PULSE RESPONSE MEASUREMENT AND PROCESSING BY SIX-PORT REFLECTOMETER

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Summary In this paper the pulse response estimation of radio channel by Six-port reflectometer (SPR) is described. The measurement of pulse response is in real time, with baseband conversion and without demodulation. This system is simple, small, exact and inexpensive. In the present, it is insisted on signal processing in real time. In present time it is requested to use faster systems of signal processing, so the using of high performance digital devices is needed. Pulse response of radio channel, six-port reflectometer and radio channel are simulated in program language Delphi 7. In this work the pulse response measurement of MIMO radio channel by Six-port reflectometer technique. A pulse response matrix, Rayleigh fading in the radio channel, SPR technology, AWGN radio channel has been simulated in program language Delphi 7.

1. INTRODUCTION

A six-port reflectometers technology (SPR) enters a progress lately, promising its mass application in the field up to now unexpected – software defined radio (SDR) and mobile multimedia networks. SPR can be applied as a broadband input equipment of receivers, performing direct baseband conversion (Direct Conversion Receiver, DCR) without demodulation. Thanks to real time signal processing, the low bit error rate, broadbandness, extremely high-frequency band applying, simplicity and possibility of monolithic integration, the six-port reflectometers technology found its application also in the field of telecommunications.

The exact phase shift is not necessary for the quadrature modulated signals. The application is mainly in the field of wireless local area networks WLAN. Among the other perspective applications we can name antennas with the electronic controlled radiation pattern (smart antennas) and systems for the direction of arrival estimating. In the principle, those antennas consist of antenna elements, SPRs and a local oscillator, which is connected to the first input of each SPR. The SPR measures the relative phase between the received signal and signal from the local oscillator.

2. SIX-PORT REFLECTOMETER PRINCIPLE

Six-port method is the method of vector experimental circuit analysis, i.e. the scattering parameters measurement method (transmission and reflection coefficients), as well as complex (vector) parameters measurement. The vector measurement methods of scattering parameters may be divided into two groups:

- Wave separation method.
- Interference method.

All actual heterodyne analyzers belong to the first group. The SPR belong to the second group. In the wave separation method one of the measured circuit ports is excited by the wave with harmonic time response (stimulus) and the responses at outputs of all ports are extracted (including the wave reflected from excited port). To separate the reflected wave, the directional coupler is needed. The scattering parameters will be created as the ratio between complex responses amplitudes and the excited wave. So, the ratio of complex amplitudes and a phase differences it is needed to measure on a microwave frequency.

The response of the stimulus is not separated at the interference method, on the contrary, a several linear combination (LK) of stimulus is created in a measuring equipment, to measure only final amplitude, not phases. From amplitude information it is possible to get the size and the phase of the scattering parameters. To obtain one parameter we need at minimum three LKs. An optimum number is four and the stimulus dominates in one of them. We call this LK as a reference signal.

LKs may be created and monitored at various ports of the measurement system at the same time, or step by step on one port (multistage systems). The first mode is characteristic for the SPR. The other mode is a measuring line, where the input wave and reflected one from measured object are mixed together along the line, so a standing wave is created. The amplitude of the standing wave is measured by probe sliding along the line [1].

3. RECEIVER OF SIX-PORT REFLECTOMETER

The linear six-port is a basis of the SPR (Fig. 1), whose one port is connected to the local oscillator (LO), RF signal from an antenna is supplying to other port and other ports are connected to power detectors (D_1 to D_4). The SPR electric state is characterized by 12 complex wave variables a_i, b_i, i = 1...6, which represent ports' input and output waves. The parameters are not independent; they are connected together by six-port scattering parameters S_j that is by six equations:

$$b_j = S_{j1}a_1 + S_{j2}a_2 + S_{j3}a_3 + S_{j4}a_4 + S_{j5}a_5 + S_{j6}a_6 \qquad j = 1..6 \quad (1)$$

Because four ports are terminated with defined impedances (detectors), additional four constraints emerge:

$$a_i = \Gamma_{Di} b_i \qquad i = 1..4 \qquad (2)$$

where Γ_{Di} is detector reflection coefficient.

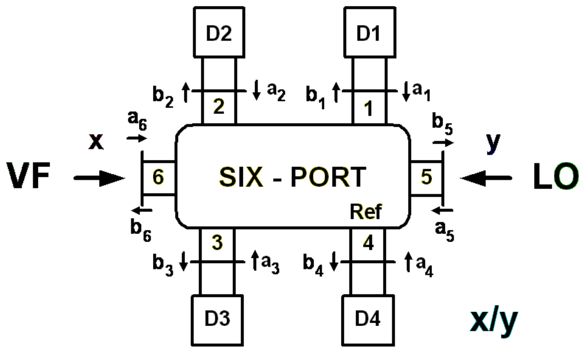

Fig. 1. Principle of the SPR [1]

We can write wave impinging to the detector:

$$b_i = A_i a + B_i b = bA_i\left(\frac{a}{b} + \frac{B_i}{A_i}\right) = \mathrm{b}A_i(\Gamma - q_i) \qquad i = 1..4 \quad (3)$$

where A_i , B_i are complex parameters and q_i are q-points of reflectometer.

The receiving principle results from equation (3). The received RF signal $x \equiv a_6$ enters the port 6 and signal $y \equiv a_5$ is generated by local oscillator. Both signals are independent. A complex ratio of input signal phasor and local oscillator signal phasor is result of reception.

The input signal: $x(t) = X_0 M(t)\exp(j\psi_0)\exp(j\omega_0 t)$ (4)

The signal from local oscillator: $y(t) = Y_0 \exp(j\omega_0 t)$

The final signal:

$$v(t) = x(t)/y(t) = (X_0/Y_0)\exp(j\psi_0)M(t) = \alpha M(t) \qquad (5)$$

where M(t) = I(t) + jQ(t) is a modulation signal in the baseband. The signal which is directly proportional to modulation signal is processing result. The receiver is tuned by local oscillator, i.e. the frequency of the received signal is equivalent to the frequency of the local oscillator [1].

4. MIMO RADIO CHANNEL

Where MIMO is know multiple-input multiple-output, SIMO is know single input multiple output and MISO is multiple input single output (Fig.2). For example, multiple-input multiple-output have the more elements of the receiver and transceiver antenna. The systems MIMO, SIMO, MISO belong to smart antenna systems.

Fig. 2. The principle of MIMO channel

5. MIMO CHANNEL SOUNDING

The principle of the MIMO channel sounding is shown in the figure 3. A sequence is broadcast from the first antenna of transceiver and the replica of this sequence is received by all the antennas of the receiver and processed in the SPR. Then, this sequence is broadcast from the second antenna of transceiver and the replica of this sequence is received by all the antennas of the receiver again and processed in the SPR.

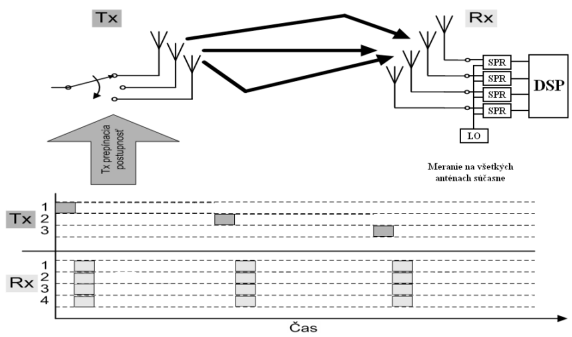

Fig. 3. The principle of MIMO channel sounding

This process is repeated as many as is number antennas of the receiver. A result of this process is a time-space matrix (Fig.4) of the pulse response of the MIMO radio channel [3].

$$\mathrm{H} = \begin{vmatrix} h_{11} & h_{12} & \Lambda & h_{1N} \\ h_{21} & h_{22} & \Lambda & h_{2N} \\ \mathrm{M} & \mathrm{M} & \Lambda & \mathrm{M} \\ h_{M1} & h_{M2} & \Lambda & h_{MN} \end{vmatrix}$$

Fig. 4. The Mathematic matrix of the pulse response in the MIMO system

Where *M* is the number of antennas of the transceiver and *N* is the number of antennas of the receiver.

For better understanding, the mathematic matrix of the pulse response is shown as the graphical matrix of the pulse response in the figure 5.

H =

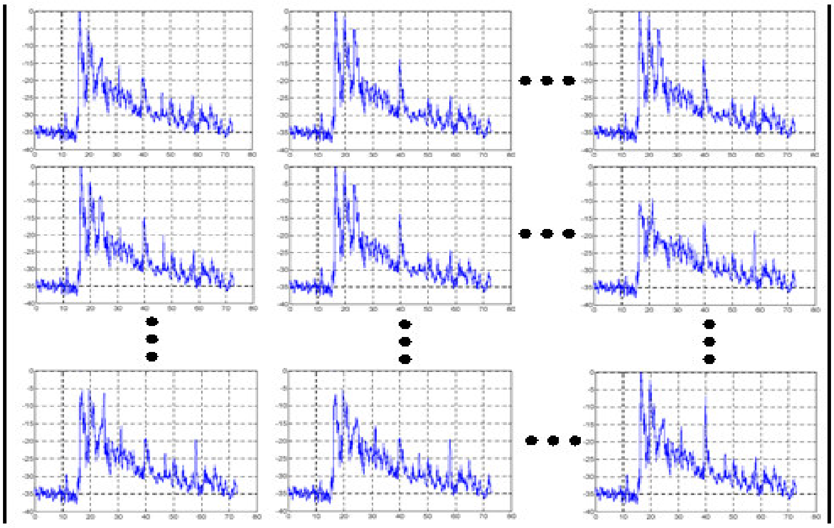

Fig. 5. The Graphical matrix of the pulse response in the MIMO system

4. CONCLUSION

In this paper the pulse response estimation of radio channel by Six-port reflectometer (SPR) is described. Pulse response of radio channel, six-port reflectometer and radio channel are simulated in program language Delphi 7. In this work the pulse response measurement of MIMO radio channel by Six-port reflectometer technique. A pulse response matrix, Rayleigh fading in the radio channel, SPR technology, AWGN radio channel has been simulated in program language Delphi 7.

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