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A METHOD OF DETERMINATION OF RADIO COMMUNICATION CHANNEL RESPONSE

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A method of determination of a radio communication channel response is presented. The impulse response was determined with calculation of the cross-correlation between sent and received signals. As an input signal was used the high-frequency signal modulated with a pseudorandom sequence. Some results of experiments obtained in a real propagation environment are included.

Keywords: Radio channel, Impulse response, Multipath propagation.

Introduction

Knowledge of a radio communications channel transfer function is essential in ensuring the correct reception of digital broadcasts. Classic determination of the channel impulse response using signals similar to the Dirac delta is extremely difficult. Therefore, there are noticed frequent cases of abandonment of determining the impulse response using high voltage EMD pulses because of the need to conduct separate studies on the methodology of measurements. For example, in the work is proposed to find properties of the radio channel in time and frequency domains by tests with using a vector network analyzer.

The measurement of the propagation channel impulse response plays a very important role both in improving and developing new radio communication systems. Properties of the transmission channel are dependent phenomena occurring in it and among them the presence of multipath propagation, caused primarily a reflection, deflection and dispersion of radio waves [1, 2]. This propagation also depends on the terrain, the volatility of the formation, land development. Above factors make the channel characteristics are not stationary. As a result of these phenomena, any signal from the transmitter reach the receiver in the form of several components of different and time-varying attenuation and delay.

The paper presents some results of experiments conducted in a real propagation environment.

Parameters of Radio Communication Channel

A signal transmitted by the radio communication channel can be represented using formula [4]:

$$s(t) = a(t)\exp\{j[2\pi f_0 t + \varphi(t)]\} = \tilde{a}(t)\exp(j2\pi f_0 t) \tag{1}$$

where:

$a(t)$ – an amplitude of the signal,
$\phi(t)$ – a phase of the signal,
f_0 – carrier frequency,
$\tilde{a}(t) = a(t)\exp[j\varphi(t)]$ - complex amplitude.

For the multipath propagation the signal received is determined by [2]:

$$y(t) = \sum_n \beta_n(t)\, s[t - \tau_n(t)] = \sum_n \beta_n(t)\exp\{j2\pi f_0[t - \tau_n(t)]\}\,\tilde{a}[t - \tau_n(t)] \tag{2}$$

where:

$\beta_n(t)$ – attenuation coefficient of the n^{th} propagation path,
$\tau_n(t)$ – propagation delay of the n^{th} path.

An important parameter describing the channel is so called channel coherence band B_c. The band is defined as the frequency range in which the input signals, distant in frequency axis by less than B_c, are correlated to the output of the channel amplitude and phase responses. It can be written as [3]:

$$B_c \approx \frac{1}{T_m} \tag{3}$$

where T_m is a time channel memory, i.e. measure of the dispersion of delay in which subsequent copies of a sent signal are received due to the multipath propagation.

The parameter is defined as the time after which the correlation function decreases, depending on the definition, to $\varepsilon = 1/e$ or $1/10$ of its maximum value [6]. It is also often called as the correlation time and approximately describes the duration of the channel impulse response for RF excitation pulse with a very small duration.

The next parameter characterizing the radio communication channel is a coherence time T_d defined as the time at which the channel impulse response are correlated [4]. It is connected with the Doppler effect and approximately depends on the inverse of the maximum Doppler frequency f_{Dmax}, i.e. [3]:

$$T_d \approx \frac{1}{2\, f_{D\max}} = \frac{\lambda}{2 \cdot v} \tag{4}$$

where:

λ – a wavelength,
v – a speed of the mobile station

Description of Measurement Method

A main goal of investigations was to determine the response radio communication channel for input being the BPSK-modulated signal. The signal of 2440 MHz carrier frequency was modulated a linear sequence of length 511 bits at a rate of $f_{symb} = 25$ Msymbols/s. A power of the output signal was 10 mW and it was filtered by the root raised cosine filter with a roll-off factor 0.35. A block diagram of the test stand is shown in Figure 1.

A broadcasting part of the stand was a vector signal generator being a source transmitting the reference binary sequence. The 571 SAS horn antenna having: an operating band from 700 MHz to 18000

MHz, a power gain 9 dBi for 2400 MHz frequency, a main beam width equal to 48° for the vertical polarization and 30° for the horizontal one was used as a radiant signal. As a receiving part the LPDA-A0075 antenna having: an operating band from 800 MHz to 2500 MHz, a power gain 7 dBi, a main beam width equal to 60° for the vertical and 70° for the horizontal polarization was applied. The receiver provided reception of signals with bandwidth of 40 MHz and conversion of the signal to an intermediate frequency of 70 MHz. An acquisition of signals was performed using a 14-bit AD converter [5].

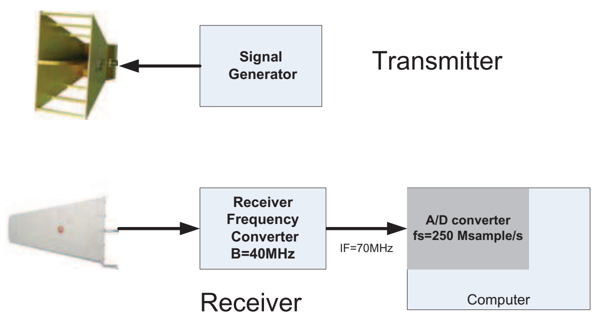

Figure 1. Block diagram of test stand

Firstly, the modulated signal was sent, via a cable, from the generator to the receiver and registered. After conversion of the frequency of 70 MHz it was sampled at a frequency f_s =250 MHz. A such prepared digital signal having the number of 5110 samples was used as the reference signal. Its autocorrelation function, after filtering of high-frequency components connected with the carrier frequency (70 MHz), is shown in Figure 2. A time duration of "pulse correlation" is 80 ns, i.e. a double value of the symbol duration, and is consistent with the relationship:

$$t_{impkor} = \frac{2}{f_{symb}} = \frac{2}{25 \cdot 10^6 \, Hz} = 80ns \qquad (5)$$

In the next step of investigations, signals were transmitted in a real propagation environment and reaching the receiving antenna were recorded. Broadcast signals were modulated with the sequence adopted to tests. The received signal was not seen as a course in time. Also, in a spectral analysis of the recorded signal was not observed increased a frequency range with an increased power spectral density. This is due to the fact that the signal power at the receiving point was less than the noise power.

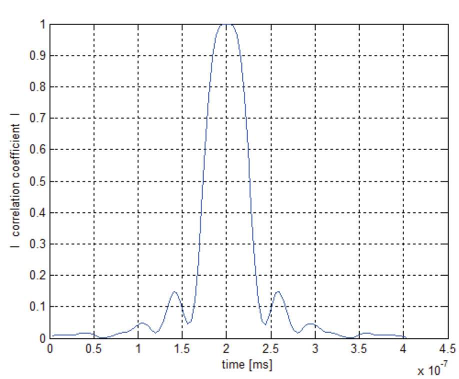

Figure 2. Autocorrelation function of reference signal

In order to state the radio communication channel response determined a cross-correlation between the reference signal and the signals received. Time delay of the signals received from the respective propagation paths determined based on a distance between the first and the next peaks of the correlation function. Naturally, concentration of these maxima cross-correlation function is repeating every dissipative sequence duration, i.e. 5110 samples. Relations between the values of cross-correlation function maxima define the relationship of power signals received by the antenna from different propagation paths.

Results of Experimental Study

The transmitting and receiving antennas were directed at a perpendicular flat wall of a large building situated at a distance of approximately 37 m from the transmitting antenna (Fig. 4 and 5). Towards this wall the measuring signal was transmitted. The registration of the received signal were carried out in sessions lasting about 2 seconds.

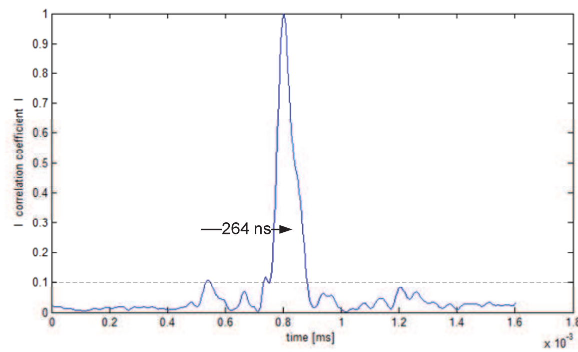

Figure 3. Cross-correlation function between reference and registered signals

As mentioned, the cross-correlation function was determined with the reference signal. Analysis of the maximum value of the correlation coefficient, shown in Figure 3, allows to compare the time delay between the maxima of the correlation function and distances of transmitting and receiving antennas from field obstacles.

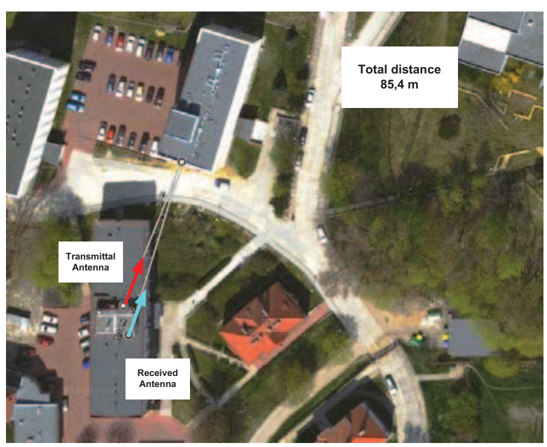

Figure 4. Approximate determination of second path of signal propagation from transmitting to receiving antenna

The first maximum was an effect of reception of the signal directly from the transmitting antenna. A low value of the correlation coefficient, even though the distance between the antennas was 7.5 m, resulted from the facts that the transmitted signal came from a mirror lobe and the transmitting antenna was hidden behind the wall of the building. A largest maximum of the correlation function was caused by a signal reflected from the wall distant from the transmitting antenna of approximately 37 m.

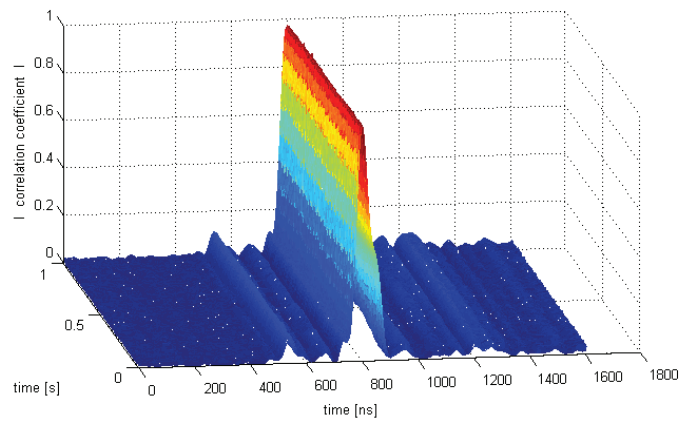

Figure 5. Cross-correlation function between reference and reflected signals

This maximum was delayed relative to the first about 264 ns, which correspond to a length of path signal equal to 79.1m. Taking into account the distance between the transmitting and receiving antennas, (equal to 7.5 m), a real distance from the transmitting antenna to the field obstacle and the receiving antenna is longer about 7.5 m. This distance was initially estimated as 85.4 m using the website Google Maps [7] (see Fig. 4).

Figure 5 shows the correlation function between the reference and reflected signals recorded at the time of 1 s. In this case, due to slow fluctuations of the received signals, observed changes of the correlation coefficient are very small. Obtained results indicate that the time channel memory T_m is equal to 1.12 μs, therefore the coherence band B_c in conditions of the scenario 1 is almost 890 kHz.

Conclusions

The presented method for specifying the number of the essential propagation paths and determining the coherence band is a measurement technique easy to practical implementation.

However, it requires high-quality research equipment and using signals of possible high speed modulation to assure the measurement will be sufficiently precise. Used in the experimental study BPSK modulation speed was a limit speed for the signal generator. Also, a required width of the received band being above 25 MHz is for many laboratory receivers a quantity exceeding their parameters. Applied measurement set had only one receive path and therefore it was not possible to determine the direction of signal arrival.

Therefore, further investigations are needed to determine the direction of arrival of the signal for the individual observed maxima, and making tests for the transmitting antenna in motion.

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