STUDIA INFORMATICA 2008
Volume 29 Number 4B (81)

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AN IDEA OF AN EMERGENCY COMMUNICATION SYSTEM BASED ON ISM BANDS

Summary. The paper describes novel system of emergency communication based on ISM bands. Possible theoretical range of the system is estimated. Moreover background on the emergency communication is presented.

Keywords: wireless communication, emergency communication system

IDEA SYSTEMU KOMUNIKACJI KRYZYSOWEJ PRACUJĄCEGO W PASMACH ISM

Streszczenie. Artykuł opisuje nowatorski system komunikacji kryzysowej pracujący w pasmach ISM. Oszacowany jest teoretyczny zasięg systemu. Ponadto, opisane jest wprowadzenie do komunikacji kryzysowej.

Słowa kluczowe: komunikacja bezprzewodowa, system komunikacji kryzysowej

1. Introduction

Originally concept of the system has been presented in [8]. This paper recalls main idea of the system and enriches it with some more conclusions.

Most of the communication in modern society is based on simple assumption that everything will work properly: all of the communication nodes and their links. But there are – at least possible – such situations when it is not a valid assumption: during disasters (fire, flood, hurricanes), wars, etc. Computers, communication networks, cellular phones, Internet could STOP working... Do we have enough means of communications for such conditions?

The paper presents a new and prospective system of emergency communication that works in ISM bands. It is quite simple, cheap and could be implemented rather easily, without much effort. This paper presents a concept of a system rather than a complete research and the author requests discussions and proposals regarding its further development.

2. Emergency communication

Today, local and governmental entities (civil defence) administer most of the emergency and distress communication. Moreover some of the public systems are used in such situations. They can be divided into two groups: wired and wireless.

- Wired systems:
  Telephone – stations are not self-contained: wires and cables can be damaged or destroyed; central switching could go down or become overloaded;
  Fax – allows transferring much more information than in voice channels; reliability depends on the landline telephone system and electricity.
- Wireless systems:
  Cellular phones – like the landline telephone system; greater possibility of getting overloaded;
  Two-way Voice Radio – generally self-contained, reliable in adverse environmental conditions; can be used for broadcasting (not only one-to-one communication);
  Trunked Radio Systems – professional public service agencies; quick saturation of available frequency spectrum; centralised architecture;
  Packet Radio – self-contained, no need for a central node of the system; hard to transfer graphic data.

3. Amateur service

Amateur service is form of radio communication between those who obtained licence granted by local governmental offices. It is one of the oldest forms of radio communication and from its origins especially devoted to different emergency situations such as hurricanes, earthquakes and floods. Nowadays it is still a very robust and reliable means of communication. Digital modes used by amateurs are very efficient in terms of power density compared especially with voice communication. PSK31 mode occupies only 31,5 Hz of radio spectrum, when SSB voice channel has width of almost 3 kHz!

Many studies in the field of emergency communication using amateur service have been conducted, however two points should be emphasised.

First system [2] is based on amateur equipment: very low power transceivers (Yaesu FT-817, 5 W power out) with simple antennas. It allows for voice and data transmission in short-wave bands over many hundreds of kilometres. The author has shown that data modes are better than voice transmission.

Handheld and battery-powered device built by an amateur group [3] after connection with the transceiver and the keyboard, can serve as a data transmission unit utilising digital modes (BPSK31, QPSK) on the short-wave amateur bands. Along with a portable transceiver and a simple antenna it could also be recognised as a powerful emergency communication device.

There are also more solutions that could be used in almost any emergency case. Those are:

- WinLink 2000 [4] (Global Radio Email System) that allows for the global exchange of text messages over the radio interface;
- PSKmail [5], which is a narrow band mail delivery system for use by the radio amateurs via short-wave communications using PSK125 mode (bandwidth 129 Hz).

Moreover, the oldest form of communications using Morse code is always available. It requires a very simple equipment, but it requires proficiency in the Morse code operating, which seems to be rather ancient than contemporary form of communication. Bandwidth of such a transmission is less demanding than the voice transmission – typically it is assumed that CW channel is 100 Hz wide while keying with an average speed.

4. Concept of the system

4.1. Node architecture

The proposed system of an emergency communication is based on simple nodes that consist of five modules: antenna (ANT), transceiver (TRX), microcontroller (μC), keyboard (KBD) and display (LCD) as shown on Figure 1. The assumptions are that those devices have to be independent, small, simple, cheap and battery-powered due to a limited energy source during emergencies. They should be able to exchange simple text data.

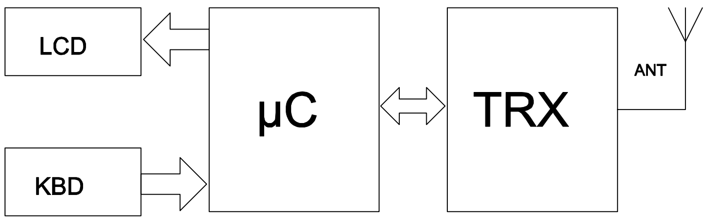

Fig. 1. Node architecture
Rys. 1. Architektura węzła

It is presumed that as a wireless system it will work in one of the ISM (Industrial, Scientific, Medical) bands because they are available without licenses. There are many ISM bands as shown on Table 1, so decision has been made to choose UHF band (433 MHz) – it has better propagation conditions than the microwave bands and it is not so crowded as 2,4 GHz band.

Table 1

ISM bands for short-range devices

Frequency range	Maximal power
433,05 – 434,79 MHz	10 mW
868,0 – 869,2 MHz	25 mW
868,7 – 869,2 MHz	500 mW
2400 – 2483,5 MHz	10 mW

4.2. System architecture

The system is composed of many nodes that are interacting between themselves, so it is a full mesh topology. A transmission can be also done through some kind of repeater allowing wider range. The architecture of a repeater is not considered at this time. Third possibility is a mixed topology, when some of the nodes exchange data directly, and some of them exchange data with the repeater participation.

4.3. Networking issues

There are many networking issues while designing such a system. The problem of band determination is solved above, while others are to be addressed now.

- In physical layer it must be determined which modulation should the system use.
- In data link layer method of media access control have to be chosen.
- In network layer routing algorithms must be determined.
- In transport layer algorithms of a possible transmission error correction are to be decided.
- In higher layers message’s format has to be determined.

Possible solutions heavily depend on the selection of the prefabricated modules. While the μC module is rather universal, the radio module (TRX) has most influence on the decisions that are made.

There are many competing radio chips on the market developed by the leading vendors such as Texas Instruments and Analog Devices.

- Texas Instruments’ chips belonging to CC 11xx family use FSK, GFSK, MSK and OOK modulation techniques. They are able to work with a maximum data rate up to 500 kbps.

The maximal receiver sensitivity is –110 dBm, the maximal transmitter output power is 10 dBm. The declared current consumption is less than 20 mA.

- Analog Devices' chips representing ADF702x family can use ASK (ADF7020), FSK, and FSK's variants as the modulation techniques. Maximum data rate varies from 25 kbps (ADF7021) to 384 kbps (ADF7025). The level of maximal transmitter output power is 13 dBm, while the best receiver sensitivity has values between –117 dBm and –123 dBm. Current consumption is less than 30 mA (ADF7020: 19 mA, ADF7021: 28 mA, ADF7025: 27 mA).

As single chips are not easy to use, some companies deliver ready to use radio modules. One of the most prospective for aforementioned emergency communication systems is a family of radio modules fabricated by Hope Microelectronics [7]. HM-TR transparent wireless data link module (see Fig 2, (source: [7])) provides communication protocol that is self controlled and completely transparent to the user interface. HM-TR is based on the FSK modulation and works in a half duplex mode. Data rate, operation frequency (four ranges), transmitter frequency deviation and receiver's bandwidth are configurable. It is delivered with a standard UART interface, TTL or RS232 logic level selectable. It is very reliable and small (24x43 mm). The typical transmission power in 433 MHz ISM band is declared as 8 dBm, while the receiving sensitivity –109 dBm. Current consumption should be no more than 48 mA while transmitting and 34 mA in receive state. The maximum data rate of its UART port is 19200 bps.

Utilising such modules frees designer from all of the above issues. However it is no longer possible to keep an eye on all of the important objectives because those modules do not allow too much possibility of modifying and adjusting. It is very important to decide whether using ready modules is better than developing own transceivers. FSK modulation is broadband and mentioned chips and modules allow for quite high data rate, which is not necessarily important in an emergency communication system. On the other hand PSK techniques used by radio amateurs are very narrow band but they cannot provide error correction. When comparing standard FM channel (12,5 kHz) and the one used by PSK31 (31,5 Hz) signal bandwidth it is obvious that for the emergency system, when the power management is critical the latter is much better in terms of power density.

Further research will be conducted in two paths: one of them will confirm if factory-ready modules are suitable for developing such a system, second will prove the possibility of developing a cheap radio module based on the PSK digital modes used by radio amateurs.

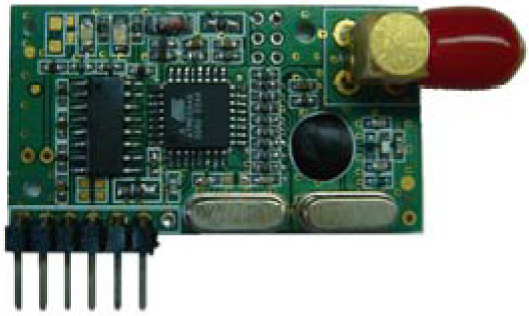

Fig. 2. HM-TR transparent wireless data link module
Rys. 2. Moduł do przezroczystej bezprzewodowej transmisji danych HM-TR

4.4. Range estimation

This subchapter consists of possible, theoretical range estimation. The range is computed for two environments – free space and urbanised environment. For simplicity thermal noise is not considered. From the Friis transmission equation [6] (Equation 1) we can derive possible usable range of the proposed system.

$$\frac{P_r}{P_t} = G_t G_r \left(\frac{\lambda}{4R\pi} \right)^2 \tag{1}$$

where:

P_r is power received by the receiving antenna,

P_t is power input to the transmitting antenna,

G_t and G_r are the antenna gain of the transmitting and receiving antennas,

λ is the wavelength,

R is the distance.

More general formula (Equation 2) incorporates path loss exponent n, which describes the influence of the transmission medium between the transmitter and the receiver.

$$\frac{P_r}{P_t} = G_t G_r \left(\frac{\lambda}{4\pi} \right)^2 \left(\frac{1}{R} \right)^n \tag{2}$$

In free space $n = 2$. Medium that attenuates radio signal is indicated with $n > 2$.

The path loss is the ratio of the powers between the transmitter and receiver antennas expressed in logarithmic units. Assuming gain of the antennas equal to 0 dBi:

$$PL(R) = 20\log\left(\frac{4\pi}{\lambda} \right) + 10n\log(R) \tag{3}$$

4.4.1. Estimation of path loss in free space

For given:

$f = 433{,}92$ MHz – centre frequency of ISM 433 MHz band ($\lambda \cong 0{,}69$ m),

$n = 2$ (free space),

the path loss over R distance is summarised in Table 2.

Table 2

Path loss in free space

R [m]	**PL(R) [dB]**
5	-39,17
10	-45,19
20	-51,21
50	-59,17
100	-65,19
150	-68,71
200	-71,21
250	-73,15
300	-74,73

4.4.2. Estimation of path loss in urbanised environment

For given:

$f = 433{,}92$ MHz – centre frequency of ISM 433 MHz band ($\lambda \cong 0{,}69$ m),

$n = 4$ (specific for office buildings),

the path loss over R distance is summarised in Table 3.

Table 3

Path loss in urbanised environment

R [m]	**PL(R) [dB]**
5	-53,15
10	-65,19
20	-77,23
50	-93,15
100	-105,19
150	-112,23
200	-117,23
250	-121,11
300	-124,28

4.4.3. Conclusions on possible range

Assuming transceiver parameters 8 dBm as output power and –109 dBm as receiver sensitivity and necessary signal-to-noise ratio 20 dB, the path loss between nodes has to be less than 97 dB. It means that such nodes should work without any problems in idealised conditions (free space) even over long distances, but in real scenarios the range will be rather limited. Mentioned results show that usable range will be between 50 and 100 metres in urbanised environment.

5. Final conclusions and future works

Presented system is still under construction. Theoretical discussions prove its engineering success. Further research will confirm whether utilisation of prefabricated radio modules is efficient when using quite wide FSK channel. It will be compared with developed radio module that will work with PSK digital mode. If the latter is going to be a better choice then issues presented in subchapter 3.3. (data link and higher layers) have to be resolved.

It is also necessary to answer the question if text communication is sufficient in emergency cases. Maybe such systems should provide multimedia communication?

Another problem could arise after its deployment – possible saturation of available radio spectrum when using FSK modulation and high density of the devices.

Last and most important question: is the system REALLY necessary for an ordinary man? Maybe more efforts should be directed toward efficient systems designed for qualified staff rather than for consumer market?

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Recenzent: Dr inż. Wojciech Mielczarek

Wpłynęło do Redakcji 25 września 2008 r.

Omówienie

Artykuł opisuje nowatorski system komunikacji kryzysowej pracujący w pasmach ISM. Na wstępie omówione jest wprowadzenie do komunikacji kryzysowej. Następnie przedstawiona została proponowana architektura węzła systemu (rys. 1) wraz z potencjalnymi problemami, które mogą być konieczne do rozwiązania. Zaprezentowano istniejące rozwiązania pozwalające ułatwić budowę systemu. Oszacowany jest także teoretyczny zasięg systemu dla otwartej przestrzeni (tabela 2) oraz obszarów zurbanizowanych (tabela 3).

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