requirements for Equipment

The general requirement for a Handheld Vibration Measuring Device is that devices connect and read data from sensors when measuring acceleration and frequency value, send information back to the sensor. Perform signal processing and analysis in the frequency domain by FFT transform, calculate the corresponding acceleration and frequency value; There are two modes on the device:savedata modes and automatic modes, allowing to save raw data in real-time, saving data as separate files on the memory card; Display the numerical measurement value on the LCD screenor on the computer by simulation software.

From thegeneral requirements above, the self-made device should have the following features;

Using an accelerometer sensor to measure the vibration signal, the Device measures acceleration and frequency in the range: 0 ÷ <1000Hz; accuracy ± 5%. The acceleration, frequency are displayed directly on

the LCD screen in real-time.The device can communicate with a computer according to the RS-232 standard; Allows analyzing, displaying, and storing data now from the measuring device on the memory card in real-time: real-time settings, alarm thresholds, calibration mode on the device. After being saved to the memory card, the data can be analyzed, processed, and printed by using computer data analysis simulation software.

3.2. Components Selection

The structure of the device is shown in figure 2.
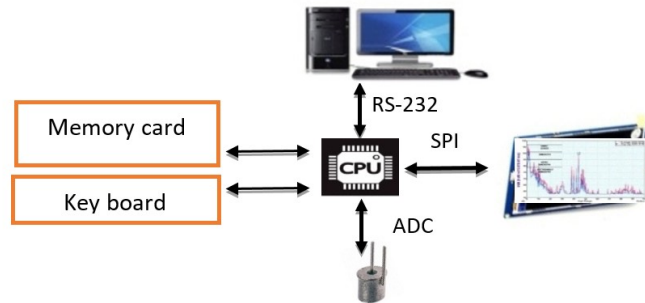
Figure 2:Structurediagram of the handheld vibration measuring device

- HN100 sensor is selected. This sensor can measure acceleration in 3 directions. Integrated noise filter, reducing the amount of data to be analyzed, helping to transfer data at high speed.

- Microcontroller STM32F407 made by ST semiconductor.

- LCD16X2 screen display

The measuring device will measure parameters, including acceleration and frequency. Measured values are transmitted to the communication center processor. At the microprocessor, the measured values will be analyzed, processed, and displayed on the LCD screen and stored in a memory card in real-time.

## 3.3. Programming on Microcontroller and Simulating Data Analysis on Computer

The data transmitted between the main blocks is shown as following:
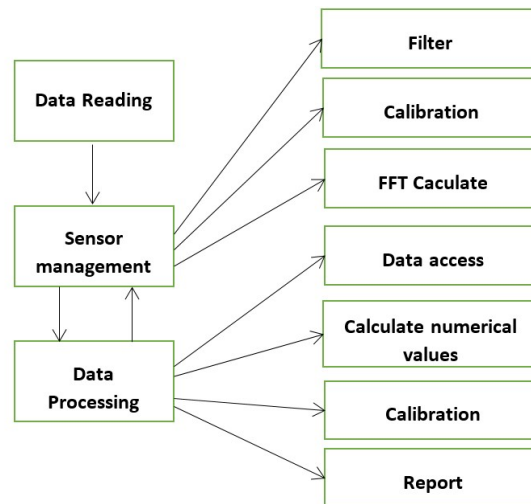
Figure 3:Interactive diagram of data transmission between major blocks

The signal to be measured from the sensor is sent to the Data reading unit to read the data and stored in the buffer memory. Sensor management unit for performing filtering, calibration, and FFT calculation. The data processing unit performs data access, numerical value calculation, calibration, and reporting.

The algorithm on the microcontroller is shown in Figure 4.
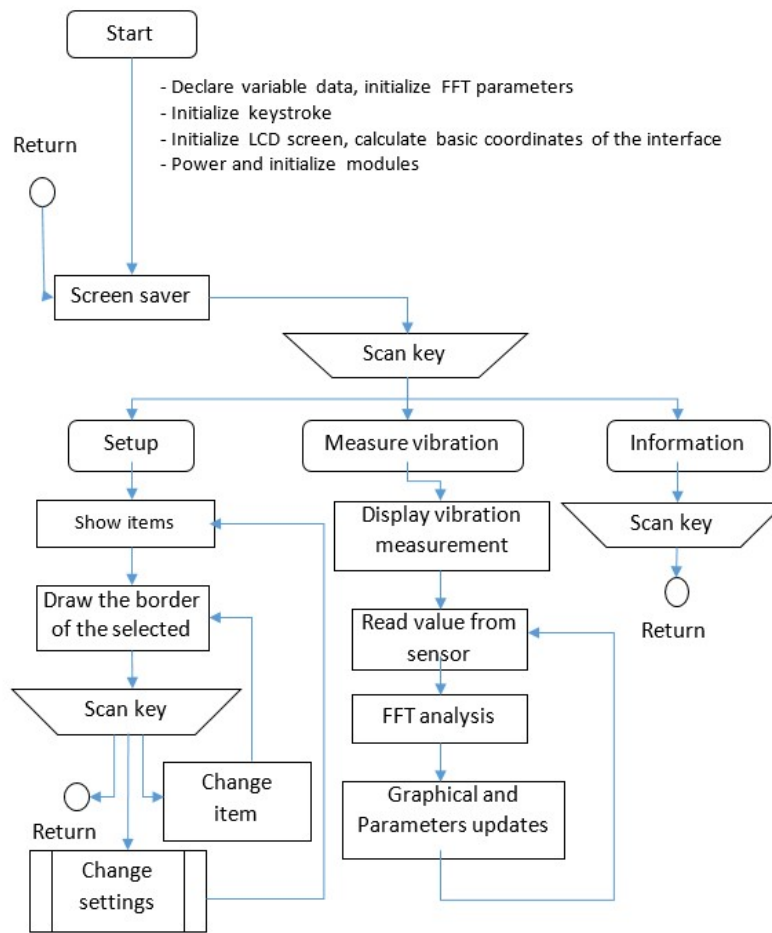
Figure 4:Algorithm on the microcontroller

We are using the DS-5 Community Edition compiler to write programs and Matlab software to simulate and analyze data on the computer.

Simulation software and calibration

Using MatLab software to simulate and analyze data on a computer

Step 1: Analyze the data read from the pulse generator and compare the results

Step 2: Correctthe sampling parameters, window functions, and filter parameters so that the analyzer gives the smallest error results.

Step 3: Use the above set of parameters in programming the data analyzer on the microcontroller.

Step 4: Compare the results of data analysis on the microprocessor and computer.

Step 5: Adjust the microprocessor program to get the smallest error from the results on the computer.

The algorithm on the computer is shown in Figure 5:
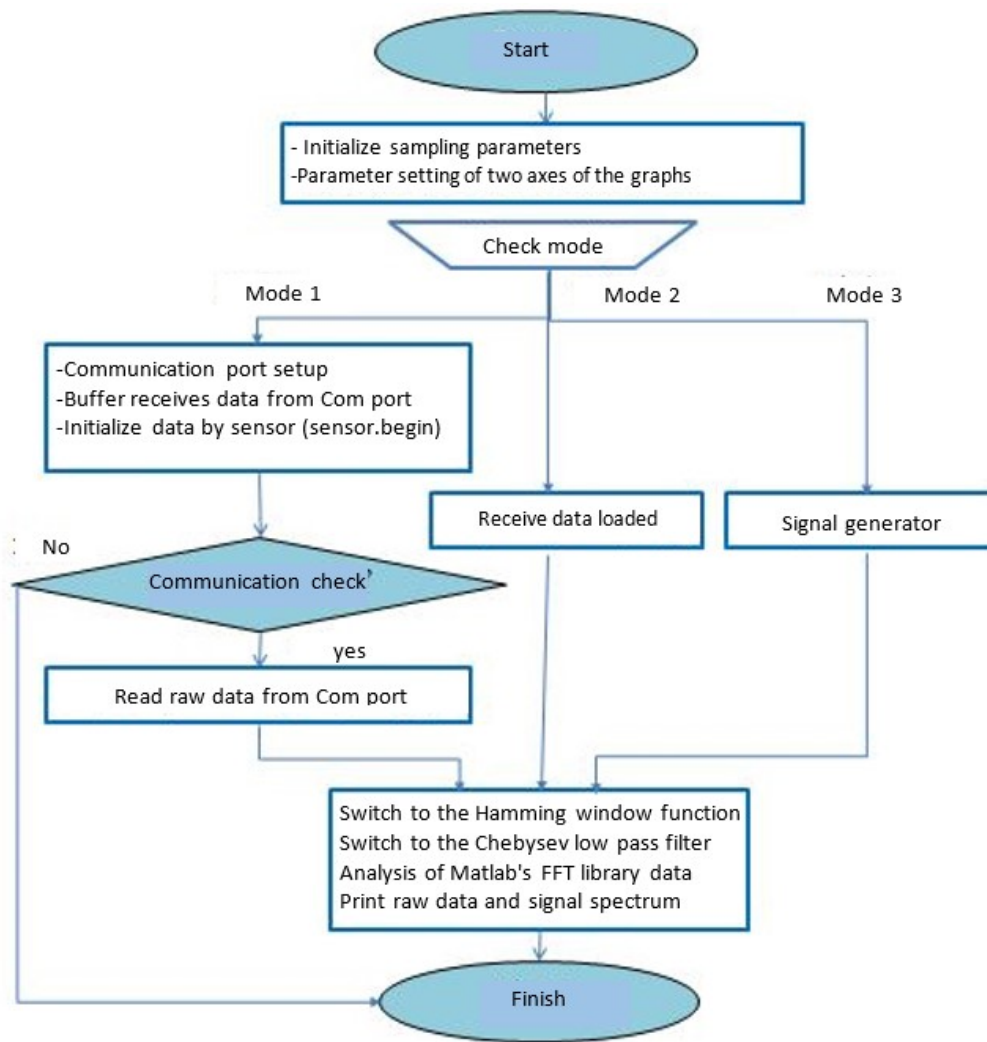
Figure 5:Algorithm flowchart on the computer

The program will present some main functions as the following:

- There are three modes in the program:

Mode 1: Direct connection with measuring equipment to collect and analyze data.

Mode 2: Analysis of data obtained from memory cards.

Mode 3: Generate sample vibrato, and analyze the results for calibration and software upgrade purposes.

- Allows displaying the spectrum according to the linear frequency scale and logarithmic frequency scale

- Allows spectral display with amplitudes of acceleration, velocity, and displacement.

- Allows data storage to the SD card.

4. Simulation Results

To evaluate the self-made device's performance and accuracy, standard equipment Type 3160-B-042 of Brüel&Kjær with 4 input channels, 2 output channels, integrated SD card port is used to compare and evaluate.The sensors of the two devices are placed close together on the same plane. A speed-setting motor is used to create vibrations and adjusted at different speeds. We get the following results:

4.1. Frequency and Acceleration

The test is done 20 times to ensure correct evaluation of deviceerror.Table of test results shows the choice of the value measured from the self-made device with the maximum error of 20 measurements

Table 1: Test results at different motor speeds

Motor speeds	Pick	Parameters measured from Self-made device		Parameters measured from standard device		Error(%)	
		Frequency	Acceleration	Frequency	Acceleration	Frequency	Acceleration
500rpm	1	52,34	0,0980	53	0,09900	1.25	1
	2	18.9	0,0064	18	0,00624	5	4.07
	3	71,88	0,0118	70	0,01130	2.69	4.53
600rpm	1	62,5	0,1295	63	0,12500	0.79	3.40
	2	42,2	0,0174	42	0,01670	0.48	4.57
	3	84,38	0,0060	84	0,00585	0.45	3.16
800rpm	1	82,81	0,1178	84	0,11700	1.42	0.49
	2	28,12	0,0202	28	0,02000	0.43	1.39
	3	55,47	0,0140	56	0,01390	0.95	1.38

Table 1 shows that the acceleration and frequency values of the two measuring devices are similar at different motor speeds. The self-made device has an error within the allowable threshold (less than ± 5%) compared to the standard device.

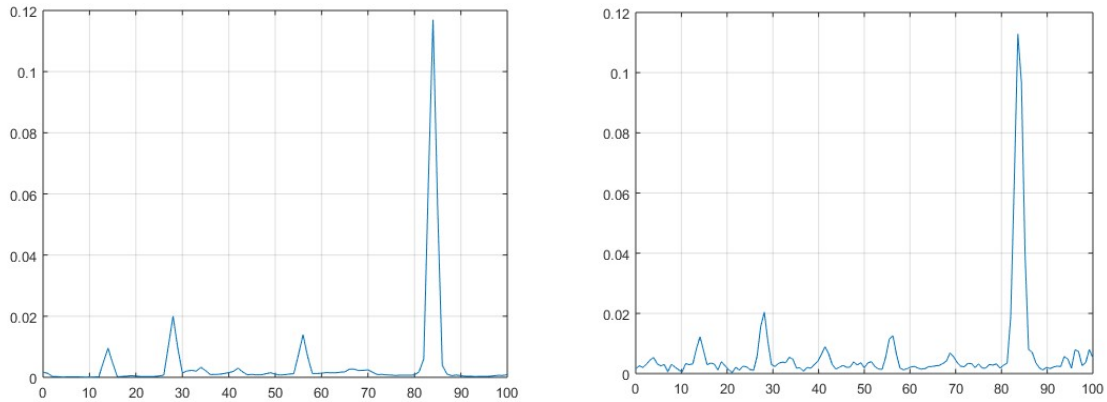## 4.2. Signal spectrum

Standard device   **Self-made device**
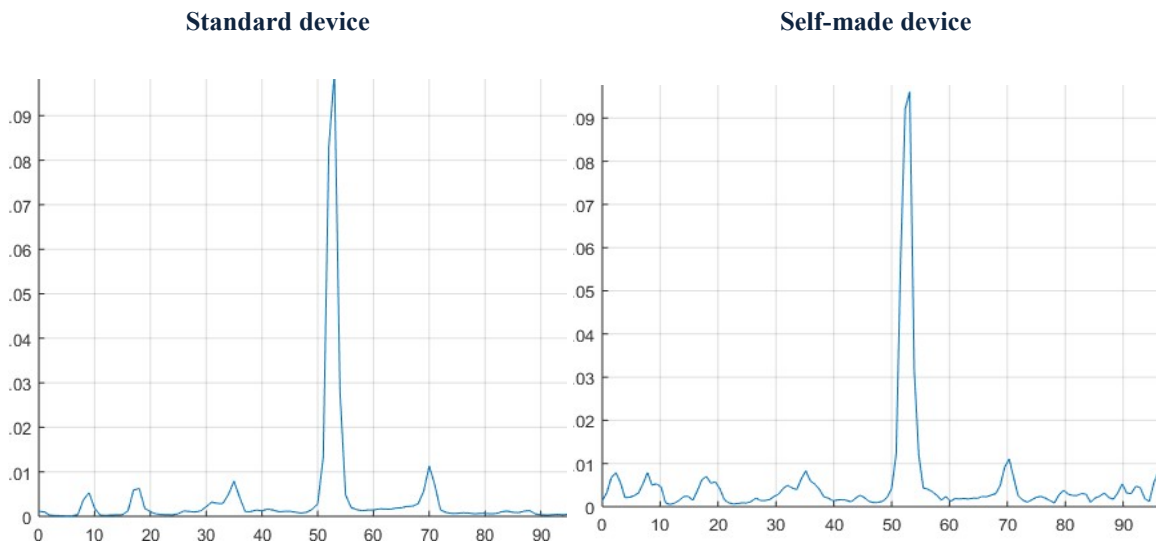
Figure 6: Signal spectrum at 500 rpm Motor speed
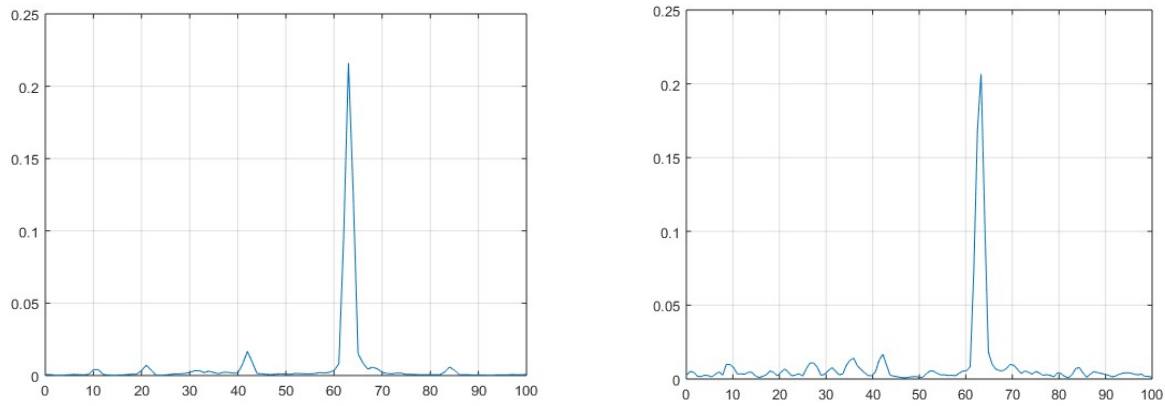
Figure7: Signal spectrumat 600 rpm Motor speed

Figure 8: Signal spectrumat 800 rpm Motor speed

The signal spectrum obtained from two measuring devices is similar. However, the self-made device still has some other pulses. Figures 6 to 8 show the vibration signal spectrum on a linear scale obtained from two measuring devices. The Y-axis represents vibration acceleration (m/s2); the X-axis represents vibration frequency (Hz).

The self-made device works stably. Comparing the measured values simultaneously shows that the tool's error compared to the standard device is <± 5%. Compare the vibration signal spectrum measured from the standard device: the sample signal still appears some noise. Therefore, it is necessary to improve the interference filter for the device.

5. Conclusion

The design of handheld vibrators for industrial machines has been completed. Compared with many portable vibration measuring devices on the market, this device's outstanding feature is the bundled software developed on the Matlab platform, so data is analyzed accurately at high speed. Therefore, it will help the users to efficiently and proactively analyze data. Finally, the self-made measuring device has an acceptable error (<±5%), supports the vibration monitoring to adjust the machine operation mode, helps increase the equipment's life, and reduces the business's investment costs.

References

[1].   World HealtSong, Yong Sheng, and You Liang Ding. "Fatigue monitoring and analysis of orthotropic steel deck considering traffic volume and ambient temperature." Science China Technological Sciences 56.7 (2013): 1758-1766.

[2]. Benjamin, Jack R., and C. Allin Cornell. Probability, statistics, and decision for civil engineers. Courier Corporation, 2014.

[3]. Ko, Hyoungho. "Highly configurable capacitive interface circuit for tri‐axial MEMS micro-accelerometer." International Journal of Electronics 99.7 (2012): 945-955.

[4]. Hayes M., "Statistical Digital Signal Processing and Modeling", John Wiley&Sons, 1996.

[5]. RulphChassaing, "Digital Signal Processing and Applications with the C6713 and C6416 DSK", Wiley-Interscience, 2005.

[6]. Tretter Steven A., Communication System Design Using DSP Algorithms: With Laboratory Experiments for the TMS320C6713™ DSK, Springer Science & Business Media, 2008

[7]. www.nxp.com/docs/en/data-sheet/MMA8451Q.pdf

[8]. https://cdn-shop.adafruit.com/datasheets/ILI9341.pdf

[9]. https://datasheets.maximintegrated.com/en/ds/DS1302.pdf

[10]. http://www.fecegypt.com/uploads/dataSheet/1480848837_sdcard_001-13589.pdf

[11]. https://cdn.sparkfun.com/datasheets/Prototyping/19608.pdf

[12]. https://www.onsemi.com/pub/Collateral/NCP1117-D.PDF

[13]. http://www.atmel.com/Images/Atmel-42735-8-bit-AVR-Microcontroller-ATmega328-328P_Datasheet.pdf

[14]. http://www.tcvn.gov.vn/sites/head/media/articles/images/admin/09.2015/75ac3622-2217-4098-a6da-3f97cab923d5.pdf

Author's Biography

Nguyen Thi Dieu Linh, has more than 18 years of academic experience in electronics, IoT, Telecommunication, Big Data, and Artificial Intelligence. She has published more than 20 research articles in national,international journals, books, and conference proceedings. She is a reviewer for Information Technology Journal, MobileNetworks and Applications Journal, and some international conferences. Now she is working as Deputy Head of Science and Technology Department, Hanoi University of Industry (HaUI), Vietnam.

Hoang ManhKha, is the Dean of Faculty of ElectronicsEngineering, Hanoi University of Industry, Hanoi, Vietnam. He has published many articles in ISI/Scopus indexed journals and conferences. He is alsoserving as a reviewer for the Journal of Science and Technology. His research interestsinclude digital signal processing, wireless communication, positioning engineering,nature-inspired optimization, and smart antennas.

Le AnhTuan,is a lecturer in the Faculty of Electronic Engineering, Hanoi University of Industry, Hanoi, Vietnam. He has published several articles in ISI/Scopus indexed journals and conferences. His research interestsinclude digital signal processing and Telecommunication.

Tran Ngoc Duc is a lecturer in the faculty of Electrical and Electronic Engineering, Namdinh University of Technology Education, Namdinh, Vietnam. He has more than 20 years of academic experience in electronics. He has published several articles in ISI/Scopus indexed journals and conferences. His research interestsinclude digital signal processing and Telecommunication.