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**Information technology — Radio frequency identification for item management — Part 65:
Parameters for air interface communications for streaming sensors based on ISO/IEC 18000-63**

First edition

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Foreword

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This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 31, *Automatic identification and data capture techniques*.

A list of all parts in the ISO/IEC 18000 series can be found on the ISO and IEC websites.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html and www.iec.ch/national-committees.

Introduction

Passive-backscatter Interrogator-Talks-First (ITF) systems comprise Interrogators, also known as readers, and tags. To differentiate the tags in ordinarily ITF system from the functional tags defined in this specification, the functional tag is referred as to streaming sensor. A streaming sensor comprises, at least, a tag, which exploits the backscatter technology to establish the tag-to-interrogator link, and an optional digital sensor. If a stream sensor involves a digital sensor, the tag provides a unique identification number for the digital sensor as well as working as a wireless modem between the interrogator and the digital sensor. Depending on the usage of the system, the interrogator may process, store and pass-through the received data from the tag. General functions as an item management application, specifically inventory, reading and writing tags, are utilizing functionality defined in ISO/IEC 18000-63.

This document is based on ISO/IEC 18000-63. The unique features of this document are to accommodate the backscatter communication capability to various digital sensors and to allow simultaneous communication between streaming sensors and interrogators.

The described backscatter sensor system supports the following system capabilities in addition to the basic capability of ISO/IEC 18000-63:

- allocation of dedicated subcarrier frequency, bitrate and channel coding method to a selected set of streaming sensors;
- start and stop control of continuous data streaming from the set of streaming sensors to the interrogator;
- configuration and read/write of digital sensors from the interrogator through the tag in a streaming sensor.

Information technology — Radio frequency identification for item management — Part 65: Parameters for air interface communications for streaming sensors based on ISO/IEC 18000-63

1 Scope

This document defines the air interface based on ISO/IEC 18000-63 for radio frequency identification (RFID) devices operating in the 860 MHz to 930 MHz used in sensing as well as item management applications.

This document specifies the physical and logical requirements for a passive-backscatter Interrogator-Talks-First (ITF) system.

This document specifies:

- logical and physical procedures between the interrogator and tags to allocate a dedicated subcarrier channel to each of the tags to produce continuous data streaming.
- logical and physical procedure between the interrogator and the tags to start and stop the continuous data streaming.
- logical interface between the interrogator and the tag to configure a digital sensor and to receive data from the digital sensor through the tag.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

- ISO/IEC 18000-63
- ISO/IEC 19762, *Information technology — Automatic identification and data capture (AIDC) techniques — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions giving in ISO/IEC 19762 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1

streaming sensor

streaming sensor comprises a tag and a digital sensor

Note 1 to entry: A tag is essentially a radio frequency integrated circuit to handle bilateral wireless communication with interrogator

3.2

digital sensor

sensor which furnishes a digital interface, particularly SPI in this document

Note 1 to entry: An analog digital converter with digital interface is considered to be a type of digital sensors.

3.3

streaming

continuous data transmission using a dedicated subcarrier signal from a streaming sensor to interrogator

3.4

differential coding

channel coding produced as the differential with respect to the previous symbol

4 Symbols, abbreviated terms and notations

4.1 Symbols

f designated DCO frequency

X 14 bits DCO value

4.2 Abbreviated terms

DCO digitally controlled oscillator

SPI serial peripheral interface

P/S parallel to serial conversion

RSSI received signal strength indicator

SSC streaming sensor configuration

XPC_W1 XPC word 1

4.3 Notations

This document uses the following notational conventions.

— States are denoted as capital.

EXAMPLE STREAMING

— Commands are denoted in italics. Variables are also denoted in italics. Where there can be confusion between commands and variables, this protocol will make an explicit statement.

EXAMPLE *StreamStart*.

5 Streaming sensor

5.1 General

A streaming sensor can produce a continuous sensor data measurement over a dedicated subcarrier channel using streaming data frames. The frequency and the bandwidth of the dedicated subcarrier channel are allocated dynamically after inventory by the Interrogator. A streaming sensor logically comprises a tag and an optional digital sensor typically connected using an SPI interface. A streaming sensor may house more than one digital sensor and use one at a time by specifying the active digital sensor.

Configuration of the tag and the digital sensor in a streaming sensor is performed by writing to a specific memory address with a *Write* or *BlockWrite* command of ISO/IEC 18000-63. Sensor data is collected by the Interrogator as the digital sensor transfers measurements, and the tag maps them into a specific memory address to be read by a *Read* or *BlockRead* command of ISO/IEC 18000-63 for a one-time data capture. Alternatively, the tag assembles the digital sensor measurements into stream data frames. The initiation of streaming is triggered by *StreamStart* command. An on-going data streaming is terminated by *StreamStop* command. If multiple streaming sensors are used simultaneously by allocating different subcarrier channels, concurrent data collection from multiple streaming sensors can be realized.

5.2 Full duplex operation in backscatter communication

Control of streaming sensors, for example to suspend an ongoing stream, by issuing a command from an Interrogator requires a full duplex operation in backscatter communication.

For a streaming sensor to recognize a command while the streaming sensor is actively backscattering and harvesting power, the streaming sensor, specifically the tag in the streaming sensor, continuously samples the incoming signal only when the tag is in the matched states, as shown in Figure 5-1.

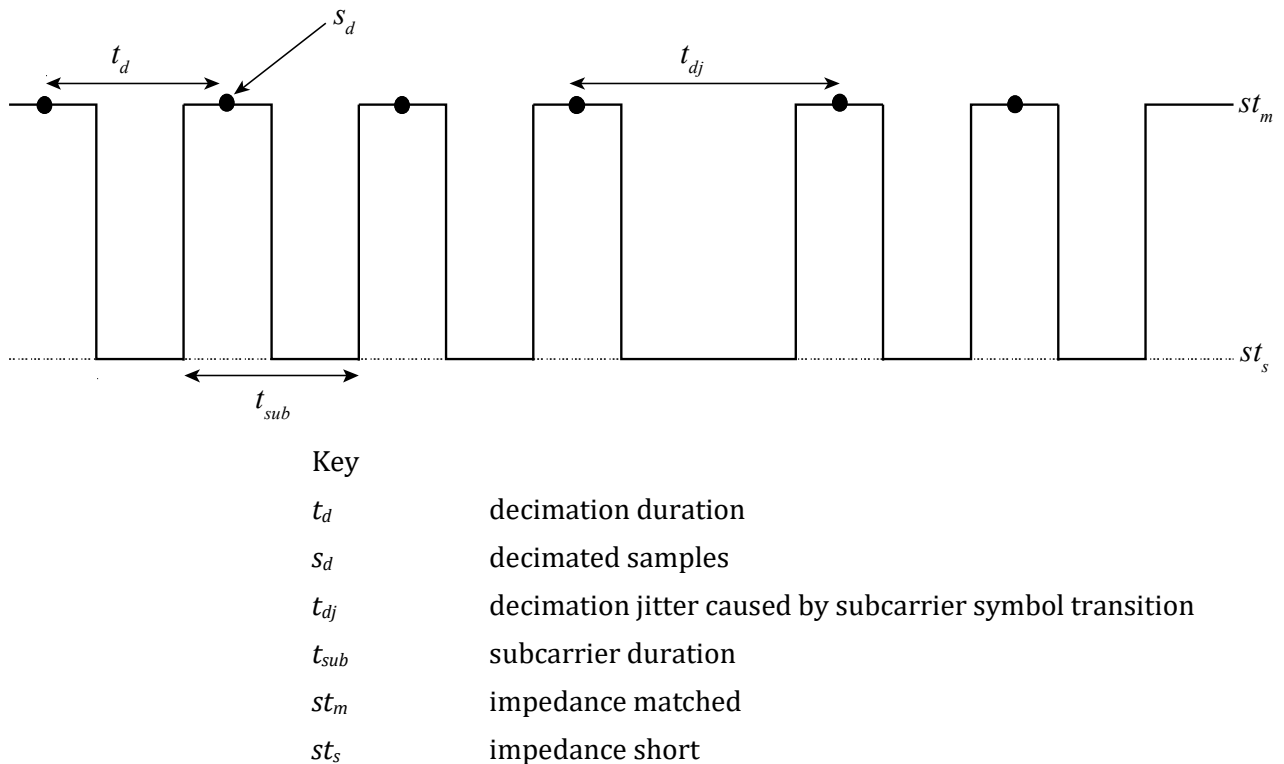


Figure 5-1 — Subcarrier synchronized decimation to realize the true duplex in backscatter communication

Because of the subcarrier symbol transitions, the decimated samples are inevitably subjected to sampling jitter of one subcarrier duration. To mitigate the jitter noise, any command from the Interrogator in the

full duplex operation shall be transmitted with a sufficiently slow symbol rate compared with the subcarrier frequency.

A command in the full duplex operation, such as *StreamStop*, is sent with 10 kHz coded rate with 2,5 kbps bitrates using the encoding shown in Figure 5-2. The nominal modulation index of commands in the full duplex operation is 0,5 to prevent the counterpart streaming sensors from powering down.

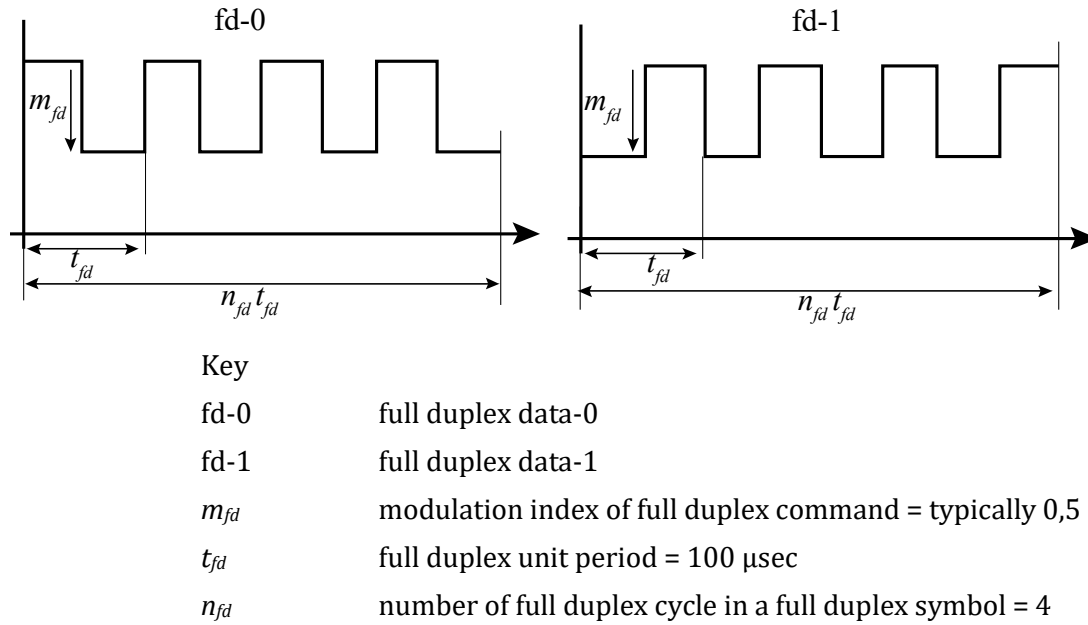
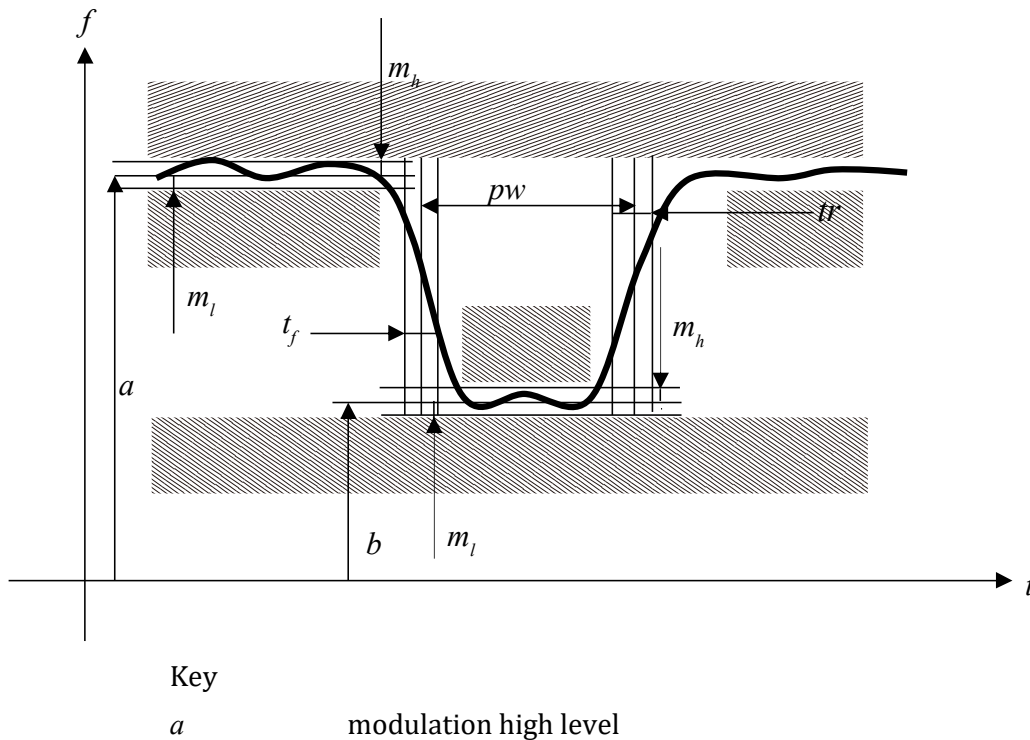


Figure 5-2 — Full duplex command encoding

Encoded commands in the full duplex operation shall be pulse-shaped to suppress unwanted emissions in neighboring frequency channels; the RF envelope shall conform with this. Parameters of RF envelop in the full duplex operation are defined in Figure 5-3. Specification of parameters in Figure 5-3 are defined in Table 5-1.



b	modulation low level
m_l	envelope ripple low level
m_h	envelope ripple high level
t	time
t_f	envelope fall time, 10-90%
t_r	envelope rise time, 10-90%
pw	pulse width measured at $0,5(a+b)$

Figure 5-3 — Interrogator-to-Tag RF envelope in full duplex communication

Table 5-1 — RF envelope parameters in full duplex communication

Parameter	Symbol	Minimum	Nominal	Maximum	Units
Modulation Depth	$(a-b)/a$	40	50	60	%
RF Envelope Ripple	$m_h = m_l$	0		0,05 (A-B)	V/m
RF Envelope Fall Time	t_f			33	μs
RF Envelope Rise Time	t_r			33	μs
RF Pulsewidth	pw	48	50	52	μs

A typical pulse-shaping filter is a raised cosine filter with a roll-off factor from 0,8 to 1,0.

A command in full duplex operation is sent by adding a twenty-two-bit full duplex frame_start pattern, comprising sixteen 0s followed by 101010, and terminated with a four-bit full duplex frame_end pattern, 0000, which is preceded by CRC-5 as shown in Table 5-2. In the Table, 0{16} represents sixteen consecutive 0s.

Table 5-2 – Full duplex command frame

	Full duplex frame_start	Command and Data	CRC	Full duplex frame_end
number of bits	22		5	4
Description	0{16}101010		CRC-5	0000

The data after the frame_start should produce a CRC-5 as follows:

- the generation polynomial is $x^5 + x^3 + 1$;
- the 5-bit register is preloaded with 01001_2 ;
- the data MSB was the input and all the data has been clocked;
- the final 5 bits are inverted to obtain CRC-5;
- for checking, the register filled with 01001_2 all the data, including CRC-5 clocked, and checked if the output is 00000_2 .

5.3 Configuration of streaming sensor

As a streaming sensor works as a Full Function Sensor of ISO/IEC 18000-63, the Full Function indicator (FS) bit 216_n shall be set to 1₂ in XPC_W1 (see 6.3.2.1.2.5 of ISO/IEC 18000-63). The Streaming Sensor

Configuration (SSC) memory pointer shall be implemented in the TID memory at memory word 2A_h MSB first, as in Figure 5-4.

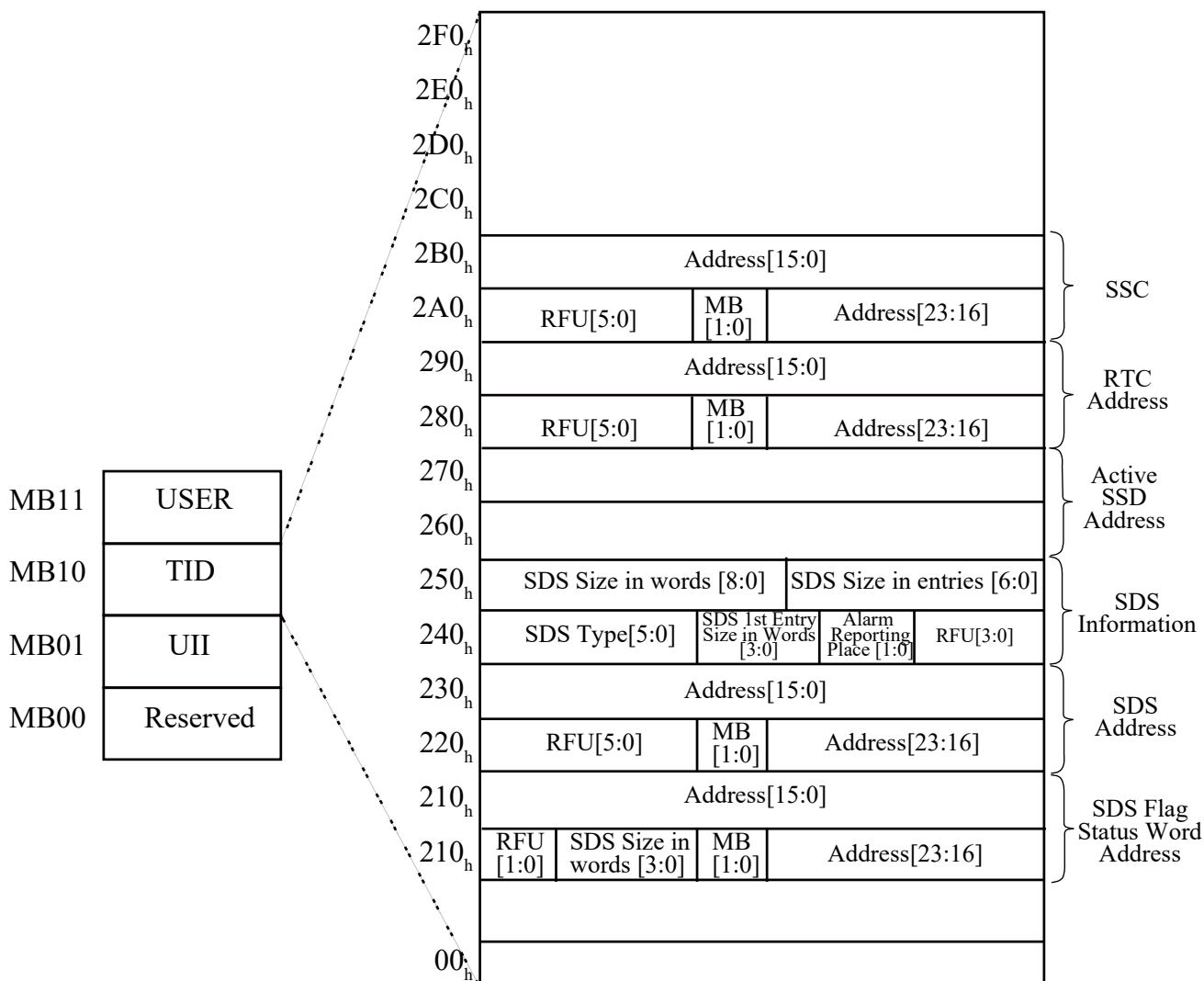


Figure 5-4 — Structure of T-ID memory for stream sensor configuration

The SSC memory pointer shall comprise 6 bits reserved for future use (RFU), followed by 2 bits identifying the memory bank (MB) where the SSC is stored, and a 24-bit field specifying the starting word address of the SSC in linear (non-EBV) format (see Table 5-3).

Table 5-3 – Structure of Streaming Sensor Configuration (SSC) memory pointer

	RFU	MB	Word address
number of bits	6	2	24
description	Reserved for future use	Memory bank selector	SSC starting word address

5.4 Streaming sensor state machine

The state flow for a streaming sensor is shown in Figure 5-5. The typical streaming sensor is first inventoried and then recognized as a streaming sensor as an Interrogator checks the FS bit in XPC_W1. In some application scenarios, target streaming sensors may be recognized by an application using their UIIs.

A dedicated subcarrier channel is allocated to a streaming sensor by writing to the Streaming Sensor Configure (SSC) registers whose leading address is given by the SSC memory pointer in TID memory. After the allocation of a subcarrier channel, the digital sensor configuration, such as sampling rate, sensing range and sensing initiation, is done in the OPEN state. Then, the streaming sensor is moved to the DCO_LOCKED state by a *Write* or *BlockWrite* command to a specific register (DCO_LCK), waiting for a *StreamStart* command. Or the streaming sensor responds to a sequence of *Read/Block Read* or *Write/Block Write* operations to collect data from the digital sensor, to confirm the configuration of the digital sensor or to configure the digital sensor further. When temporal sensor data collection or temporal GPIO control is needed, not in the form of streaming, the Interrogator only needs to issue suitable *Write/Read* commands to specific registers after sensor configuration without moving the state machine to a DCO_LOCKED state.

A streaming sensor moves to a STREAMING state when a valid *StreamStart* command is received. A streaming sensor returns from the STREAMING state to the DCO_LOCKED state when the streaming sensor receives a valid *StreamStop* command or a designated number of stream frames is transmitted by the streaming sensor. State transition table of streaming sensor is given in normative Annex A.

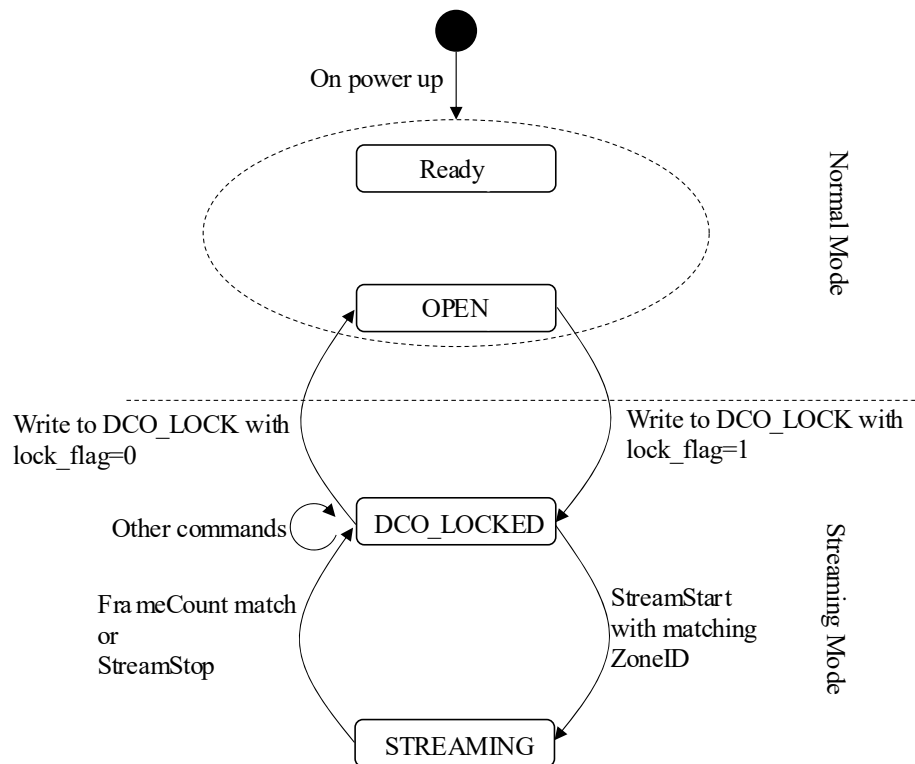


Figure 5-5 — State machine of streaming sensor

5.5 Communication protocol

5.5.1 General

The high-level overview of the communication protocol of a streaming sensor is shown in Figure 5-6. The communication between an Interrogator and streaming sensors follows three stages:

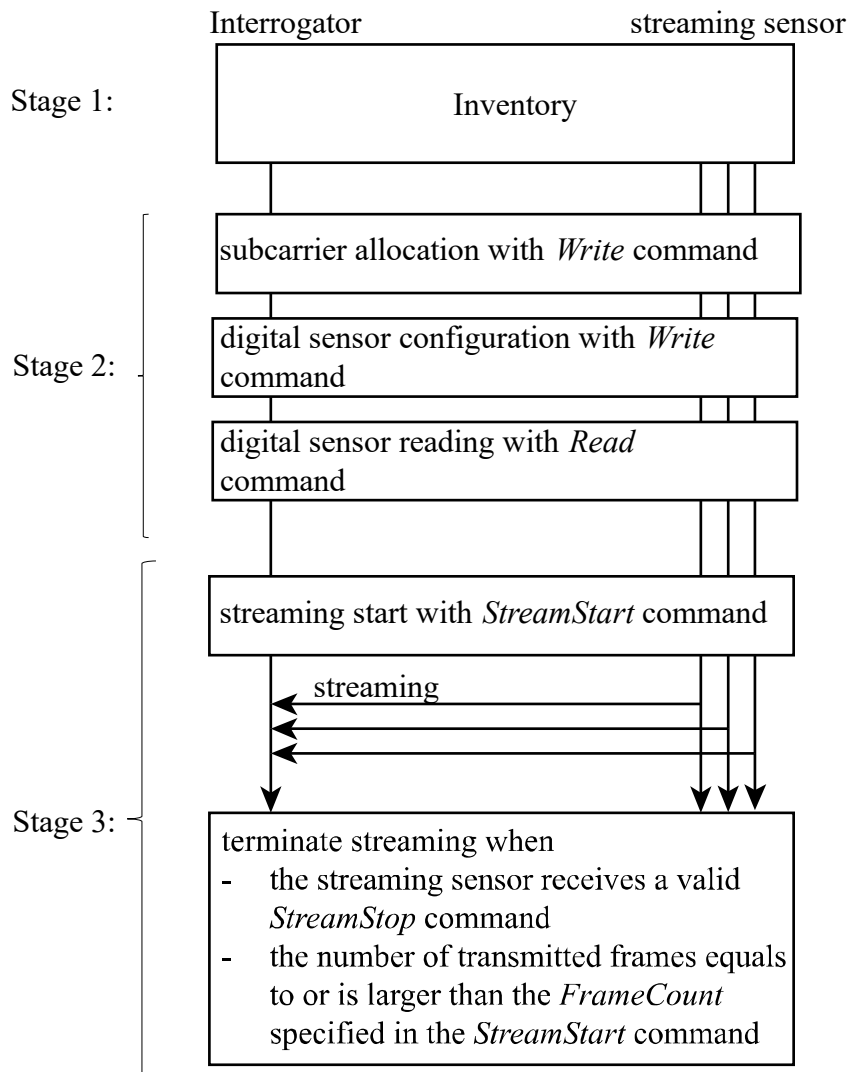


Figure 5-6 – Communication protocol between Interrogator and streaming sensors

- (1) Stage 1 Inventory: In this stage, the Interrogator performs normal inventory operations. Although the algorithm for subsequent subcarrier allocation depends on Interrogator implementation, the collection of received signal strength indicators (RSSI) during the inventory process is recommended to prioritize detected streaming sensors.
- (2) Stage 2 Subcarrier assignment and allocation: A unique subcarrier is assigned¹ and allocated to each streaming sensor using a *Write* or *BlockWrite* command to the SSC. Each streaming sensor is given a zone identification number (zone ID) that distinguishes the corresponding Interrogator. After the subcarrier allocation, the Interrogator can configure the sensor in a streaming sensor using the command encapsulated in the *Write* or *BlockWrite* command. When a subcarrier channel and the sensor configuration are completed, each streaming sensor is placed into the DCO_LOCKED state by writing to DCO_LOCK register, explained in subclause 5.5.2, essentially

¹ Assignment means the determination of subcarrier frequency chosen for a particular streaming sensor. Whereas, allocation means the communication between the reader and streaming sensor that enables setting the assigned subcarrier.

awaiting a *StreamStart* command. Typical command and reply sequences of *Write* and *Read* in Stage 2 are illustrated in Annex C.

- (3) Stage 3 Streaming: To start streaming from all streaming sensors, an Interrogator sends a *StreamStart* command.

Implementation example of streaming sensor is provided in Annex B. Typical command and reply sequence in Stage 3 is given in Annex C.

5.5.2 Writing configuration to tag and digital sensor

The special register addresses used in the configuration of a tag and digital sensor are shown in Table 5-4. The Relative Memory from the SSC column represents the relative memory address from the SSC memory pointer in the TID memory bank. The values should be stored as MSB first byte order.

Table 5-4 – Special register addresses

Memory alias	Description	Relative Memory from SSC
SPI_WRITE	Writes a byte data to the sensor from a tag	00 _h
DCO_CNT	Sets the subcarrier frequency	01 _h
SUB_DIV	Sets the division number of the tag clock and bitrate of the subcarrier	02 _h
SPI_INST	Sets the write and read instruction bytes used in the SPI interface	03 _h
STR_CNT	Specifies the leading address and number of bytes for the sensor to read. Zone ID can also be specified with this command	04 _h
DCO_LOCK	DCO frequency lock and unlock. Unless a tag is in the DCO_LOCKED state, the tag does not produce subcarrier streaming	05 _h
SPI_CNT	The SPI interface is configured through this register to accommodate many types of sensors	06 _h
DEMO_CLK	Division value of subcarrier cycles to sample a <i>StreamStop</i> command	07 _h
SPI_DATA	Leading address of memory to which digital sensor data is transferred and read by interrogator using READ command	08 _h

The definitions of memory aliases are explained in the following subclauses.

5.5.2.1 SPI_WRITE

The high byte and low byte are, respectively, the address and data for a tag to write data to a digital sensor, as shown in Table 5-5. The tag uses a sensor-specific write command specified in the SPI_INST register. Depending on the type of digital sensor, the configuration of the digital sensor is specified through SPI by the Interrogator writing to the SPI_WRITE register.

Table 5-5 – SPI_WRITE register

	Sensor Address	Data
number of bits	8	8

Description	SPI address	Data written to the address
-------------	-------------	-----------------------------

5.5.2.2 DCO_CNT

The DCO_CNT register specifies the subcarrier frequency with coarse, middle and fine-tuning values, as shown in Table 5-10. The three registers allow the implementation of three independent and overlapped digital controllers in a tag.

Table 5-6 – DCO_CNT register

	RFU	Coarse Register	Middle Register	Fine Register
number of bits	2	4	5	5
Description		Coarse tuning register	Middle tuning register	Fine-tuning register

5.5.2.3 SUB_DIV

The SUB_DIV register sets a subcarrier channel frequency and the bit rate by dividing the master oscillator frequency specified by the DCO_CNT register, as shown in Table 5-7.

Table 5-7 – SUB_DIV register

	RFU	Subcarrier decimator	Bitrate decimator
number of bits	6	3	7
Description		Control word to produce subcarrier channel frequency	Control word to produce bitrate

5.5.2.4 SPI_INST

SPI_INST defines the *WRITE* and *READ* command bytes used in the SPI communication between a tag and digital sensor as the tag to be the master. High 8 bits for *WRITE* and low 8 bits for *READ* sensor and tag communication as in Table 5-8.

Table 5-8 – SPI_INST register

	SPI write	SPI read
number of bits	8	8
Description	SPI WRITE command	SPI READ command

5.5.2.5 STR_CNT

STR_CNT defines the data register and the data length to be read from a tag in a STREAMING state, as shown in Table 5-9. The high 8 bits (15:8) is the starting address. Bits (7:4) is the number of bytes minus 1² to be read.

Additionally, STR_CNT can be used to read the digital sensor register value with a *Read* command. Although an SPI sensor register is usually bound by a byte, a *Read* always returns two bytes (one word)

² This “minus 1” is to specify up to 16 bytes of data instead of 15 bytes.

data. Therefore, the number of bytes should be an odd number, such as 1, 3 or 5, and the second byte should be discarded by the Interrogator.

Table 5-9 – STR_CNT register

	Leading address to SPI read	Number of bytes to read	RFU	Zone ID
number of bits	8	4	1	3
Description	Leading address of sensor	Number of reading bytes minus 1		Zone ID in a streaming data frame

5.5.2.6 DCO_LOCK

This register controls the active digital sensor, the state transition of a streaming sensor, and the choice of coding in a streaming data frame, as shown in Table 5-10. When a streaming sensor wakes up or is moved to an OPEN state, the default value of the lock flag is “unlock.” Upon receiving a DCO_LOCK with lock flag 1, the streaming sensor moves to the DCO_LOCKED state. A streaming sensor does not start streaming even when a *StreamStart* command is received if its state is not DCO_LOCKED. The lock flag shall be automatically set to zero when the stream sensor receives *SELECT* or *QUERY* as Figure 5-5.

Table 5-10 – DCO_LOCK register

	RFU	Target sensor	Coding option	RFU	Lock Flag	RFU
number of bits	6	2	2	2	1	3
Description		0 = SPI CS0 1 = SPI CS1	0 = Convolutional coding 1 = Miller coding 2 = Differential Convolutional coding 3 = Differential Miller coding		0: False 1: True	

5.5.2.7 SPI_CNT

This register defines the settings of the SPI interface, as shown in Table 5-11. The default value at reset is 0x0000.

Table 5-11 – SPI_CNTL register

	RFU	ASSL	ACC_OFF	SPI_MODE
number of bits	12	1	1	2

Description		Active slave select level (ASSL), which is chip select (CS) status for an active slave device. 0: Active L level 1: Active H level	Auto Command Code OFF (ACC_OFF) 0: The command code defined by SPI_INST is automatically added to the SPI Write/Read sequence. 1: The command code defined by SPI_INST is NOT automatically added in the SPI Write/Read sequence.	See Table 5-12
-------------	--	--	---	----------------

SPI_MODE specifies the operation mode (clock polarity and phase) of SPI communication as shown in Table 5-12. The tag should set CPOL and CPHA to the following values.

Table 5-12 – SPI_MODE bit field definition

SPI mode	CPOL	CPHA	Data shift timing	Data sampling timing
00	0	0	SCK falling edge	SCK rising edge
01	0	1	SCK rising edge	SCK falling edge
10	1	0	SCK rising edge	SCK falling edge
11	1	1	SCK falling edge	SCK rising edge

CPOL: clock polarity

CPOL = 0 is a SCK that idles at L level

CPOL = 1 is a SCK that idles at H level

CPHA: Clock phase

CPHA determines the timing (i.e. phase) of the data bits relative to the clock pulses.

5.5.2.8 DEMO_CLK

The DEMO_CLK defines the decimation cycles of the given subcarrier frequency to produce the coded symbol rate of command in the full duplex operation, as shown in Table 5-13. The coded symbol rate of the commands in the full duplex operation is 10 kHz toggles. The coded symbol rate is 2,5 kbps, as defined in 5.2. The uncoded High 8 bits are reserved for future use. For example, if the allocated subcarrier frequency is 240 kHz, the divisor shall be set to 0x18(24) to produce the coded full duplex symbol rate, 10 kHz.

Table 5-13 – DEMO_CLK register

	RFU	Divisor
number of bits	8	8
Description		Decimation cycle of allocated subcarrier frequency to produce the coded symbol rate of full duplex command symbol rate

5.5.2.9 SPI_DATA

This register specifies the memory bank and leading address to which digital sensor data is transferred for reading and streaming.

Table 5-14 – SPI_DATA register

	RFU	Leading Address
number of bits	8	8
Description		Word pointer to which digital sensor data is transferred for reading

5.5.3 Streaming data frame

Streaming data is transferred from the streaming sensor to the Interrogator on a continuous streaming data frame shown in Table 5-15. The leading 5 bits, comprising 10 alternating symbols, are the preamble without any encoding. The rest of the frame shall be encoded with either Convolutional, differential Convolutional, Miller or differential Miller coding. The rest of the frame after the preamble shall produce the CRC-16 as follows:

- Generation polynomial is $x^{16} + x^{12} + x^5 + 1$
- 16-bit register preloaded with 0xFFFF
- Data MSB was input, and all the data clocked
- The final 16 bits inverted to obtain CRC-16

For checking, the register filled with 0xFFFF, all the data, including CRC-16 clocked, and checked if the output is 0x1D0F.

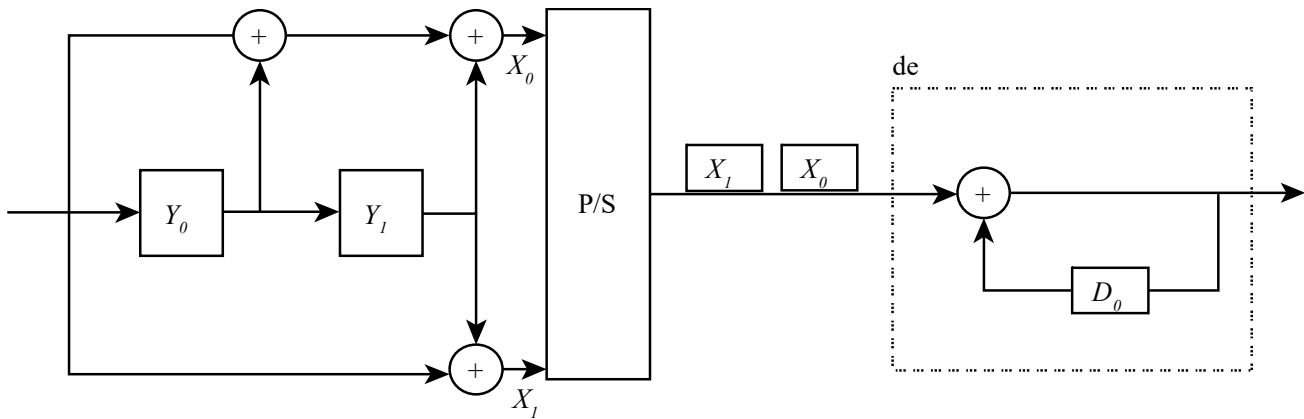
The Interrogator typically specifies zone ID, whereas the sequence ID is the frame ID automatically incremented by one in each frame by the streaming sensor. The data length N is specified by the Interrogator by writing to a special register or is shared with the Interrogator.

Table 5-15 – Streaming data frame format

	Preamble	Zone ID	Sequence ID	Data	CRC 16
number of bits	5	3	8	$16 \times N$	16
description	Alternating 10 symbols 1010101010	Interrogator zone ID	Circulating from 0 to 255 (8 bits)	Data	

5.5.4 Streaming data encoding

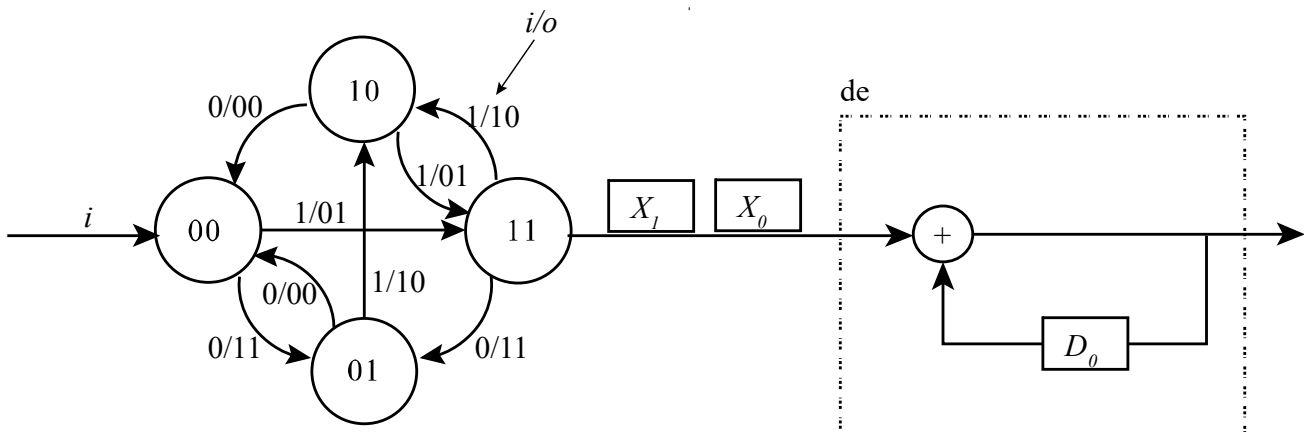
To facilitate the demodulation of the subcarrier channel by the Interrogator, Convolutional coding, differential Convolutional coding, Miller coding, or differential Miller coding could be optionally used in the streaming data frame. The Convolutional coding and Miller coding state model and differential encoder are shown in Figure 5-7 and Figure 5-8.



Key

- de optional differential decoder
- D_o Delayed symbol whose initial value is zero
- X_o encoded symbol 0
- X_1 encoded symbol 1
- Y_o shift register 0
- Y_1 shift register 1

Figure 5-7 — Convolutional coding and optional differential coding



Key

- de optional differential decoder
- D_o Delayed symbol whose initial value is zero
- i input symbol
- o encoded symbols
- X_o encoded symbol 0

X_1	encoded symbol 1
Y_0	shift register 0
Y_1	shift register 1

Figure 5-8 — Miller coding and optional differential coding**5.5.5 StreamStart**

This command triggers the streaming from the designated interrogation zone, which is specified using the zone ID.

Table 5-16 – StreamStart command

	StreamStart	Zone ID	FrameCount	CRC-5
number of bits	16	3	16	5
Description	1110 0010 0000 0110 (0xE206)	Zone ID	number of the frame count to terminate the streaming	CRC-5

StreamStart shall be preceded by a FrameSync. Generally, the *StreamStart* command is issued several times to prevent any designated stream sensor from failing to start. Streaming sensors whose zone ID matches the zone ID in a *StreamStart* command move to STREAMING state. Stream sensors, whose zone IDs are different from the zone ID in a *StreamStart* command, continue to remain in the DCO_LOCKED state. There is no response from a streaming sensor to acknowledge a *StreamStart*.

A streaming sensor counts the number of transmitted streaming data frames with a unit of 256 frames since the triggering *StreamStart* command. The unit FrameCount increment corresponds to one cycle of the eight-bit sequence ID in the streaming data frame. When the number of actually transmitted frames matches the FrameCount, a streaming sensor automatically terminates its streaming and moves to a DCO_LOCKED state. There is no frame count limitation when the FrameCount is set to be all zero, 0x0000.

5.5.6 StreamStop (Full duplex operation)

The Interrogator can suspend ongoing data streaming from a group of stream sensors belonging to a specified Zone ID by issuing a *StreamStop* command in the full duplex command frame defined in Table 5-17.

Table 5-17 – Full duplex StreamStop command

	Full duplex frame_start	Command	Zone ID	CRC	Full duplex frame_end
number of bits	22	8	3	5	4
Description	0{16}101010	11011011 ^a	Zone ID	CRC-5	0000
^a The eight bit opcode of <i>StreamStop</i> , 11011011, does not collide with any eight bit opcode of ISO/IEC 18000-63 interrogator-to-tag link because it is used in the full-duplex operation explained in 5.2. The opcode 11011011 is chosen to follow the command length convention of ISO/IEC 18000-63.					

5.5.7 Subcarrier and bitrate allocation

The 14-bit DCO value defined in Table 5-6 forms overlapped coarse, middle, and fine register values, as shown in Figure 5-9.

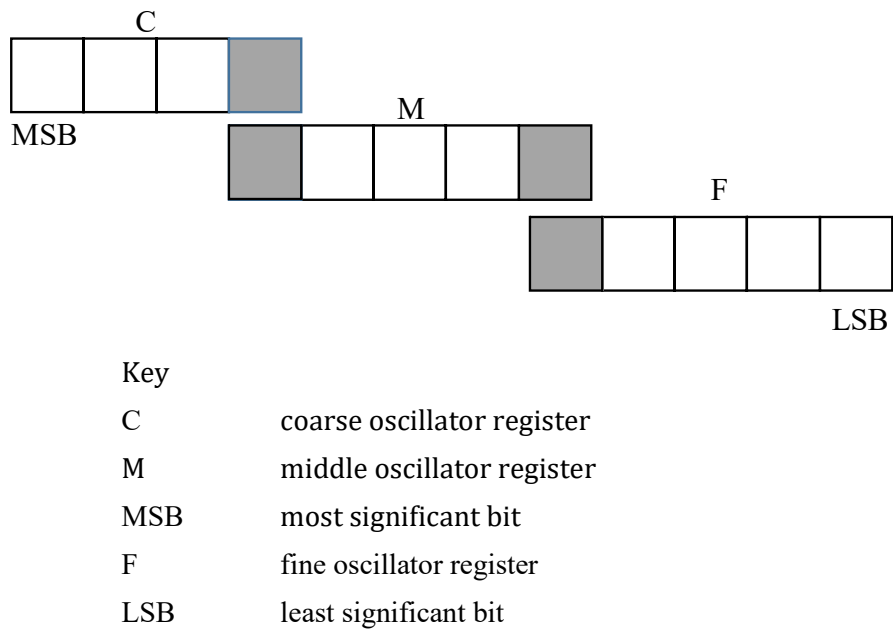


Figure 5-9 – Overlapped DCO_CNT register values

The finest frequency resolution is 400 Hz with an offset of 691200 Hz; a 14-bit value X relates to the actual frequency f as follows:

$$f = 400 X + 691200$$

Consequently, one subcarrier frequency can be represented, in general, with four patterns of register values, thereby allowing deviations in the adjusting accuracy of the three DCO controllers. The choice of a specific register value depends on the implementation.

The subcarrier channel frequency and bitrate can be configured as listed in Table 5-18. Two bitrates, 120 kbps and 40 kbps, are mandatory.

Table 5-18 – Subcarrier frequency and bitrate with DCO_CNT and SUB_DIV registers

DCO control word			CH	divider control word		baseband bit rate (B bits (7bits))				
Code (14bits)				Dividing ratio (3 bits)	sub. Freq (kHz)	120 kbps	100kbps (optional)	40kbps	20kbps (optional)	10kbps (optional)
c	m	f								
0111	11101	10000	1	100	100					0001010
1010	11111	10000	2	100	120				0000110	0001100
0011	10010	10000	3	011	140					0001110
0100	11011	10000	4	011	160			0000100	0001000	0010000
0110	10100	10000	5	011	180					0010010
0111	11101	10000	6	011	200		0000010		0001010	0010100
1001	10110	10000	7	011	220					0010110
1010	11111	10000	8	011	240	0000010		0000110	0001100	0011000
0010	10101	11000	9	010	260					0011010
0011	10010	10000	10	010	280				0001110	0011100
0011	11110	11000	11	010	300					0011110
0100	11011	10000	12	010	320			0001000	0010000	0100000
0101	10111	11000	13	010	340					0100010
0110	10100	10000	14	010	360				0010010	0100100
0111	10000	11000	15	010	380					0100110
0111	11101	10000	16	010	400		0000100	0001010	0010100	0101000
1000	11001	11000	17	010	420					0101010
1001	10110	10000	18	010	440				0010110	0101100
1010	10010	11000	19	010	460					0101110
1010	11111	10000	20	010	480	0000100		0001100	0011000	0110000
1011	11011	11000	21	010	500					0110010
0010	10101	11000	22	001	520				0011010	0110100
0010	11011	11100	23	001	540					0110110
0011	10010	10000	24	001	560			0001110	0011100	0111000
0011	11000	10100	25	001	580					0111010
0011	11110	11000	26	001	600		0000110		0011110	0111100
0100	10100	11100	27	001	620					0111110

Annex A (normative)

State transition tables for Streaming Sensors

A.1 Present state: DCO_LOCKED

Table A.1-1 — Present state: DCO_LOCKED

Command	Condition	Action	Next State
<i>Write</i>	DCO_LOCK register with lock_flag = 0		OPEN
<i>Write/Read</i>		None	DCO_LOCKED
<i>StreamStart</i>			STREAMING

A.2 Present state: STREAMING

Table A.2-1 — STREAMING state-transition table

Command	Condition	Action	Next State
<i>StreamStop</i>	specified zone ID matches	–	DCO_LOCKED
N/A	specified number of stream data packets sent		DCO_LOCKED

A.3 Present state: OPEN

Table A.3-1 — OPEN state-transition table^a

Command	Condition	Action	Next State
<i>Write</i>	Write to DCO_LOCK with lock_flag =1		DCO_LOCKED
^a Open state-transition after receiving commands other than <i>Write</i> to DCO_LOCK follows Table B.16 of ISO/IEC 18000-63			

Annex B
(informative)

Stream Sensor implementation guide

B.1 Stream Sensor Configuration

B.1.1 Subcarrier allocation and bitrate configuration

Generally, the tag design to generate the subcarrier frequency in a streaming sensor falls under the scope of the tag manufacturer. However, there is a proven way to generate a specified subcarrier frequency with a relatively slow clock rate of the master clock in a tag by adjusting the frequency of the oscillator in a tag to be an integer multiple of a designated subcarrier frequency; this is done using a digitally controlled ring oscillator (DCO). Alternatively, a subcarrier frequency can be produced by decimating a single master clock in a tag. However, in such a design, a high subcarrier frequency tends to involve bias, which may violate the subcarrier accuracy requirement.

As the subcarrier frequency produced by a streaming sensor does not immediately match the specified frequency owing to the instability of the DCO clock in practice, the following communication protocol performs an iterative adjustment wherein two commands, DCO_CNT, are used repeatedly as shown in Figure B.1. The DCO_CNT register defined in 5.5.1 specifies the clock frequency, whereas the SUB_DIV register specifies the decimation ratio to produce a subcarrier frequency from the DCO clock and defines the bitrate as in Clause 5.

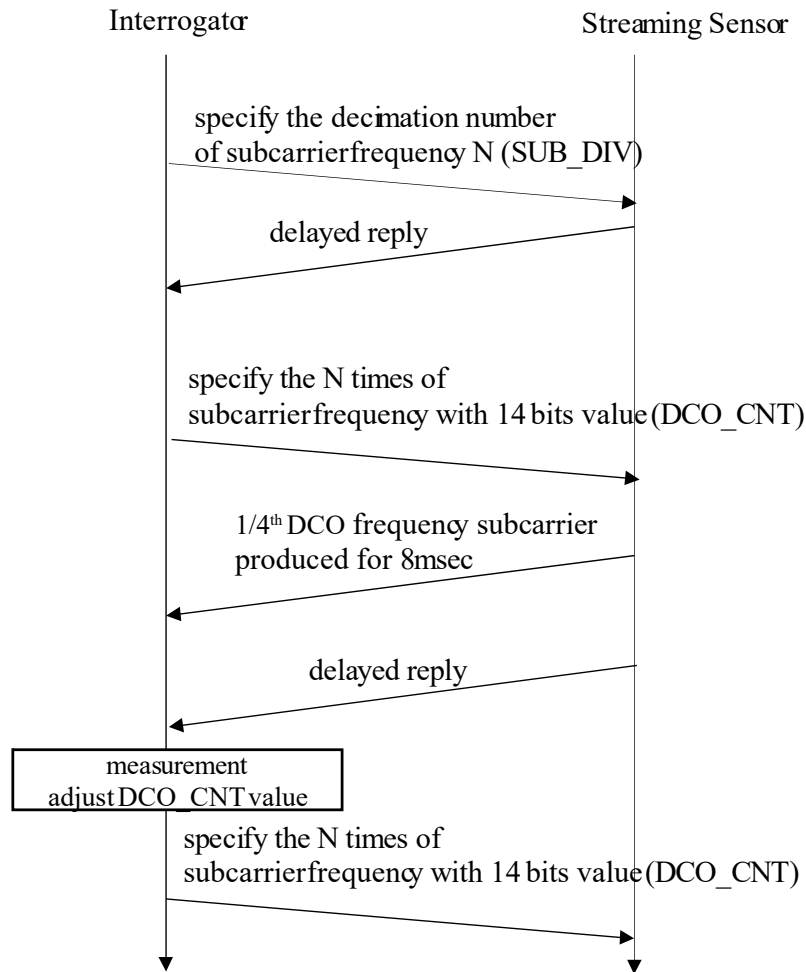


Figure B.1-1 — Iterative subcarrier frequency allocation

B.1.2 Subcarrier frequency and bitrate allocation example:

Assuming that an Interrogator allocates a 200 kHz subcarrier channel to a stream sensor after inventory, the DCO frequency of the stream sensor should be 1.6 MHz according to Table 5-18. For DCO control, the Interrogator expects to receive a 400 kHz (1/4th DCO) subcarrier frequency for a predefined time period after issuing a DCO_CTL. The choice of 1/4th DCO is a vendor-specific value.

- (1) The DCO_CTL is 0111 11101 10000. Suppose that the received subcarrier frequency is 404000 Hz, which is approximately 1 % higher than the designated frequency. Therefore, the Interrogator lowers the tag's clock by approximately 1 %.
- (2) The Interrogator knows that the DCO frequency is 1.6 MHz, and the received subcarrier frequency is multiplied by four. This yields $1616 = 404 \times 4$ kHz, which is 16 kHz higher than the designated frequency. The DCO frequency is adjusted with 0.4 kHz resolution for 1 bit of DCO fine division.
- (3) The bias of 16 kHz can be compensated with $16/0.4 = 40 = 0 \times 28 = \text{b0010 1000}$, which is subtracted from the original DCO_CTL = 0111 11101 10000. This yields a 0111 11100 01000 register value.

B.2 Sensor data streaming implementation

The tag in a streaming sensor should collect digital sensor data through its SPI interface and assemble the data into the streaming data frame. A simple implementation to transfer the data obtained from a digital sensor are synchronously transferred to the backscatter modulator, as shown in Figure B.2-1.

This can be done by providing the bitrate-level SPI CLK signal from a tag to a digital sensor. The register address of digital sensor, which contains desired data and the number of outputs bytes are specified with STR_CTL register. The output bytes are copied to SPI_DATA register for normal mode reading and streaming.

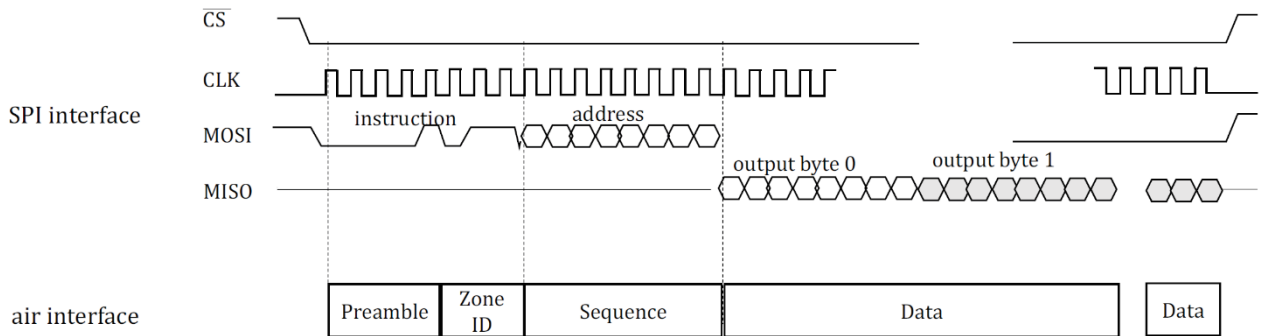
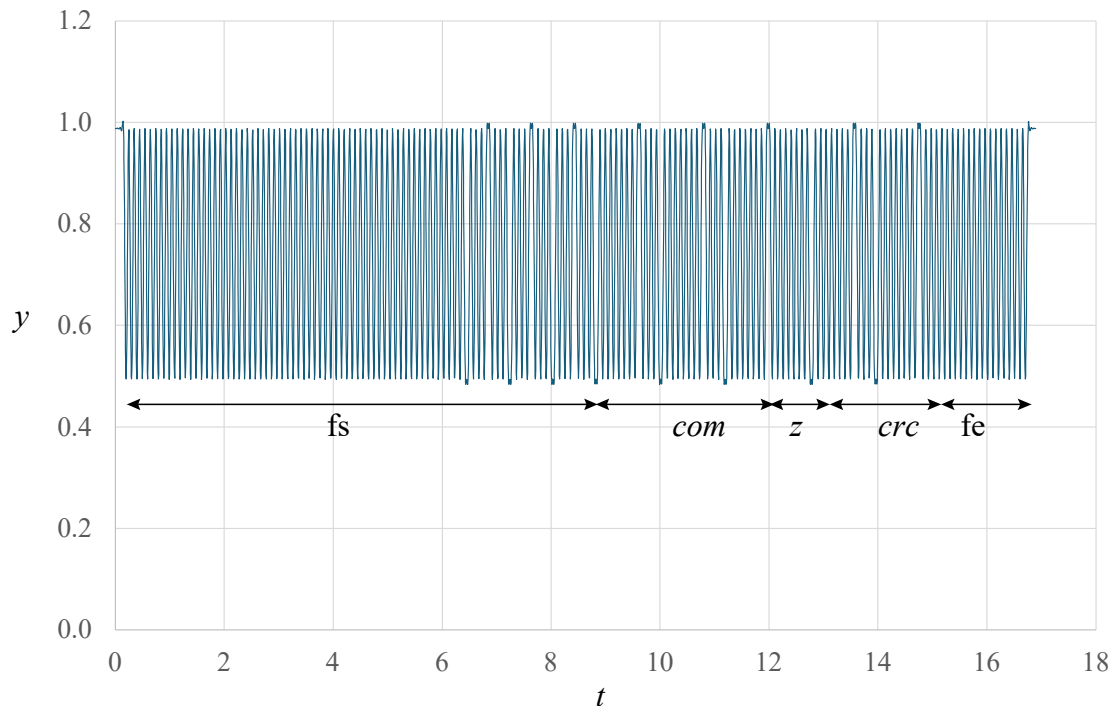


Figure B.2-1 — Sensor data exchange between SPI and air interfaces

B.3 *StreamStop* command waveform example

An example of the waveform of a *StreamStop* command can be produced by using a raised cosine filter with a 1.0 roll-off factor, as shown in Figure B.3-1, which comprises zoneID = b'1 and CRC5 is b'10110.



Key	
com	command
crc	CRC5
fe	frame end

fs	frame start
t	time in milli-second
y	envelope amplitude
z	zone ID

Figure B.3-1 —Example *StreamStop* command wave shape.

Annex C

(informative)

Write and Read command and reply sequence in Stage 2

Typical command and reply sequences for *Write* and *Read* operations in Stage 2 of air protocol between Interrogator and Streaming sensor are illustrated in Figures C.1 and C.2. Other sequences using commands such as *Flex_Query* and *HandleSensor*, and repetition of a sub-sequence can be employed depending on the use case.

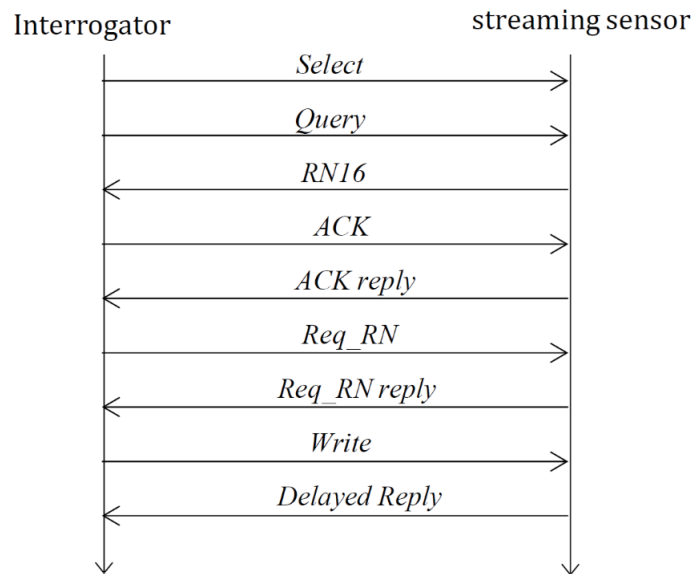


Figure C.1 — Typical *Write* command and reply sequence in Stage 2

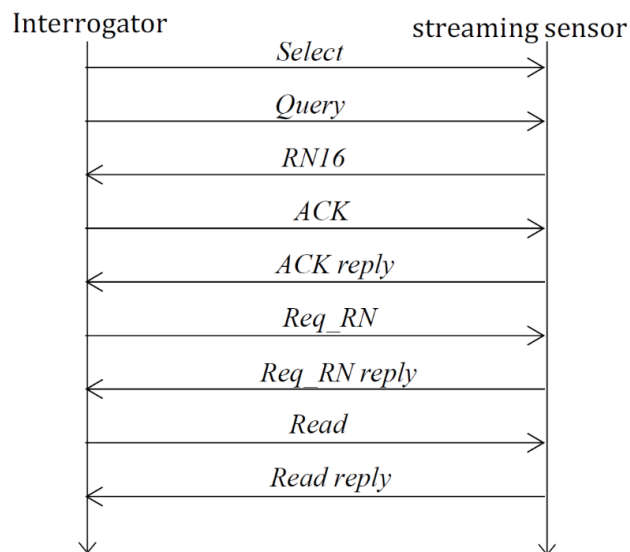


Figure C.2 — Typical *Read* command and reply sequence in Stage 2