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PASSIVE RADIO FREQUENCY MONOIMMITANCE TRANSPONDERS

Proceeding from the conducted analysis of the technologies of modern transponders, variants of building passive radio frequency monoimmitance transponders are proposed as well as a circuit of the passive monoimmitance transponder that performs logic function "OR", the operation of which has been simulated in AWR Design Environment 9.00 software package.

Key words: *radio frequency passive transponder, monoimmitance logic.*

Introduction

Radio frequency transponders have been increasingly used in various spheres of human life. One of the reasons for this is reduction of their price and size. However, intelligent transponders that contain microchips are still rather expensive. In addition, construction of passive transponders, based on microchips powered from the polling signal, is a complicated task. Therefore, construction of passive radio frequency intelligent transponders without microchips is a relevant problem [1].

The use of monoimmitance logic in radio frequency transponders can provide implementation of simple logic operations with the application of polling signal. In addition, their advantage is simple manufacturing technology, which would significantly reduce the price of monoimmitance transponders as compared with transponders based on chips. Therefore, the paper aims at the development of circuit solutions, which would make it possible to build passive radio frequency transponders.

Main part

Let us consider main characteristics of the existing radio frequency transponders. One of them is frequency range, by which transponders are conventionally divided into the following groups [2, 3]:

1. Low frequency range (30 – 300 kHz)

Low-frequency radio frequency transponders have small reading distance (less than 1cm), but low cost. They are used for access control, identification of animals and inventory systems. Information between the transponder and the reader is transmitted by means of electric or magnetic field.

2. High frequency range (3 – 30 MHz)

Such transponders have average reading distance (less than 1 m) and high cost. They are used for access control as well as for smart cards. Information is transmitted using inductive coupling.

3. Ultrahigh (UHF) frequency range (300 MHz – 5.8 GHz)

Transponders with long-distance and high-speed reading require precise targeting of the reader. They are used for monitoring railway transportation of load, in the systems of payments for drivers' use of the road. Information is transmitted by electromagnetic waves in ultrahigh frequency range.

As monoimmitance logic is based on the application of transmission line properties in UHF range, it is expedient to use electromagnetic waves of UHF range for transmitting information between the radio frequency transponder and the reader.

Passive radio frequency transponders do not have their own electric energy source and, therefore, the entire energy required for their operation must be obtained from the electromagnetic signal, supplied from the reader. Reading distance of the passive transponders depends on the energy supplied from the reader. An advantage of passive transponders is their practically unlimited service life as well as their smaller weight and lower price as compared with active transponders. A disadvantage of passive transponders is the necessity to use more powerful readers.

Active radio frequency transponders have a built-in autonomous battery that supplies the entire or part of the energy for integrated circuit operation and, therefore, they require a less powerful reader. An advantage of active transponders as compared with passive ones is much greater (at least 2 – 3 three times) read range and high permissible motion speed of the active transponder in relation to the reader.

As monoimmitance logic does not have active elements, it is more expedient to develop passive radio frequency monoimmitance transponders.

Another feature of radio frequency transponders is their functionality. Conventional single-bit radiofrequency transponders, which are usually passive, operate on the basis of such physical effects as resonance of LC circuits, frequency multiplication by nonlinear energy storage, resonance of a ferromagnetic element based on the magnetostrictive effect, etc. Such transponders perform a single function – they report their presence or absence in the polling area.

For radio frequency transponders of a wider function, microchips, which can be powered by a battery, are usually used, or in the case of a passive transponder, they can receive power from the input UHF signal. However, for chip operation the input signal power should not be lower than a certain value, which limits the range of such transponders. Therefore, an advantage of radio frequency monoimmitance transponders may be the possibility of constructing intelligent transponders that do not depend on the input signal power due to the absence of active elements.

Procedures for transmitting data from the transponder to the reader can be divided into three types [2]:

– the use of backscatter, with frequency of the reflected bounce corresponding to the frequency of the reader. It is used by most long-range transponders [4];

– load modulation. The field of the reader is affected by the change of the transponder load; the output signal frequency corresponds to the input frequency;

– use of subharmonics and generation of n-fold harmonic oscillation in the sensor;

If the backscatter principle is used, a passive radio frequency monoimmitance transponder can have the structure shown in Fig. 1:

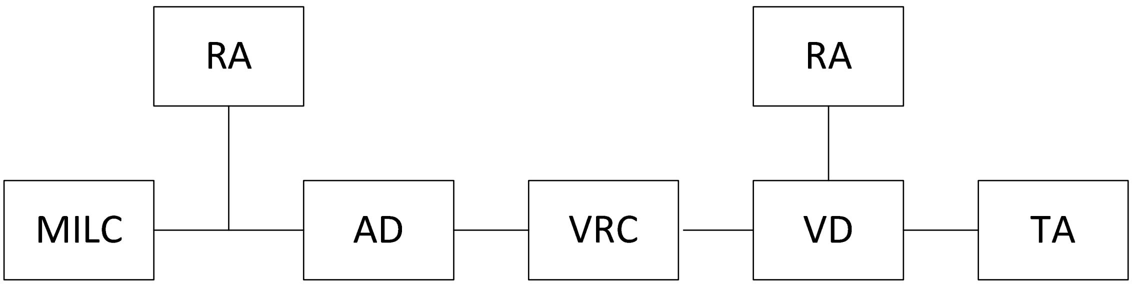

Fig. 1. Structural diagram of the passive radio frequency monoimmitance transponder, based on the backscatter principle

In Fig. 1 MILC – monoimmitance logic circuit, AD – amplitude detector, VRC – voltage-resistance converter, VD – voltage divider, RA – receiving antenna, TA – transmission antenna.

The transponder operates in the following way. In the presence of an input UHF signal, supplied from the receiving antenna to the monoimmitance logic circuit, at the input terminals of the amplitude detector a standing voltage wave of a certain voltage appears, which the amplitude detector converts into the constant voltage. After that, constant voltage is converted into resistance. This resistance appears at one of the voltage divider arms, while at the other arm there is resistance of the receiving antenna. In the process of the monoimmitance logic circuit operation the ratio of these resistances varies, which results in amplitude modulation of the signal that is transmitted from the receiving to the transmitting antenna.

A possible variant of the passive radio frequency monoimmitance transmitter implementation (without connection of logic circuits), based on the backscatter principle, is presented in Fig. 2.

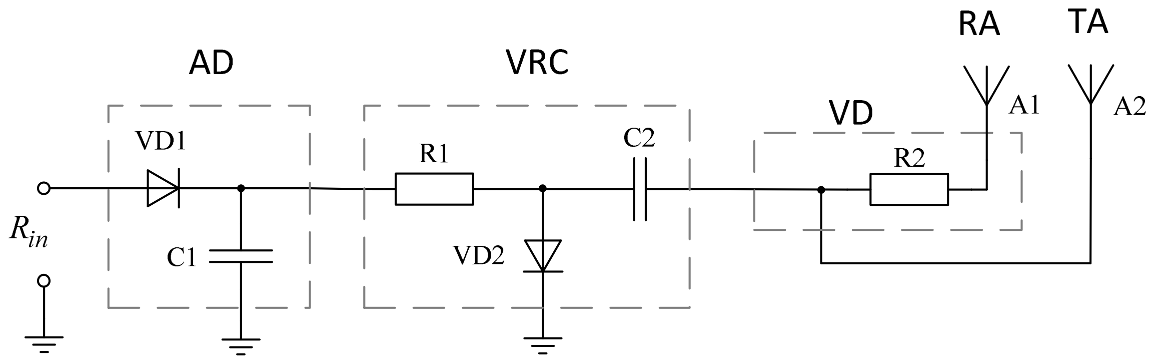

Fig. 2. A possible variant of the passive radio frequency monoimmitance transmitter implementation, based on the backscatter principle

If the principle of n-fold harmonic oscillation generation is used, a frequency divider (FD) may be added to the transponder circuit:

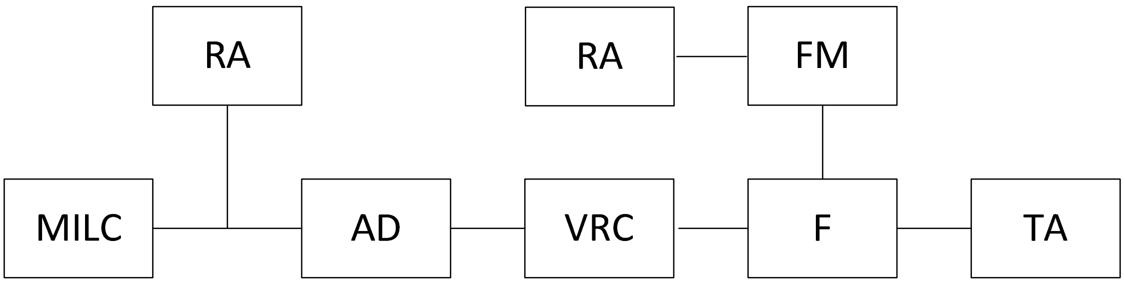

Fig. 3. Structural diagram of the passive radio frequency monoimmitance transponder, based on the principle of n-fold harmonic oscillation generation

In Fig. 3 MILC is monoimmitancce logic circuit, AD – amplitude detector, VRC – voltage-resistance converter, F – filter, FM – frequency multiplier, RA- receiving antenna, TA – transmitting antenna.

A possible option of the passive radio frequency transmitter implementation, based on the principle of 2-fold harmonic oscillation generation, is presented in Fig. 4.

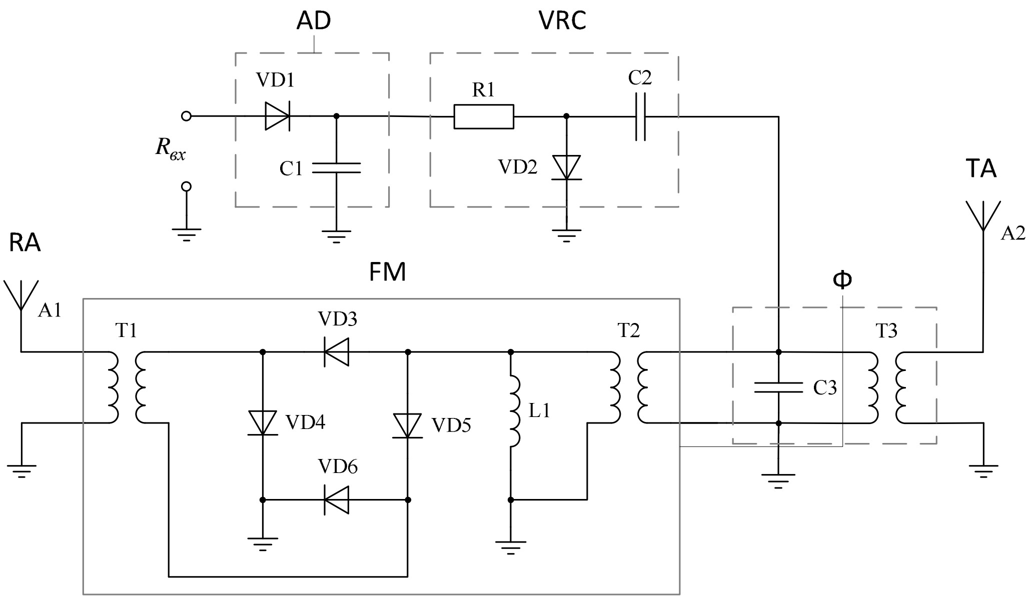

Fig. 4. A possible option of the passive radio frequency monoimmitance transmitter implementation, based on the principle of 2-fold harmonic oscillation generation

If the principle of n-fold harmonic oscillation generation is used, there is a possibility of simultaneous transmission and receiving of a signal by the reader. However, the presence of frequency multiplier in the sensor circuit causes significant attenuation of the transponder output signal.

We will consider the use of monoimmitance logic circuits for passive radio frequency monoimmitance transponders by the example of monoimmitance logic R-element “OR”. As a transmitter circuit we will use the circuit built on the backscatter principle, which provides lower losses of the useful signal as compared with the transmitter, based on the principle of n-fold harmonic oscillation generation.

The monoimmitance logic element “OR” could have an unlimited number of inputs and a single output. Transponder with the “OR” element could be used for the changed state indication (the change in active resistance) of one of the object array objects. It should be noted that the sensor transmits information about the fact of the state change itself and not information for the object identification. Examples of such use could be the container tightness control, operability of the system components, etc.

A simplified mathematical model of the monoimmitance logic R-element is described by equation [5]:

$$R_{out} = Z_0^2 \Big/ \frac{Z_1^2/R_1 \cdot Z_2^2/R_2 \cdot \ldots \cdot Z_n^2/R_n}{Z_1^2/R_1 + Z_2^2/R_2 + \ldots + Z_n^2/R_n}, \tag{1}$$

where Z_0 – wave resistance of the transmission line output segment, $Z_1 - Z_n$ – wave resistances of the transmission line input segments, $R_1 - R_n$ – active resistances connected to the element inputs.

Structural diagram of the passive radio frequency monoimmitance transponder with logic element “OR” is shown in Fig. 5.

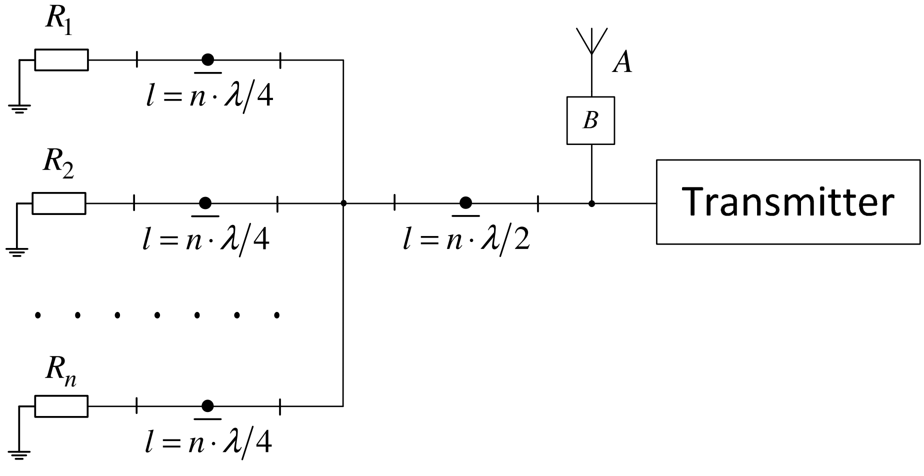

Fig. 5. Structural diagram of the passive radio frequency monoimmitance transponder with logic element “OR”

Since the developed transmitters invert the signal, to obtain a non-inverted signal at the output of the transponder in Fig. 5, logical element "NO" is added to the circuit of the monoimitance logical element "OR". The operating threshold of the monoimitance logical element "OR" can be established by setting the wave resistance of the transmission line segments.

Using modelling of the circuit of the passive radio frequency monoimmitance transponder with the three-input "OR" element in the software package AWR Design Environment 9.00, the voltage values at the output of the circuit have been obtained under the conditions of availability of all the possible logical resistance values at the circuit inputs. For modelling, in this case and further resistance of 5 Ohm was used as a logical “0”, and resistance of 150 Ohm – as a logical unit. The supply voltage at the receiving antenna was 3 V. Fig. 6 shows the transponder circuit in AWR Design Environment 9.00 software package.

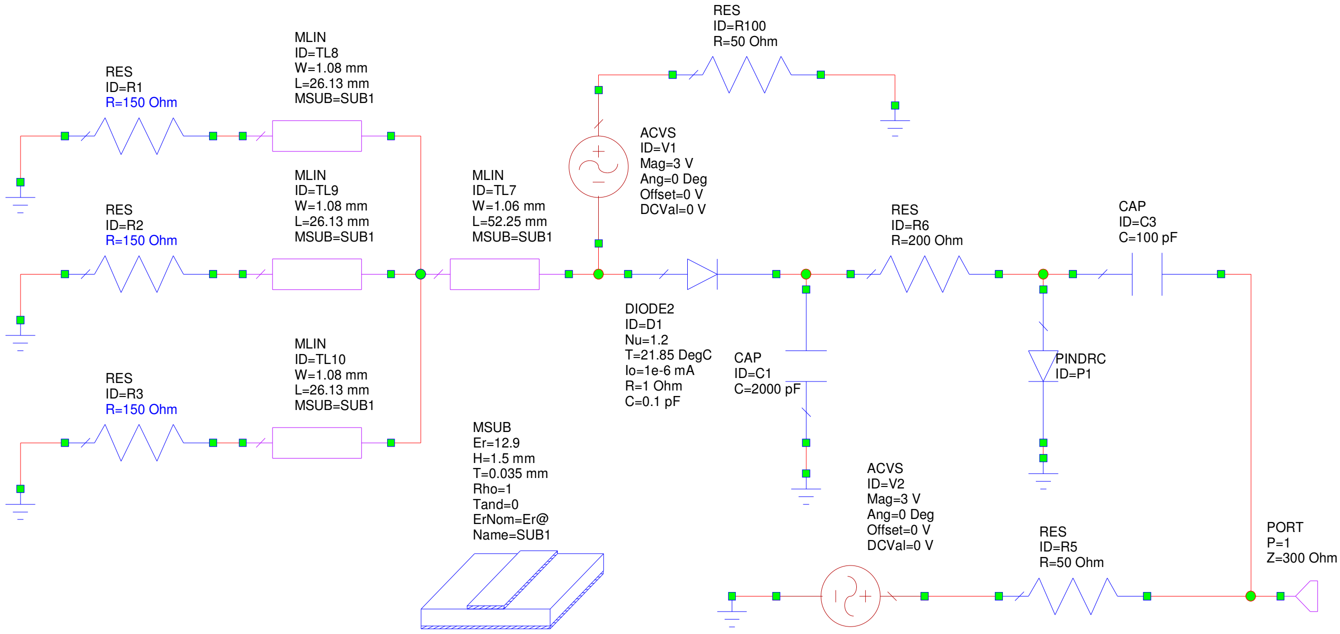

Fig. 6. Circuit of the passive radio frequency monoimmitance transponder with the logic element "OR" in AWR Design Environment 9.00 software package

Modelling results are presented in the graph of Fig. 7:

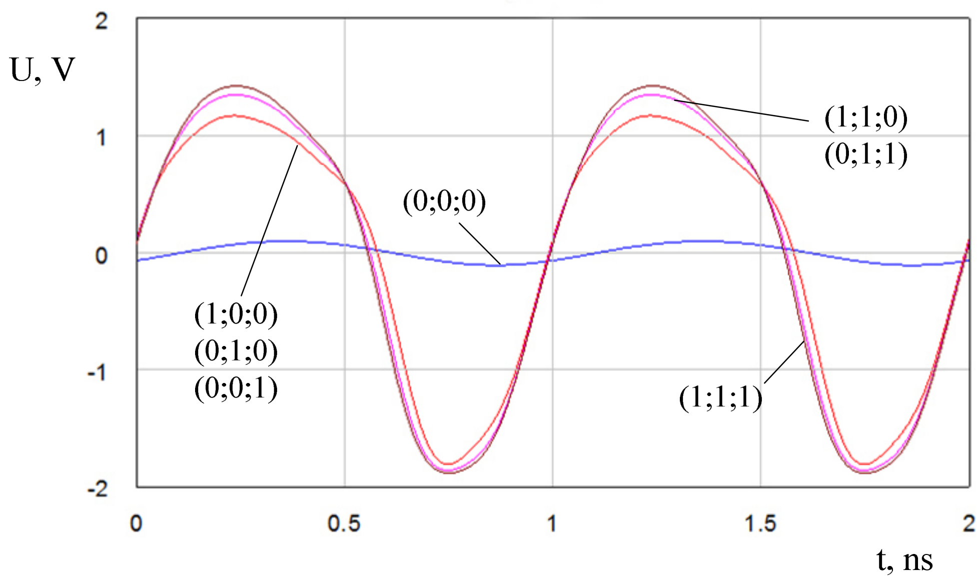

Fig. 7. Oscillograms of the output voltage under different logic states at the inputs of the circuit of passive radio frequency monoimmitance transponder with the three-input "OR" element

From graphs in Fig. 7 we can conclude that the voltage levels at the output of the passive radio frequency monoimmitance transponder circuit with the logical element "OR" with three inputs correspond to the truth table of the logical element "OR": the amplitude of the output voltage under the input logic states (0; 0; 0) does not exceed 100 mV, while in all other cases the value of the voltage amplitude is within the range of 1.8 – 1.9 V.

Conclusions

Proceeding from the analysis of modern technologies of radio frequency transponders, the principles of building transmitters for monoimmitance logic have been chosen, particularly, of the transmitter that implements the backscatter principle and the transmitter based on the principe of two-fold harmonic oscillation generation. The use of such transmitters enables building passive radio frequency monoimmitance transponders that perform logic operations without having constant power supply source. As an example of such transponders, the transponder with logic function "OR" is considered. Modelling of its operation in AWR Design Environment 9.00 software package was conducted and graphs that prove its operability were obtained.

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