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Krystyna Maria Noga*, Ryszard Studański*

EXPERIMENTAL INVESTIGATIONS TO DETERMINE THE IMPULSE RESPONSE OF A RADIO-COMMUNICATION CHANNEL

ABSTRACT

This article presents a method for determining the impulse response of a radio-communication channel using a signal modulated with a pseudorandom signal. It includes examples of impulse responses determined for real propagation conditions in the ISM band (Industrial Scientific Medical).

Key words:
radio-communication channel, impulse response of radio-communication channel.

INTRODUCTION

Present day digital radio-communication systems should optimally use the assigned band, ensuring high speed and quality of transmission. Propagation of radio signals, especially in an urban and mountainous environment is characterized by multi multipath, which is the cause of frequency selective flat fading. There is a tendency to use multi-band systems whose occupied transmission band is many times larger than could be expected from the used transmission speed. Use of wideband systems can protect against fading. If the band is larger than the coherence band the probability of signal fading across the whole band is very little. Coherence B_c can be evaluated when the impulse response of the radio-communication channel is known, as channel memory time reciprocity T_c. Memory time T_c is determined as the difference between the time for signal arrival along the shortest and the longest

* Gdynia Maritime University, Faculty of Marine Electrical Engineering, Morska 81-87 Str., 81-225 Gdynia, Poland; e-mail: rstudanski@wp.pl; jagat@am.gdynia.pl

paths, and the intensity level of analyzed signals should not be lower than 1/e in relations to the signal of the highest intensity [5], [6].

THE METHOD USED TO DETERMINE AN IMPULSE RESPONSE

The aim of the investigations was to determine a radio-communication channel response to an input which was constituted by a signal with BPSK modulation. A signal of carrier frequency 2440 MHz was modulated at speed f_{symb} = 25 M symbol/s by means of a 511 bit long linear sequence. The output signal was filtrated by means of a raised cosine filter with roll-off factor 0.35. The output signal intensity was 10 mW. The block diagram of the measuring station is presented in figure 1.

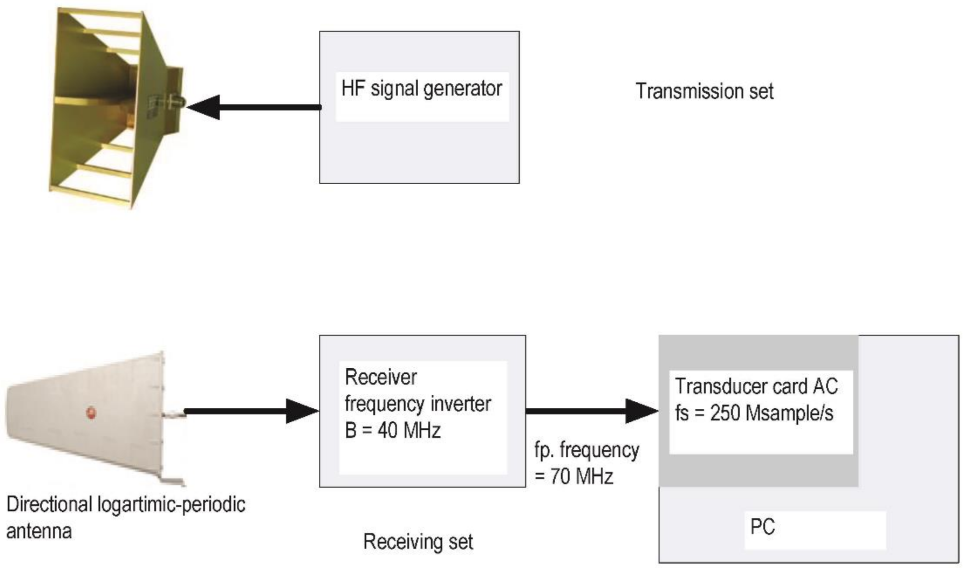

Fig. 1. The block diagram of the measuring station

The transmission part of the station was composed of a vector signal generator, which was the source of the signal transmitting an assigned binary sequence. SAS 571 tube antenna having a working band in the range 700 MHz — 18 000 MHz, energy gain 9 dBi for frequency 2400 MHz, and main beam width 48 for vertical polarization and 30° for horizontal polarization was the signal radiator. The receiving part was composed of antenna LPDA-A0075 having the working band in the range 800 MHz — 2500 MHz, and energy gain 7 dBi and main beam width 60° for the vertical polarization and 70° for the horizontal polarization. The receiver ensured reception of signals in the band having the width 40 MHz and conversion of the signal into intermediary frequency 70 MHz. A 14b bit analogue-digital transducer was used for signal acquisition.

At the beginning of the investigations the transmission signal was recorded directly from the generator, using a cable, and the modulated signal was transmitted to the receiver. After the signal changed to frequency 70 MHz, it was sampled at a frequency of f_S = 250 MHz. The digital signal prepared this way, having 5110 samples, was used as the model signal. Autocorrelation of this sequence, after filtering the high frequency components resulting from high carrier frequency (70 MHz), is presented in figure 2. The duration time of the 'correlation impulse' is 80*ns*s, i.e. twice as much as the duration time of the symbol and complies with the dependence

$$t_{impkor} = \frac{2}{f_{symb}} = \frac{2}{25 \cdot 10^6\, Hz} = 80 ns \,. \qquad (1)$$

The obtained autocorrelation factor values do not form a traingle as the signal finally adopted for the investigations was not a zero-one sequence of the maximum length, but only a high frequency signal modulated by means of a pseudorandom sequence and ultimately shaped by a bandpass filter.

In the next stage of the investigations signals were emitted in a natural propagation environment and signals reaching the antenna were recorded. The transmitted signals were modulated by means of the sequence adopted for the investigations. The received signal was not visible as a waveform recorded in time. Also in the spectrum analysis of the recorded signal the frequency interval of increased spectral density intensity. This results from the fact that the signal intensity at the reception point was lower than the noise intensity.

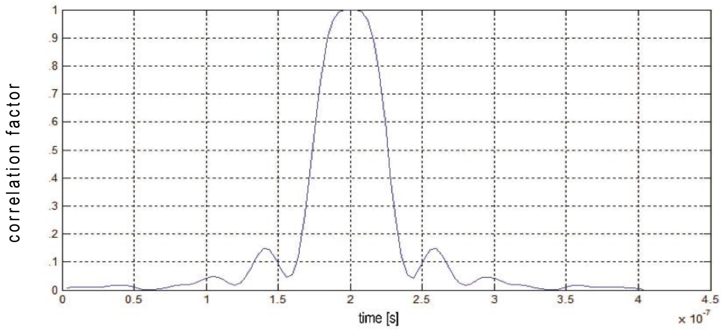

Fig. 2. Normalised function of model signal autocorrelation

In order to determine the radio communication channel response the mutual correlation was determined between the model signal and the received signals. Delays of the signals received from the particular propagation paths were determined on the basis of the interval between the first and successive maximum values of the correlation function. Obviously the concentration of the maximum values of the correlation function reoccurs each duration time of the dispersion sequence, i.e. every 5110 samples. The relations among the maximum values of the mutual correlation function determine the relations of intensity of the signals received by the antenna from various propagation paths.

The correlation function presented in the article were normalised according to the highest values of the determined correlation factor in relations to the duration time of measurement.

EXAMPLES OF DETERMING AN IMPULSE RESPONSE IN REAL CONDITIONS

Using the experience from the studies conducted in a real environment presented in publications [1], [2–4], [7] investigations were carried out for various antenna positions. The main aim of the measurements was to determine the delay times between the received signals of various propagation paths.

In the first case the receiving and transmitting antennas, were directed at a group of detached buildings. The wide arrows in figure 3 indicate the locations and directions of the antennas.

Both antennas were at the height of the roofs of the above buildings. An example of the response received is presented in figure 4. The first maximum value of the mutual correlation function between the model signal and a received signal is triggered by a signal received directly from the transmitting antenna located 7.5 m away. This low maximum value is the result of the fact that both antennas were located parallel in relation to each other, and additionally they were screened by an upward extension wall. Successive maximum values come from signals reflected from terrain obstacles marked in figure 3 with numbers corresponding to the numbering of maximum values in figure 4. The delays and lengths of the propagation paths are presented in table 1.

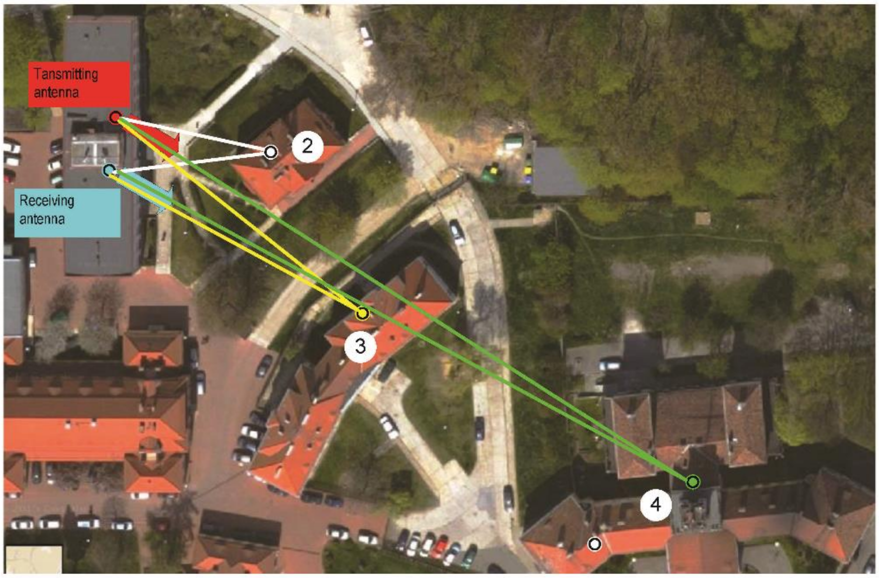

Fig. 3. The indicative propagation paths when a signal is transmitted in the direction of the group of detached buildings

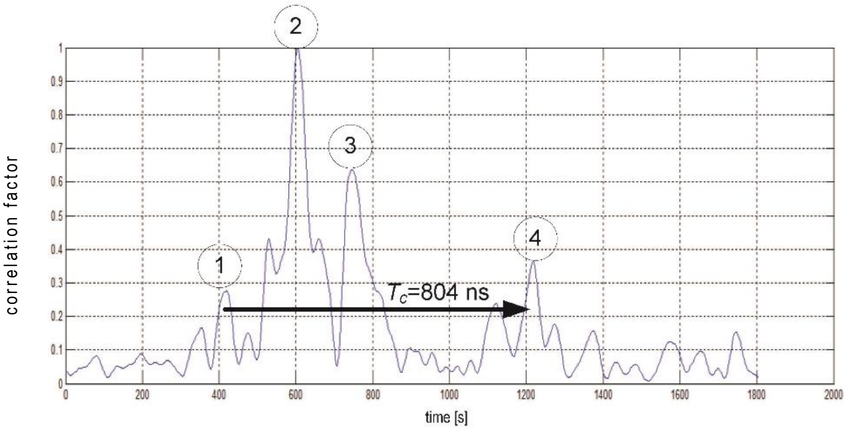

Fig. 4. An example of the mutual correlation function between the model signal and a signal recorded for the location of antennas shown in figure 3

Table 1. Calculation of delays

No. for maximum value	Delay in relation to the maximum value No. 1 [ns]	Calculated distance [m]	Distance corrected by 7.5 [m]	Distance: transmitting antenna--terrain obstacle-receiving antenna based on Google [m]
2	196	58.6	66.1	64
3	328	98.3	105.8	110
4	800	239.8	248.3	250

It should be remembered that the real propagation paths are in this case 7.5 m longer than those calculated directly from the difference between the first and successive maximum values. The calculated distances were compared with the distances determined by means the Internet site — Google Maps. And figure 5 presents the successively determined mutual correlation functions between the model signal and a recorded signal in time equal to 1 s. Small changes are noticed in the value of the correlation factor, which is a result of slowly variable fluctuations of the received signals. The results presented in figures 4 and 5 can be used to determine the coherence band B_c and it is equal almost to 1250 MHz.

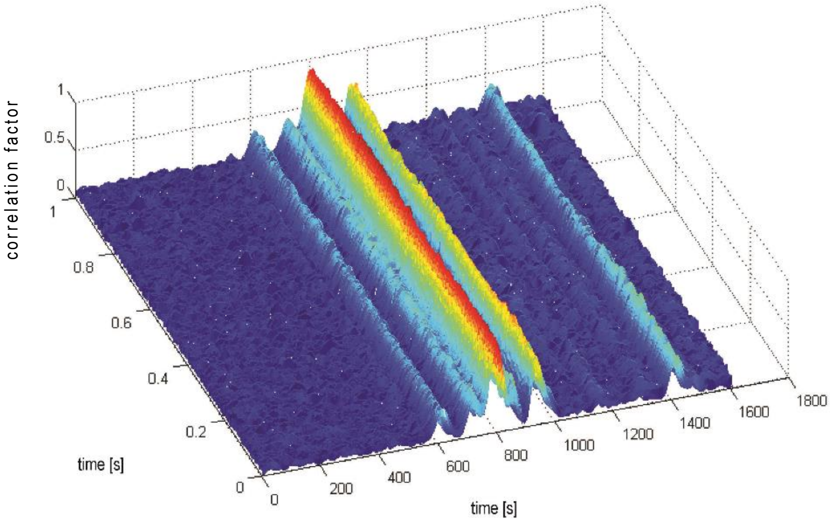

Fig. 5. The mutual correlation function between the model signal and a reflected signal for the location of antennas shown in figure 3

In the next investigation the transmitting antenna was placed away from the receiving antenna at such a distance that reception of the direct signal was impossible. The antennas were screened by high buildings. Therefore all the received signals are the signals reflected from terrain obstacles. The transmitting antenna was placed at a height of 1.5 m above the ground surface. The location of antennas is presented in figure 6.

The received impulse response is presented in figure 7. It can be seen that despite many possible reflections from the buildings surrounding the yard it is practically two signals that have significant meaning. Yet, it is not possible to indicate the paths for signal arrival at the receiving antenna as a single track was used in the acquisition process.

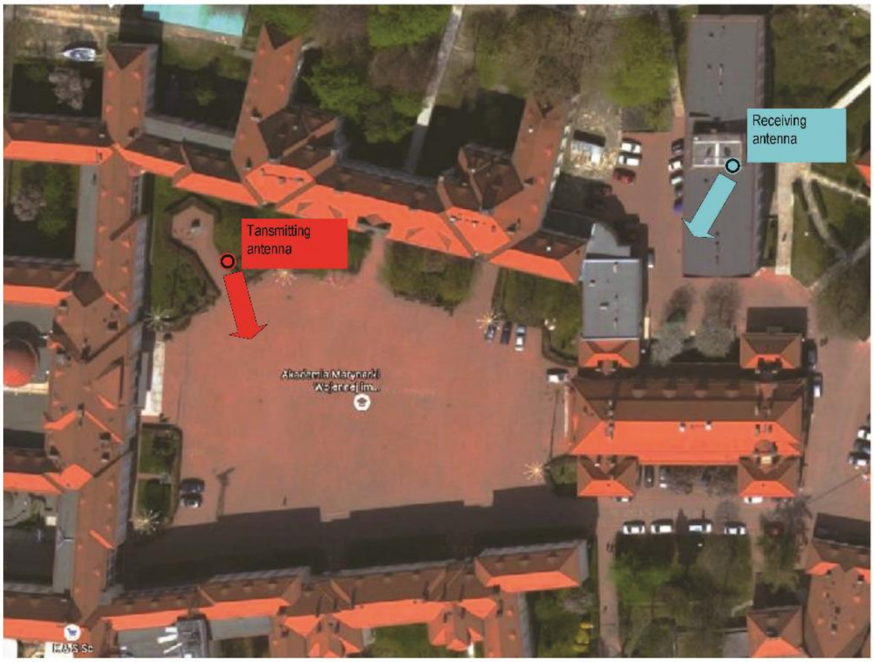

Fig. 6. The location of the antennas;
transmitting and receiving, absence of direct reception

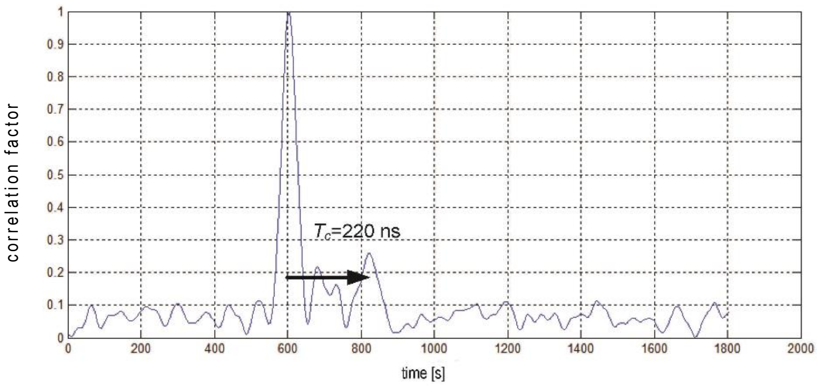

Fig. 7. An example of the mutual correlation function between the model signal
and a signal recorded for the location of antennas shown in figure 6

Figure 8 shows the successively determined impulse responses within the interval of 1 second. The obtained results can be used to determine channel memory time T_c as 220 ns. Thus the coherence band B_c is more than 4.5 MHz.

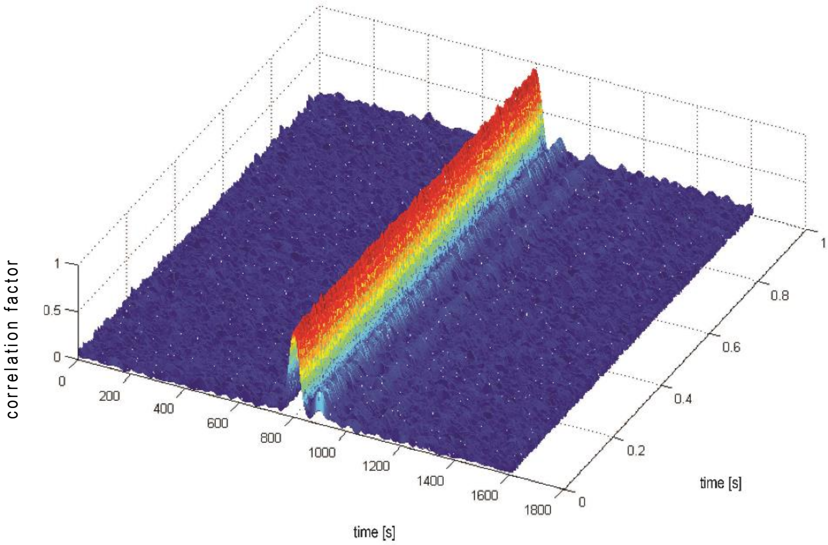

Fig. 8. The function of mutual correlation between the model signal and a reflected signal for the location of antennas shown in figure 6

CONCLUSIONS

The method presented in this article for determining the number of significant propagation paths and the coherence band is more and more often used for determining the impulse response of a telecommunication channel. In order for a measurement to be sufficiently precise, signals of possibly high modulation speed should be used. The BPSK modulation speed used in the investigations was the terminal speed for the signal generator employed. The required band width received over 25 MHz is also the magnitude exceeding the parameters featured by many laboratory receivers. The measuring set used had one receiving track and for this reason it was not possible to indicate the direction from which the signal arrived. In the nearest future the investigation set is intended to be improved so that its functionality will be enhanced by a capability to determine the signal arrival direction for particular observed maximum values.

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WYZNACZANIE ODPOWIEDZI IMPULSOWEJ KANAŁU RADIOKOMUNIKACYJNEGO — BADANIA EKSPERYMENTALNE

STRESZCZENIE

W artykule przedstawiono metodę określania odpowiedzi impulsowej kanału radiokomunikacyjnego za pomocą sygnału zmodulowanego ciągiem pseudoprzypadkowym. Zaprezentowano przykłady odpowiedzi impulsowych wyznaczonych dla rzeczywistych warunków propagacyjnych w paśmie ISM (Industrial Scientific Medical).

Słowa kluczowe:
kanał radiokomunikacyjny, odpowiedź impulsowa kanału radiokomunikacyjnego.