

## THE INITIAL ANALYSIS OF WIFI COMMUNICATION (DATA INTERCHANGE) FOR AGV ON THE FACTORY SHOP FLOOR

*Igor Ostrowski*<sup>1</sup>, *Piotr Szulewski*<sup>2</sup>

<sup>1</sup> Institute of Mathematical Machines), Warsaw, Poland, i.ostrowski@imm.org.pl

<sup>2</sup> Faculty of Production Engineering WUT, Warsaw, Poland, maxer@cim.pw.edu.pl

**Abstract** – The AGV (AGV-automated guided vehicle) platforms make simply transport tasks which can be easy automated and give big benefits on human work in production environment. One of problems in AGV evolution is the easy and efficient communication with base station. Such a link is most often built by WLAN using 802.11 standard [1]. This is very important for AGV to keep communication with base station (supervising computer) on some minimal quality level because of needing continuous stream of control data. It is the crucial when the cloud computing is established and permanent synchronization is realized [2] In our opinion this crucial problem is not deeply analyzed as required. This issue joins the interesting subjects of wide technical areas from robotics to communication. This paper tries to shed new light for it.

**Keywords** mobile robots, data flow, communication, wireless network, WiFi

### 1. THESIS

The main goal of realized experiment was testing the possibility of use the popular wireless equipment as a communication network for mobile robots in difficult factory environment. It is well known that for such a specific tasks the specialized equipment should be, and usually, is used. But, any "special" is always related with substantial costs and complicated usage. Changing this situation is a very attractive technical challenge and should be economically reasonable also. Because, this paper is initial, so proposal (working) thesis was formulated. The office-tailored WiFi network can be appropriate solution for successful communication in mobile industrial robots - under some limitation, of course. The basic question is to recognize and determine these restrictions

### 2. BACKGROUND

The use of the radio controlled network system in industrial task is a real fact. The new medium, according to its nature and characteristics improves new possibilities in data transfer [4]. The deployment of wireless systems in the office (home) environment over the past decade has been

remarkable. But industrial environment is uniquely different from office or home conditions. For example: high temperatures, excessive airborne particulates, multiple obstacles, vibrations and long distances separating equipment and systems. These characteristics are special challenges that make it difficult to place and reach robots, computers, controllers, NC, sensors, transmitters and other data communication devices. In other words it is really harsh environment for electromagnetic propagation reliability (it means providing reliable radio channels) [4]. The modern wireless network standards can be divided into two main classes relating to its frequency band. The first, (i.e. WiFi) operates in the ISM band (2,4 GHz), the second (i.e. WiMax) operates in the higher frequency band (5 GHz, microwave). Only first band this paper is focused on, due to the low cost and popularity. The ISM band (industrial, scientific, medical) is a span of frequencies in the 2,4 GHz range (precisely from 2,4 ÷ 2,4835 GHz). It is completely free (no any fees/charges are required) and unlicensed. It can be used by anyone to transmit information wireless. There is only one limitation - digital transmission has to be used on this band (no voice or analog transmission is acceptable). In fact, one of the most common problem for wireless systems in the industrial environment is primarily electromagnetic interference (EMI). It comes from electric motors, industrial processes, computers, drives, other transmitters, etc. According to the experience and known literature elaborations the EMI interference should be classified in two different categories [4]. They can be called as a broadband and narrowband. Broadband interference signals have a constant energy spectrum over all frequencies and high energy. The narrowband interference signals have less energy. Additionally, the broadband interferences are usually emitted unintentionally from radiating sources. Fig. 1 presents, as an example, the electromagnetic noise appeared on factory workshop as a frequency spectrum diagram.

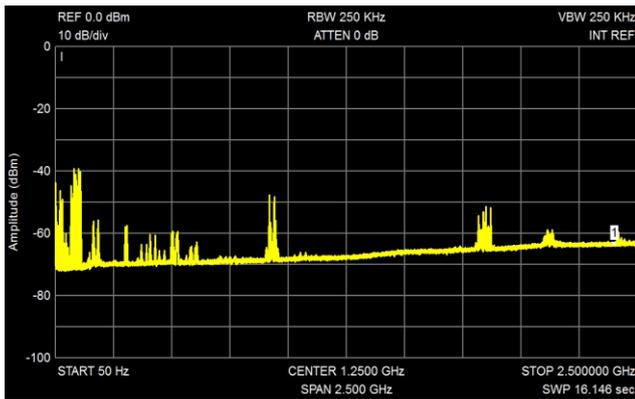


Fig. 1. The frequency spectrum of the electromagnetic noise on industrial shop floor.

As a form of electromagnetic radiation, like light waves, radio waves are affected by the phenomena of reflection, refraction, diffraction, absorption, polarization, and scattering. It should be defined several reasons of disturbing or even stop data flow over wireless networks:

- Echo – typical radio frequency (2,4 GHz) has a good penetration rate through popular construction materials like drywall, wood, plastic. But it was used to bounce off from larger objects made of metals and concrete (and it's mixture). It effects redirection the data signal and return it to the transmitter. It causes “echo” or “multi-path” propagation. Especially the multiple reflection can be expected to be high in industrial environment.
- Noise – the inelible electromagnetic emission from different sources. The transmitters and remote nodes are unable to “hear” each other. The effect is a data loss or data retransmission.
- Channel sharing – Many radio communication standards use this same frequency spectrum (for example WiFi, Bluetooth, etc.). The space is enormously crowded. Different nodes and receivers use this same radio channel frequently. The sent information is confused and need quick retransmission.
- Distance – the physical distance between transmitter and remote node is affected as signal power reducing (according to the known rules, for example WWiedeński formula). The distance could be enlarged in case of higher transmit power, receiver higher sensitivity or when the receiver/transmitter line of sight (LOS) is assured.

All mentioned disturbances can produce the dangerous delays in communication due to retransmission, re-synchronization, data loss. In the worst case it can stop transmission at all. It is not acceptable, especially for the safety reason, when critical real time data could not be delivered on requiring time (i.e. AGV movement). It should be note that due the large diversity of obstacle configuration during the signal propagation industrial environment is really not recurrent. It is practically not possible to describe

it precisely using the mathematical formulas or ready prescription. There are several complicated models were formulated and exist in research space [5]. For example: ITU-R, indoor multipath propagation, One-Slope, linear, Motleya-Keenana, Multi-Wal, Rayleigh fading, etc. The propagation models are usually simplification and the results are estimation, not precise and complete for real world. From the practically point of view this situation is not comfortable and we suppose that empirical test are really better and useful for analyzing such a complicated environment.

Radio signal path loss (RSPL) is probably the most important element in the design of any radio communications system [6]. It will determine many elements of communications system: the transmitter power, the antennas, especially their gain, height and general location. The radio path loss will also affect other elements such as the required receiver sensitivity, the form of transmission used and several other factors. It is not possible to avoid the free space signal loss. This phenomenon always occurs during the signal travels through space without any other effects (for example extra attenuating). This can be thought of as the radio communications signal spreading out as an ever increasing sphere. As the signal has to cover a wider area, conservation of energy tells that the energy in any given area will reduce as the area covered becomes larger. It is acceptable in large room like industrial hall, factory shop floor, etc. to use the Friis transmission equation. The good and popular formula for free space signal loss is:

$$RSPL(dB) = 20\log_{10}(d) + 20\log_{10}(f) + 32,44 - G_{tx} - G_{rx}$$

Where:

- d - the distance of the receiver from the transmitter (metres),
- f - the signal frequency (Hertz),
- G<sub>tx</sub> - the e gain of the transmitter antenna relative to an isotropic source (dBi),
- G<sub>rx</sub> - the gain of the receiver antenna relative to an isotropic source (dBi).

The RSSI indicator is the relative received signal strength in a wireless transmission but in arbitrary units. RSSI is an indication of the power level being received by the antenna. Therefore, the higher RSSI number means the stronger the signal. It should be note that there is no standardized relationship of any particular physical parameter to the RSSI reading. The 802.11 standard does not define any relationship between RSSI value and power level in W or dBm. From our point of view it seems to be that decibel-milliwatt unit is more useful and independent because it is referenced to real transmission power - 1 milliwatt (mW).

One of the most important parameter for radio propagation feature is SNR (signal-to-noise ratio). In fact it compares the level of a desired signal to the level of background noise [6]. It is always defined as the ratio of signal power to the noise power, usually expressed in decibels.

From the functional point of view the high throughput is a key for stable and effective transmission between mobile node (AGV) and stationary supervising computer. Throughput is a key measure of the quality of a wireless data link [7]. It is defined as the number of information bits received without error per second and we would naturally like to achieve this quantity be high as possible. The throughput of a data communications system is not a trivial and depends on a number of variables. In our research (where the video and control data are permanent transmitted as a regular stream) we decided to define the minimum, acceptable throughput as a 0,5 Mbit/s.

The radio propagation should be described by many and different terms and variables (easy or sometimes very sophisticated). During our test we decided to use three main parameters as a sufficient and precise description. There are: signal strength, noise level and effective throughput.

#### 4. INSTALLATION HARDWARE

For test purpose the special equipment was put together. The Robotino® wireless module was working as an ordinary Access point. The working channel was manually forced to 11 - due to high crowd and utilization on that frequency (Fig. 2). The dedicated network were established. It consists of only two nodes (Robotino and PC computer). All network components were put direct on the factory floor (0,5m above the ground). From the technical point of view the laboratory set consisted of: WLAN access point (standard IEEE802.2.11b/g, transmit power 20 dBm, monopole antenna with 2 dBi gain, receiver sensitivity -86 dBm) and notebook equipped with WiFi adapter (Bracom BCM94322MC, standard IEEE802.2.11b/g/n, transmit power 20 dBm, microstrip antenna with 0 dBi gain, receiver sensitivity -90 dBm).

#### 5. INSTALLATION – DIAGNOSTIC SOFTWARE

As a measurement device some sophisticated software tools were used. On the stationary computer the "Wireshark" software and expanded drivers for network interface were installed. It is a specialized data monitor and performance meter for network application. Also for general purpose, like wireless signals analysis and electromagnetic spectrum monitoring the Wi-Spy + Chanalyzer and Signal Hound USB-SA44B were used. The graphic presentation of indicated data transmission was done using the standard windows network monitor tool. The intercepted network data were analyzing using the Excell spreadsheet and presented in graphic form for useful perception and analysis.

#### 6. RESEARCH WORK

The intention of research was maximum approach to real industrial environment. The control computer was placed on the factory floor close to group of machine tools. The mobile platform Robotino® (didactic AGV platform made by Festo) was moving along the factory hall. In predefined places measurements were realized. To avoid occasionally differences in signal propagation, measurements were

several times repeated to achieve the average result which is more representative. During all research the normal production was realized (3 CNC and 7 manual machine tools). Practically there was no LOS (line of sight) between antennas (receiver and transmitter). Many different shielded components (like light walls, metal mesh fence, plastic and metal casing, etc.) disturbed the signal propagation. The active electromagnetic sources (like motors, electronic drives, control computers, etc.) also made difficult in stable communication.



Fig. 2. The WiFi channel utilization and density power transmission.

The WiFi channel utilization and density power transmission is presented on Fig. 2. It is clearly indicated that main load is located near channel 11. This is the reason we decided to establish communication on that channel which is really disadvantageous. Situation like this often occurs in reality, where transmission are realized using this same opportunity and technical possibility. The Fig.1 illuminates analyze of the electromagnetic noise (industrial shop floor) as frequency spectrum. It can be noticed that main noise is located at the first part of chart. Fortunately this is so far from the WiFi frequency but unfortunately disruption power is significant (up to -40 dBm). The inconvenient influence for stable communication is sure and remarkable.

The results of communication parameters are presented on Fig. 3. The green line shows the theoretical signal power loss (coming from Frijs equation), the solid blue line indicates the real signal strength measured during the research. The last red line is signal-to-noise ratio, also from measurement.

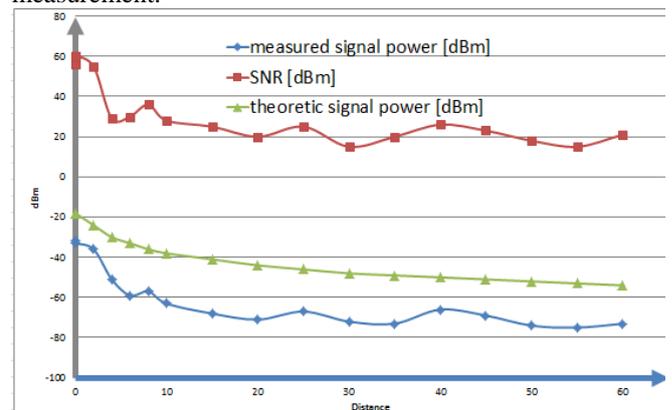


Fig. 3 The measured signals power in function of transmission distance.

The large difference between measured and theoretical signal strength is a result of existing electromagnetic noise and it's propagation which reducing the power of useful signal considerably. The Fig. 4 illuminates the measured data effective throughput in function of distance between

transmitter and receiver. The occasionally increase in throughput is observed. It is not irrational. This the evidence that “multi-path” propagation is a fact and could be useful to enlarge the communication distances.

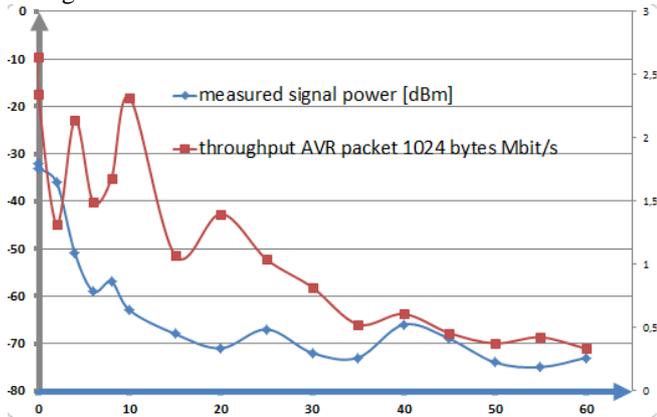


Fig. 4 The effective throughput in function of transmission distance.

## 7. CONCLUSION OF RESEARCH

As was mentioned before, the research work is in fact the first step into large problem of use the popular (cheap, easy, effective) communication standards as an industrial solution. This short and basic recognition allows us to confirm that this direction is the most positive and should be develop more precisely. According to the achieved results of realized tests and research work we can formulate the scope for next tests which should be (and will be done) done. Especially the problem of signal strength reduction in multi-diffractive environment should be analyzed and elaborated. Also the problematics of dynamic change of base station, discreet passing the connection, stability of stream during the variable velocity of mobile platform, interaction with different mobile robots, use of directional antennas, etc. have to be work out. It should be expected that role of wireless communication systems in industrial environment will be more and more significant in the nearest future. After detailed analyzing of the working installations, intelligent conclusions should be formulated. Finally, the rules, recommendations and guidelines have to be elaborated as an assistant description for user interested in introducing such a communication structure into industrial environment.

## REFERENCE:

[1] M. ANDERSSON: Wireless Technologies for Industrial Applications, <http://www.digkey.com/us/en/techzone/wireless/resources/articles/wireless-technologies-for-industrial-applications.html>, (2011)

[2] OSTROWSKI I., Wykorzystanie usług chmurowych dla sterowania robotem mobilnym na przykładzie Amazon EC2, *Elektronika - konstrukcje, technologie, zastosowania*, 2013, nr 9/2013, str. 148-152

[3] WAGNER B., et all, Location based wireless sensor services in life science automation, Proceedings of the 4th international conference on Real-world wireless sensor networks, (2010), Springer-Verlag Berlin, Heidelberg, pp. 82-93

[4] SZULEWSKI P., Functional aspects of modern wireless networks in industrial environment, *Advances in Manufacturing Science and Technology*, volume 37, No 2, 2013, pp. 79-89 (6 pkt.)

[5] HALIM A., RAZIFF A. M., Investigation of Indoor WIFI Radio Signal Propagation, IEEE Symposium on Industrial Electronics and Applications, Penang, Malaysia, 2010, pp. 117-119.

[6] BUGAJ M., WNUK M., Modelowanie rozchodzenia się fal elektromagnetycznych w warunkach idealnych i rzeczywistych, *Przegląd elektrotechniczny*, ISSN 0033-2097, R. 90 NR 7/2014, pp. 152-155

[7] LADD A., BERKIS K. E, Robotics-based location sensing using wireless Ethernet, *Wireless Networks*, Volume 11 Issue 1-2, January 2005, Kluwer Academic Publishers Hingham, MA, USA, pp. 189-204