DEVELOPMENT OF A FUNCTIONAL DIAGRAM FOR A RADIO SYSTEM FOR DIGITAL INFORMATION TRANSMISSION

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Abstract. *In the article the developed functional block diagram of the radio transmission of digital information. The functional scheme of using MAX 2022 chip, which allows using the radio that meets the requirements for noise level and transmits digital information without additional high-frequency filter RF. Is a block diagram: transmission system; transmitting the final stage of the digital transmitter; quadrature modulator and demodulator. The resulting solution greatly simplifies the functional circuit and its setting and adjustment.*

Keywords: *telecommunication, radio communication, Transmitter, Radio receiver, demodulator, modulator.*

Today telecommunications are the basis for the development of society, and information resources are becoming the main national wealth. The constantly growing volumes of transmitted information, the expansion of the range of services and a number of other factors pose the task of continuously increasing the bandwidth and speed of data transmission in digital transmission systems. Currently, radio modems are used for this purpose, which are a radio transmission system and are designed to transmit digital data.

Radio transmission systems (RTSs) are understood to be a set of technical means that ensure the formation of standard transmission channels, group paths and a linear path through which telecommunication signals are transmitted through the propagation of radio waves in open space [1].

The purpose of this work is to develop a functional scheme of a radio modem. All equipment of the transmission system (Fig.1) can be divided into two parts: channel-forming and group equipment (CGE) and receiving and transmitting equipment.

The channel-forming and group equipment at the transmitting end ensures the conversion of incoming Ethernet traffic into E1 streams, followed by the multiplexed formation of the E3 stream. At the receiving end there is a reverse signal conversion (demultiplexing and E1-Ethernet conversion).

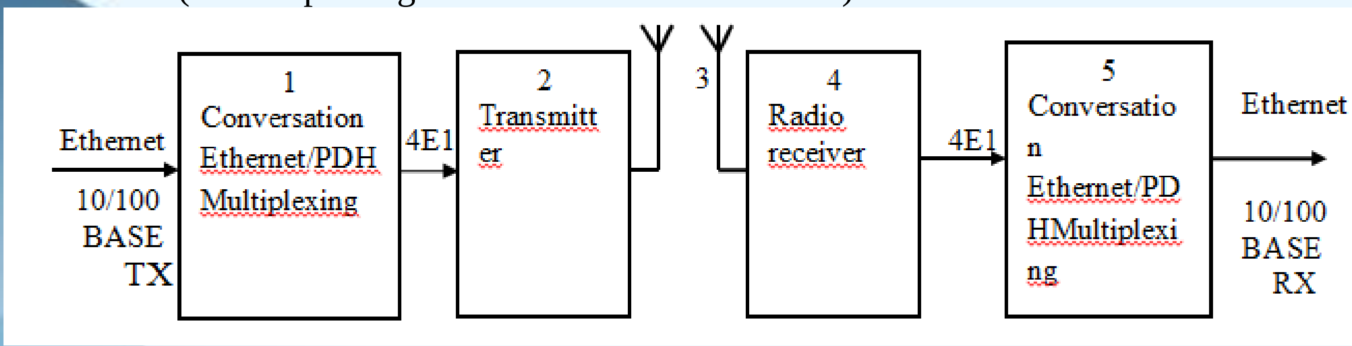

Fig.1. Block diagram of the transmission system
1,5-Channel forming equipment

2- Radio transmitting equipment
3- Radio line
4- Radio receiving equipment

In this case, a broadband radio system is used to generate a radio signal and transmit it over a distance. The radio communication system together with the radio wave propagation path form a linear path. The radio transmitting equipment consists of a transmitter and an antenna-feeder device. In the terminal equipment, a high-frequency broadband signal is generated at the transmitting end.

Reverse operations are performed at the receiving end: a high-frequency radio signal (HF) is demodulated and a useful signal is allocated. The direct conversion receiver directly demodulates the HF-signal at the carrier frequency into the baseband (the band of modulating signals), where the signal can be detected and the information contained in it can be restored.

At the transmitting end of the RTS, direct quadrature modulation of unmodulated signals occurs, as a result, the signal spectrum is transferred to the specified ultrahigh frequency range (microwave) (2.4 GHz), amplified, filtered and radiated towards the receiving station using an antenna.

In two-sided RTSs, a split antenna-feeder path is used to transmit and receive radio signals from opposite directions (Fig. 1). During transmission, the signals undergo certain distortions in all parts of the RTS. The causes of distortion are the effects of various interference and the imperfection of the characteristics of the elements.

The interference that occurs in the RTS itself is called intra-system. These include: thermal noise that occurs in the radio receiver, terminal equipment, antenna-feeder path, and transient interference that occurs during multichannel transmission in almost all elements of the RTS. In addition to intra-system interference, any RTS is affected by interference from other trunks in multi-barrel systems, from other radio-electronic means (REM), radio emissions from space, Earth, atmosphere, etc. Due to the imperfect characteristics of the RTS elements, linear and nonlinear distortions of the transmitted signals appear [1].

Figure 2 shows the developed simplified block diagram of the transmitting terminal stage of a digital transmitter, the principle of operation of which is described below. The digital stream E3 is received at the input of the common-mode and quadrature flow generation device (encoder) of the digital transmitter. As a result, the digital stream rate has an effective transfer rate of 34 Mbit/s [2]. Further, the generated digital stream is divided into two streams having twice the speed − 17 Mbit/s. These streams are used to form a common-mode digital stream (I) and a quadrature digital stream (Q). Signal processing is carried out using a quadrature modulator.

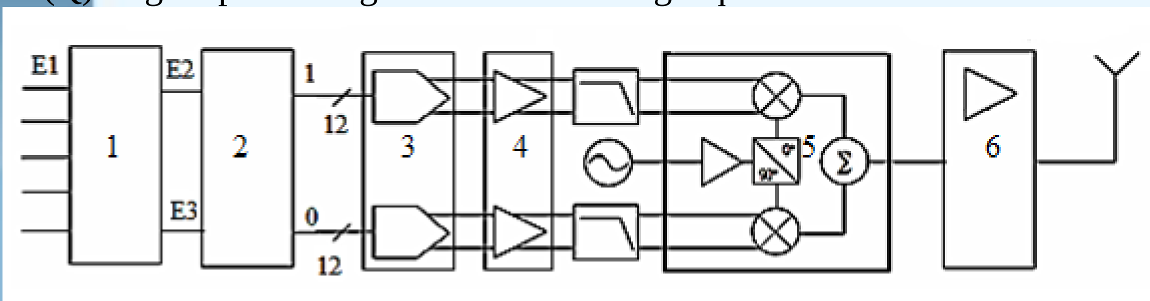

Fig.2. Block diagram of the transmitting terminal stage of a digital transmitter.

1- Multiplexer
2- Encoder
3-Digital-to-analog converter
4- Operational amplifier
5-Modulator
6-Radio frequency amplifier

The basis of the scheme is the modulator MAX 2022. This is a universal device that can be used regardless of the type of modulation, but with additional conversion of the modulating and modulated signals. Quadrature modulators are balanced–type devices that do not require filtering to isolate the total or difference component of the modulated signal. They can also be used as step-up frequency converters [3,4].

The quadrature modulator and the intermediate frequency converter (IF) to HF (in the transmitter), as well as the RF to IF converter and the quadrature demodulator (in the receiver) are analog. A digital-to-analog converter (DAC) is used at the input of the modulator, separately in each quadrature channel I and Q. In the transmitting channel, signals from a programmable logic integrated circuit (PLIC) are sent to the DAC. The carrier oscillation at the output of the modulator is high-frequency [4].

The APA300-PQ352I programmable logic integrated circuit performs the functions of multiplexing E1 into the E3 stream. This chip allows you to combine low-speed E1 channels into one high-performance E3 trunk channel.

The circuits of modern digital transceivers use a digital modulator and demodulator. At the same time, there should be an analog-to–digital converter (ADC) at the input of the demodulator (usually with a decimator), and a DAC (with an interpolator) at the output of the modulator. When the ADC and DAC are switched on in this way, high-frequency signals are converted. As a result, the modulator and demodulator operate at higher sampling rates and, accordingly, at lower noise introduced by digital conversion. The main element of the modulator and demodulator is a multiplier (mixer).

The input of the multiplier receives a modulating signal, generally expressed as

$$a_1 = A_1(t)\cos(\omega_1 t + \Delta\varphi(t)) \qquad (1)$$

Where $A_1(t)$ и $\varphi(t)$ – are the modulated amplitude and phase change and the reference oscillation

$$a_0 = A_0 \cos \omega_0 t\,;$$

The sum of two oscillations is removed from the output of the multiplier – with total and difference frequencies:

$$a_2(t) = A_1(t)\cos\,[\,(\omega_1 + \omega_0)t + \Delta\varphi(t)]\,A_2(t)\cos[(\omega_1 + \omega)t + \Delta\varphi(t)], \qquad (2)$$

where $A_n(t)$ proportionally $A_1(t)$.

The desired oscillation is isolated by filtering or without filtering – in quadrature converters. The first component, with a total frequency of $\omega_1 + \omega_0$, is allocated in the step-up frequency converters, and the second, with a difference frequency of $\omega_1 - \omega_0$, – is allocated in the step-down converters
($\omega_1>\omega_0$). When $\omega_1<\omega_0$ the second component in the expression (2)
$A_2(t)\cos[(\omega_0 - \omega_1)t - \Delta\varphi(t)$ формульную запись на рис.3:

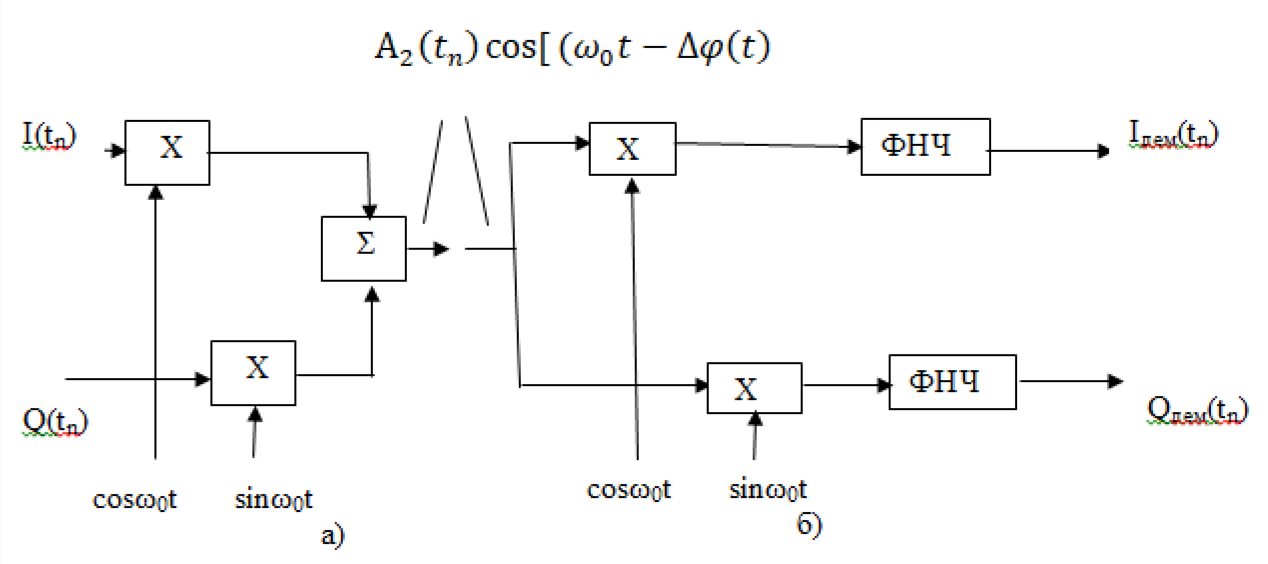

Fig. 3. Block diagram of quadrature modulator (a) and demodulator (b)

The modulators implement the mode with ω_0 (when $\omega_1= 0$), demodulators use a component of the difference frequency equal to zero (when $\omega_1 =\omega_0$).

The main modes of quadrature modulators and demodulators (Fig.3.) are modulation/demodulation of a signal with in–phase $I(t_n)$ and quadrature $Q(t_n)$ modulating parcels and modulation/demodulation of an analog signal with one sideband (OSD).

In the first mode, the modulating parcels are analog, with a constant level during each parcel and a discrete change in levels from parcel to parcel. The levels contain information about the digital code of the modulating signal. At the output of the modulator:

$$a_{мод}(t_n) = A(t_n)\cos[(\omega_0 t + \Delta\varphi(t_n) \qquad (3)$$

Where $A(t_n) = \sqrt{I^2(t_n) + Q^2(t_n)}$; $\varphi(t_n) = \mathrm{arc\,tg}[Q(t_n)/I(t_n)$; – discretely variable amplitude and phase of the modulated signal. Signals at the output of the demodulator:

$$I_{dem}(t_n) = k_{dem}A(t_n)\cos\Delta\varphi(t_n); \quad Q_{дем}(t_n) = k_{dem}A(t_n)\sin\Delta\varphi(t_n)$$

are proportional to the input signals of the modulator $I(t_n)$ and $Q(t_n)$. Note that the LF components $I(t_n)$, $Q(t_n)$ at the input of the modulator and $I_{dem}(t_n)$, $Q_{dem}(t_n)$ at the output of the demodulator represent a signal in a rectangular system, whereas the signal at the output of the modulator and the input of the demodulator, according to expression (3), is in a polar coordinate system.

The MX 2022 device (Maxim Integrated Products) is used as a quadrature modulator for the radio modem being developed, which is an ideal modulator for a ZIAF (zero-IF) (with zero IF, or direct conversion) transmitter with a single carrier.

The wide dynamic range of the device makes it possible to obtain an effective complete structure of the transmitter. Figure 2 shows a simple but nevertheless complete circuit of a high-efficiency transmitter.

The I and Q signals are routed first to a simple two-port digital-to-analog converter MAX5873. The grounding (ground-referenced) outputs of the DAC are filtered by simple LPF consisting of discrete elements to reduce the noise level of the DAC.

As a simple analog filter, an active equalizer is used (implemented on the MAX4395 operational amplifier), which suppresses the irregularities of the DAC characteristics. Also, this scheme provides additional amplification of the output signal with a coefficient of

$$K_y = 1 + \frac{R_1}{R_2}$$

Extremely low phase distortion (noise) MAX2022 allows the circuit to meet the requirements for noise levels without additional RF filters, which greatly simplifies the circuit, its configuration and adjustment.

The MAX2022 output is connected to the MAX 2059 radio frequency amplifier, which provides a carrier power gain plus 15 dBm. This variable gain amplifier includes a flexible digital controlled attenuator with a control range of 56 dB, which fully meets the highest static and dynamic power control requirements.

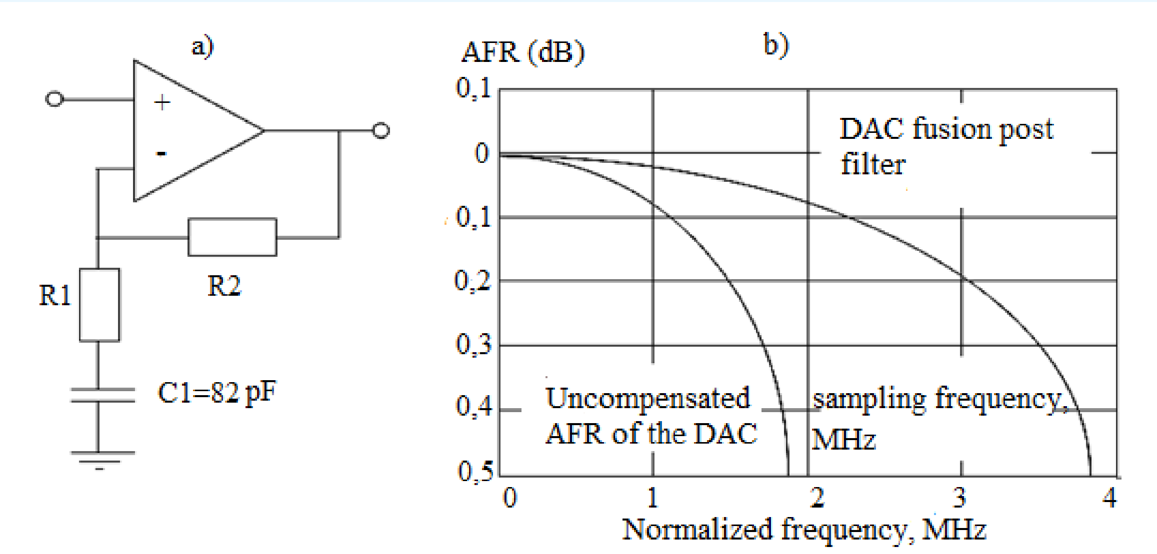

Fig.3. Diagram of a simple analog filter for equalizing the amplitude–frequency response (frequency response) DAC and the resulting frequency response: a) filter circuit; b) filter frequency response

The requirements for the output amplifier of the transmitter are largely determined by the type of signal modulation [5].

In systems with quadrature phase manipulation (QPSK) and quadrature amplitude modulation (QAM), nonlinear signal distortion in the output stage of the transmitter can lead to a significant increase in the probability of error when receiving the signal. Therefore, when using quadrature amplitude modulation, adaptive power adjustment is carried out in the transmitter, ensuring the minimum total value of the error probability.

Thus, the selected wide dynamic range of the device makes it possible to obtain an effective complete structure of the transmitter. A simple scheme of a high-efficiency transmitter has been developed. The use of an active analog filter on the MAX4395 operational amplifier provides additional amplification of the output signal. The choice of the MAX 2022 chip allows using a radio modem that meets the requirements for noise levels and transmits digital information without additional high-frequency RF filters, which greatly simplifies the circuit, its configuration and adjustment.

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