

The Issue of Data Exchange in the UHF Band RFID System with an Semi-Passive Transponder

Marek Gotfryd, Wojciech Lichoń, and Bartosz Pawłowicz

Abstract— The article discusses the specifics of data exchange in the UHF band RFID systems using semi-passive transponders. In addition to the antenna and the RFID chip, there is also an additional source of energy (eg. battery) in the structure of such transponder. The battery may be used to implement additional functions such as the ability to measure physical quantities (eg. temperature, humidity). In this regard, particular attention was paid to the discussion of phases of communication between transponder and RWD associated with additional data (measurement results). An analysis of transmitted data frames has been presented. The preliminary results of the measurements have shown that the number of memory block transmitted from transponder has an impact on the effectiveness of RFID system.

Keywords— RFID, dynamic system, data exchange, semi-passive transponder

I. INTRODUCTION

Radio frequency identification systems (RFID) are currently applicable in many fields of daily life and economy [1]. In most frequently implemented passive systems, electronic transponders are composed of two primary elements: antenna and directly connected chip [2]. Data on the tagged object and a unique Electronic Product Code (EPC) are stored in its memory. It is read contactless by read/write device (RWD).

In less popular semi-passive transponders there are also replaceable or constant energy source (for example battery) [3]. Its task is to support RFID chip activity. Thanks to this, geometric dimensions of RFID system Interrogation Zone are increased. That means the space inside which the energy and communications conditions of proper system operation are

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met [4,5]. Additional energy can also be used for execution of measurement of selected environment parameters in which tagged object exists (for example temperature, intensity of light, humidity) [3]. Results can be written in transponder memory independently of RWD (autonomously) or in response to its command. The need for wireless transfer of additional data in RFID system prolongs the duration of communication sessions [6-8] which in turn translates into modification of Interrogation Zone of RFID system. To determine the possibility of practical usage of semi-passive transponders in automated processes it is necessary to know the phenomena related to data exchange in RFID system, affecting its functioning.

II. DURATION OF BITS TRANSMITTED DURING A COMMUNICATION BETWEEN RWD AND TRANSPONDER

In UHF band RFID systems communication in scheme read/write device – transponder occurs with the use of EPC Class1 Gen2 communication protocol. Its specification takes into account requirement written in ISO 18000-6C norm [9-11]. It comprehensively defines: parameters of established radio link, structure of exchanged commands of RWD – transponders scheme, transponders answers and algorithm of anticollision in communication [12-15].

During energy and commands transmission from Read/Write Device to transponders Amplitude Shift Keying (ASK) and Pulse Interval Encoding (PIE) are being used. All inquiries of RWD must be preceded by symbol: Preamble (*PreRT*) or synchronization Frame Sync (*FS*). Their form is depicted by Fig. 1. Preamble consists of: separator of constant length equal to 12,5 μ s, logical symbol „0”, calibration symbol *RTcal* in Read/Write Device - transponder link to and calibration symbol in reverse direction link marked as *TRcal* (Fig. 1a). The FS signal has got very similar form, on its end only *TRcal* calibration symbol is missing (Fig. 1b). *T_{ari}* parameter marked on Fig. 1 has meaning of a reference time interval. According to specification requirements it can take duration equal to 6,25, 12,5 or 25 μ s.

Duration of *RTcal* calibration symbol is sum of logical “0” and “1” symbols length. On the basis of the knowledge this of *T_{RTcal}* duration is given by following formula:

$$pivot = \frac{T_{RTcal}}{2} \quad (1)$$

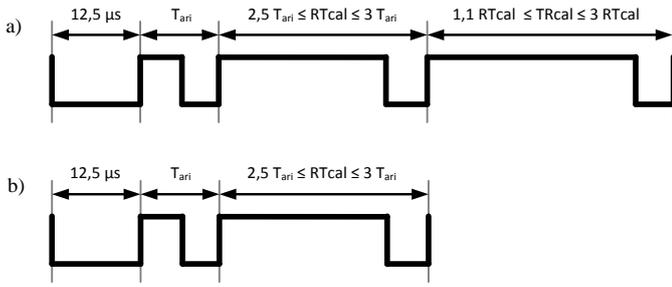


Fig. 1. The form of symbol: a) preamble *PreRT*, b) frame synchronization *FS*

In transponder's chip value of *pivot* parameter is determined. Product of reference time T_{ari} and this parameter can be taken as average T_{bTR} bit duration length during communication from RWD to transponder.

Communication in reverse direction takes place using backscattering technique. Read/Write Device sends unmodulated Continuous Wave (CW) and listens for reply. It is send using shifting of real or imaginary part of transponders chip impedance. Impedance keying speed is determined by using the Backscatter Link Frequency (BLF) which value is contained within the scope of 40-640kHz [9]. It also can be determined on the basis of $TRcal$ symbol length from dependence:

$$BLF = \frac{DR}{T_{TRcal}} \quad (2)$$

where value of Division Ratio (DR) division can take two admissible values: 8 for BLF frequency within the scope of 40-95kHz, 64/3 for 465-640kHz frequency and 8 or 64/3 for frequency within the scope of 95-495 kHz.

During data transmission from transponder to RWD Amplitude Shift Keying (ASK) or Phase Shift Keying (PSK) can be used. There are also two additional methods of transmission encoding: FM0 or Miller. The special feature of the second method is ability to extend data string sending. Using M parameter it is determined how many periods of BLF keying frequency falls on one logical symbol sent.

The period of one BLF subcarrier marked as T_{pri} , is equal from 1,5625 to 25μs. It's length is used to calculate average

duration of the bit during communication from transponder to RWD marked as T_{bTR} . It can be determined from dependence:

$$T_{bTR} = M \cdot T_{pri} \quad (3)$$

where $M=1$ for FM0 and $M=2, 4$ or 8 for Miller's encoding. Knowledge of average duration of bits determined by using equations (1) and (3) has crucial importance during determination of RWD commands length and replies from transponder

III. DATA EXCHANGE BETWEEN RWD AND TRANSPONDERS IN SEMI-PASSIVE RFID SYSTEMS

Process of data reading from memory of transponder can be divided into three stages: recognition, choice and read from transponder. It is schematically presented on Fig. 2. Time intervals between RWD inquiries and transponders' responds have been also marked as T_1, T_2 and T_4 . Their values are not precisely defined. Allowed values have been given in norm [9].

Operation of transponders' recognition is initiated by *Query* command. It is preceded by *PreRT* preamble in which information such as the bit rate of data transfer are included. In response to this command *RN16* number is sent. It is unique 16-bit transponder address (valid only in duration of current Inventory Round) and *PreRT* preamble. If that data are received by RWD without errors then the confirmation of valid communication (*ACK*) and *FS* synchronization symbols are being sent. At the end of the transponders' recognition operation the EPC number with *PreRT* preamble are being sent to RWD. It's duration time T_{ident} can be determined as sum of RWD commands length, transponders' responses and duration between them with dependence:

$$T_{ident} = T_{PreRT} + T_{que} + 2 \cdot T_{PreTR} + T_{FS} + T_{ACK} + 162 \cdot T_{pri} + 2 \cdot T_1 + 2 \cdot T_2 + T_4 \quad (4)$$

where T_{PreRT} , T_{que} , T_{PreTR} , T_{ACK} and T_{FS} mean length of adequate commands and responses, determined using the relations listed in Table 1.

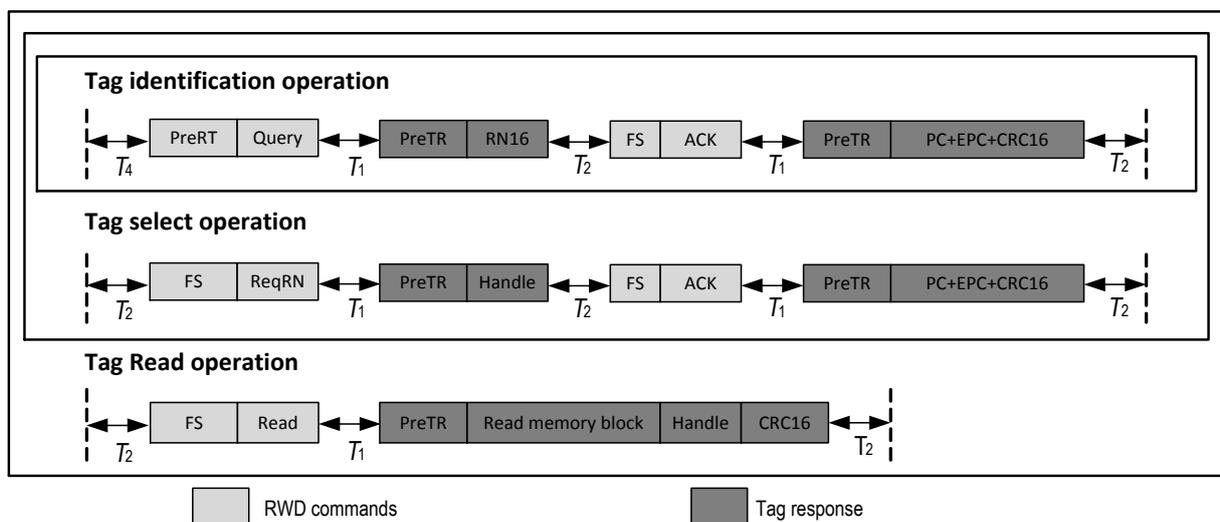


Fig. 2. Single session of UHF transponder recognition and readout of data from its memory.

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where T_{PreRT} , T_{que} , T_{PreTR} , T_{ACK} and T_{FS} mean length of adequate commands and responses, determined using the relations listed in Table 1.

The selection operation is intended to establish communication with chosen transponder which memory must be read. It is initiated by RWD which sends *ReqRN* command preceded by FS synchronization symbol. After receiving it new temporary address marked as *handle* is generated in the transponders' chip. It is necessary because in individual communication mode there may be also proceeded other operations than reading data from the memory. If transponders' temporary address is received without errors in RWD then the ACK confirmation preceded by FS synchronization symbol is being sent. In response the EPC number and adequate preamble are sent again. The duration of transponders' choice process T_{Select} can be chosen in the same manner as above by using dependence:

$$T_{Select} = 2 \cdot T_{FS} + T_{ReqRN} + 2 \cdot T_{PreTR} + T_{ACK} + 162 \cdot T_{pri} + 2 \cdot T_1 + 3 \cdot T_2 \quad (6)$$

Reading from memory of the transponder chosen earlier can be made using the *Read* command [9]. It is sent by Read/Write Device with FS synchronization symbol. In response to *Read*

command the *PreRT* preamble, temporary transponders' address *handle* and N byte of data with CRC code are being sent. The duration of the transponders' read operation

T_{Mem_Read} can be determined using the following formula:

$$T_{Mem_Read} = T_{FS} + T_{Read} + T_{PreTR} + (N \cdot 8 + 32) \cdot T_{pri} + T_1 + 2 \cdot T_2 \quad (7)$$

Its value depends largely on the number of N bytes read from memory.

IV. EXPERIMENT

As part of preliminary studies multiple attempts to read data from transponders' memory built based on AMS SL900A chip were carried out. Transponder was located on the FEIG ID ISC.MRMU102 Read/Write Device maximum antenna radiation direction. RWD was controlled by ID ISOStart 2015 (Fig. 4) development software version. Observations of the tested RFID system were carried out for transponder located on the edge of Interrogation Zone, understand as the distance of the transponder from the antenna RWD, that read of its correct EPC number was still possible. The distance between the Read/Write Device and the transponder was changed with a resolution of 1 cm (Fig. 3). To create a measurement conditions similar to those in which semi-passive transponders will eventually work to acquire energy from environment, the laboratory stand was equipped with FLUKE 5000 signal generator connected to an antenna developed under Grant No. PBS1/A3/3/2012 [16], dedicated to the RFID UHF band. Transponder was examined both in passive and semi-passive mode. The test were repeated 1000 times for different sizes of read data blocks (from five to fifty five). Transmitting data in blocks of 2-bytes was assumed. The number of these blocks were equal to 5, 20, 40 and 55 respectively. Errors in operations of read and write of data was established on the basis of the messages generated by computer, based on return data received from transponder. The results of observations of four quantities of read data has been presented in the form of graph on Fig. 6.

TABLE 1
DURATION OF RWD COMMANDS AND TRANSPONDER RESPONSES

System component	Inquiry/response	Duration in bits	Duration
RWD	PreRT	-	$T_{PreRT} = 12,5 \mu s + T_{ari} + T_{RTcal} + T_{TRcal}$
	FS	-	$T_{FS} = 12,5 \mu s + T_{ari} + T_{RTcal}$
	Query	40	$T_{que} = 22 \cdot T_{bTR}$
	ReqRN	40	$T_{ReqRN} = 40 \cdot T_{bTR}$
	Read	58	$T_{Read} = 58 \cdot T_{bTR}$
	ACK	18	$T_{ACK} = 18 \cdot T_{bTR}$
Transponder	PreTR	-	T_{preTR}
	RN16	32	$33 \cdot T_{pri}$
	PC+EPC+CRC16	129	$(128+1) \cdot T_{pri}$
	<i>Handle</i>	32	$33 \cdot T_{pri}$
	Content of the memory	$N \cdot 8$	$N \cdot 8 \cdot T_{pri}$

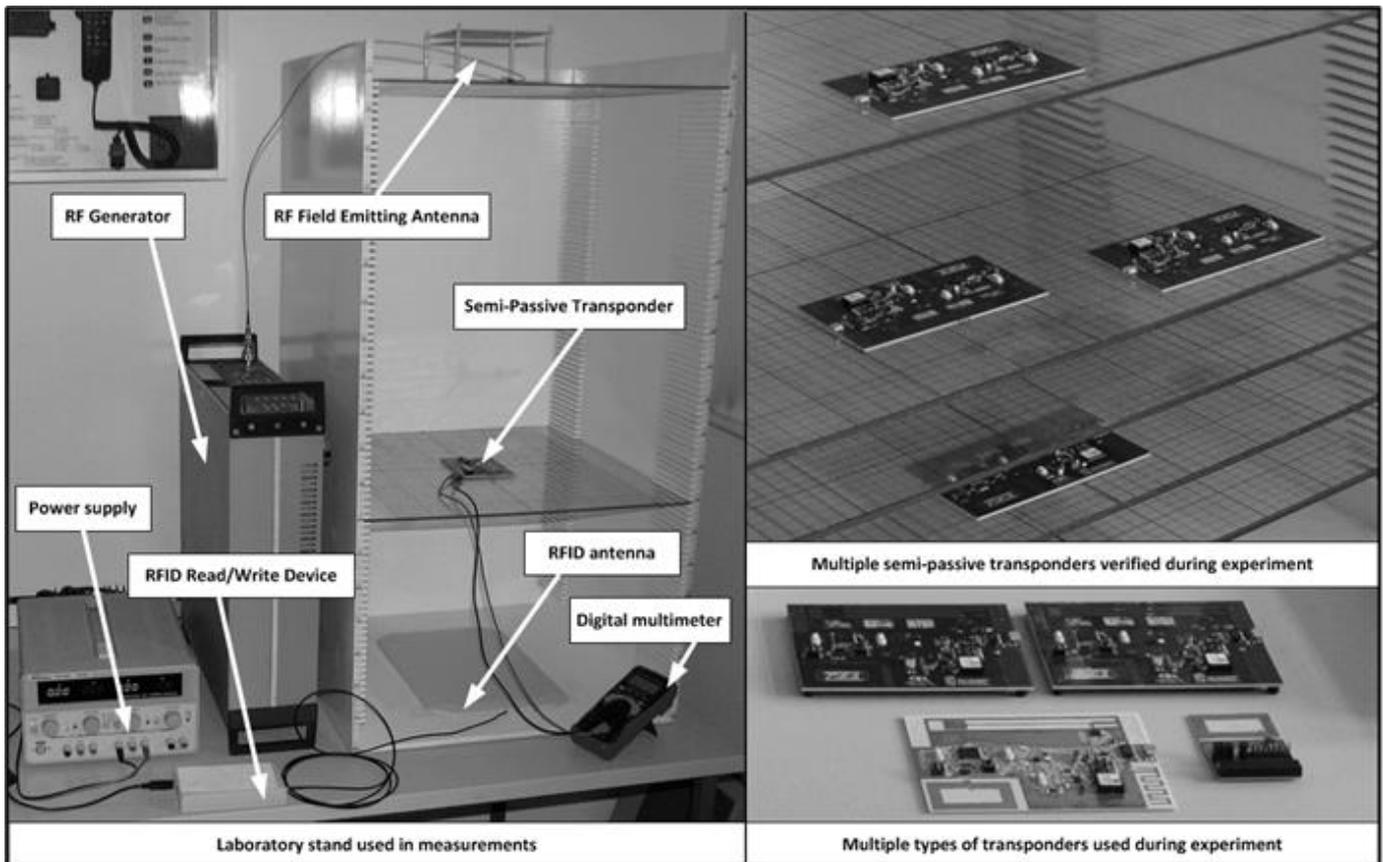


Fig. 3. The laboratory system: a) research stand used in conducted experiments, b) multiple semi-passive transponders verified during experiment, c) examples of transponders used during the experiment.

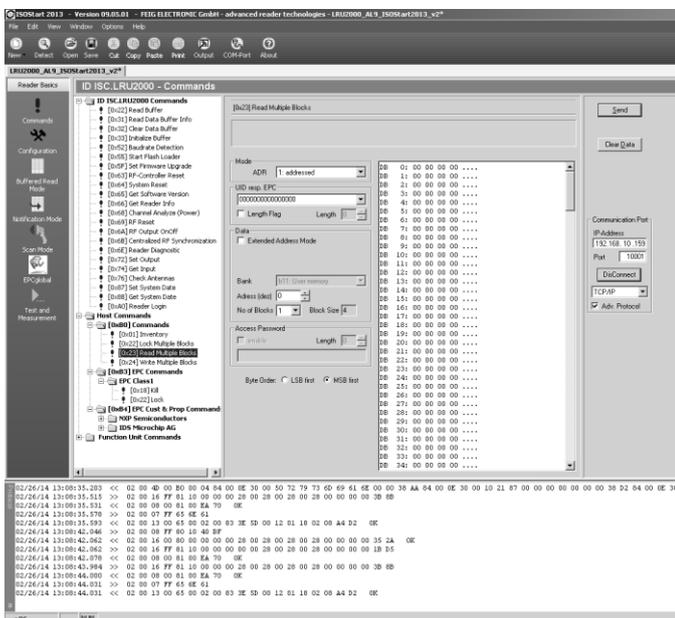


Fig. 4. ID ISOStart 2015 Software used during experiment

In case of semi-passive transponder the carrier wave supplied by RWD is in limited range used to power the chip. It is mainly used for communication. For this reason successful completion of data read process from memory of transponder is conditioned largely by correct interpretation of received RWD commands. It should be clear that thanks to additional power source data blocks can be successfully transferred from

and to transponder in longer range than for passive one working in the same conditions.

Presented considerations apply to the problem of reading memory content by only one transponder located in the Interrogation Zone. Within the planned work it is expected to develop models usable during research of RFID systems with many transponders also under conditions of dynamic change of their location and orientation.

V. CONCLUSIONS

Full usage of the possibilities of UHF band RFID systems using semi-passive transponders requires the use of additional mechanisms of data transfer implemented in communication protocol. In case of the most frequently used passive transponders only data about tagged object can be stored in memory. However in semi-passive solutions thanks to the built-in energy magazine it is possible to implement additional functions such as conducting and processing of measurement data from physical quantities sensors. For this reason the communication process with that kind of transponders is significantly longer than classical read of passive transponders' serial number.

The article addresses the issue of data exchange between RWD layout and transponder located in Interrogation Zone. The article also discusses the different phases of communication and dependences with the use of which length of communication can be determined. It should be

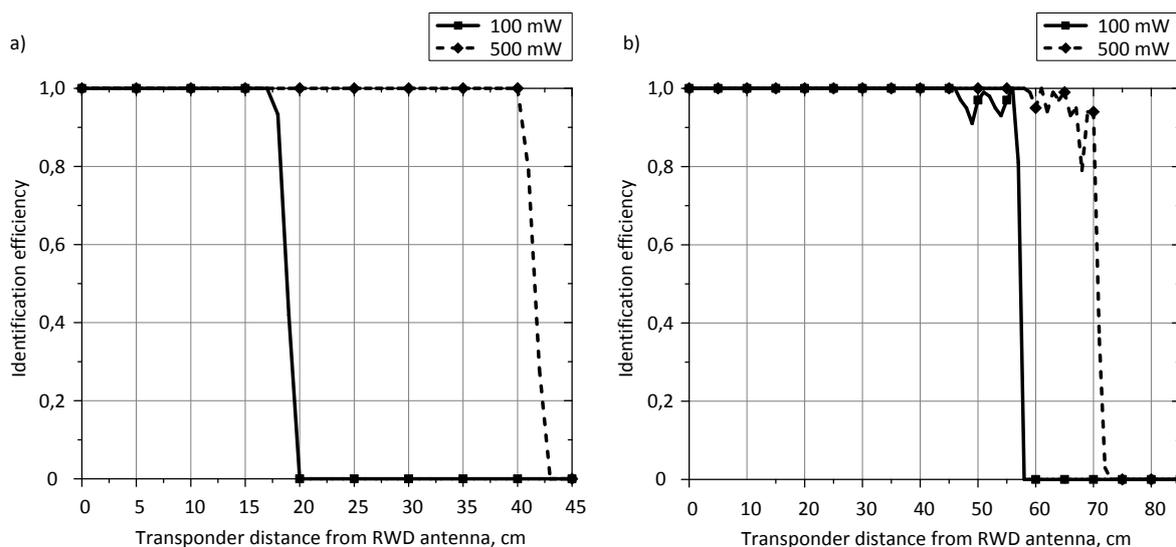


Fig. 5. The effectiveness of identification in dependence on the distance from the RWD antenna in conditions of different power supplied to antenna: a) passive transponder, b) semi-passive transponder.

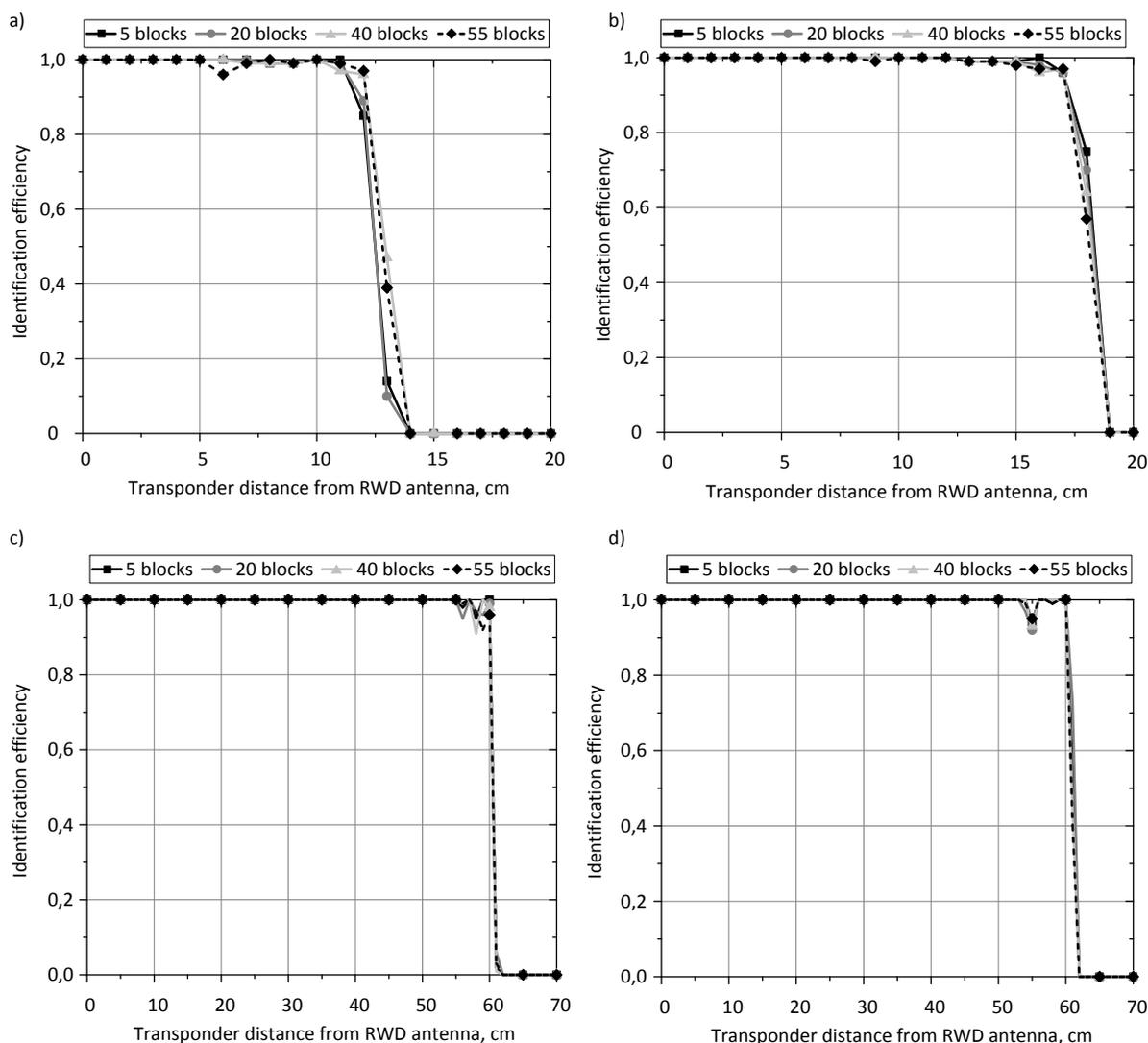


Fig. 6. The effectiveness of identification in dependence on the distance from the RWD antenna in conditions of different quantity of data blocks transmitted by the system : a) data write to passive transponder, b) data read from passive transponder , c) data write to semi-passive transponder, d) data read from semi-passive transponder.

remembered that for full description of phenomena occurring during data exchange in semi-passive RFID system it is necessary to take into account events during communication with multiple transponders (for example during collision) and also in the conditions of dynamic change of their location and orientation in space.

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