ELEKTROBIT LTD.

Sequence DT10

User's Manual

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STATEMENT OF COMPLIANCE

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur on a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one of more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and the receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for assistance.

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1. INTRODUCTION

This chapter is a short description of the Sequence DT10 high data rate radio modem and gives some ideas of its possible application.

1.1. Sequence DT10 High Data Rate Radio Modem

The Sequence DT10 is a high data rate radio modem designed for high speed reliable wireless point-to-point data links. The modem is the answer for numerous data transmission needs ranging from intelligent transportation systems to surveillance applications in industrial sites, from process control to automatically guided vehicles. The Sequence DT10 is the best solution in any harsh or mobile environment where the use of cables is not practical.

The transceiver operates in the 2.4 GHz ISM band (ETS 300 328) and uses direct sequence spread spectrum technology. The use of the ISM band is license free in Europe, North America, Australia and most of the Asian states, which makes introducing the wireless data link as simple as possible.

Typical range of the modem with omnidirectional vertical antennas is up to several hundred meters line-of-sight. The modem communicates with host equipment through an asynchronous serial interface using a modified set of standard (modem) "AT commands." With these commands the host is able to change communication parameters, send broadcast messages and make a call to a remote modem.

The communication between the radio modems is based on packets. The physical layer of the communication is compatible with the IEEE 802.11 draft standard for wireless LANs.

[photograph: Sequence DT10]

1.2. Typical Applications

The Sequence DT10 is a radio modem designed for reliable point-to-point or point-to-multipoint high speed data rate communication. Typical applications include data communication from moving platforms with elimination of signal cabling in industrial and transportation environments, temporary and/or backup communication for wired lines, etc.

[drawing: principal communication arrangements]

2. INSTALLATION

This chapter explains how to set up a data link with the Sequence DT10 radio modems, details extra equipment which may be required, and describes how the modem should be installed.

2.1. Package Contents

The basic package includes:

- Sequence DT10 radio modem;
- User's Manual;
- Registration Card.

To set up a data link at least two Sequence DT10 modems are necessary.

NOTE: To ensure availability of warranty and service, please fill out and return the registration card.

2.2. Other Equipment

Besides the modems illustrated above, other equipment and software is necessary to set up a data link.

2.2.1. Antenna

Each modem requires an antenna. Depending on the environment and distance, an omnidirectional vertical, directional, or special antenna may be selected. Review the antenna specifications.

[photos: typical antennas]

Fig. 2.1 Omnidirectional antenna for interior use and short distances (Cushcraft TN 2400 SRX)

Fig. 2.2 Antenna for mobiles (AV1479)

Fig. 2.3 Antenna for depots (AV2492)

2.2.2. Antenna Cable

Depending on the installation, it may not be possible to simply use a vertical antenna connected directly to the modem. A cable between the modem and antenna is frequently necessary. See specifications.

[photo: antenna cable]

Fig. 2.4 Antenna cable for mobiles (TNC-TNC, RG223, 3-5 m)

[photo: antenna cable]

Fig. 2.5 Antenna cable for depots (N-TNC, RG223, 10 m)

2.2.3. Plug-in Net Adapter

Unless the modem is powered through the serial connector or by a special power supply, a net adapter is necessary which matches the available line voltage and is equipped with a 2.1 mm DC Plug. See specifications.

[photos: EU, US, UK plug in net adapters]

Fig. 2.6 Plug-in net adapters (Mascot Type 8311)

2.2.4. RS-232 / RS-485 Adapter

If the host computer or terminal does not have RS-485 port, an RS-232/RS-485 adapter is required. See section 2.4 for the description of connectors and pins.

[photo: RS-232 / RS-485 Adapter]

Fig. 2.7 RS-232 / RS-485 Adapter (ICC 11)

2.2.5. Cables

The cables from modems to the host computers or terminals are normally not included in delivery. See section 2.4.1 for connector and pin descriptions.

2.3. Software

The Sequence DT10 incorporates all necessary software for transmitting and receiving data between modems.

The user is responsible for software used for sending and receiving data on the modem's serial connector in order to communicate with the host equipment.

2.4. Locating and Connecting the Equipment

2.4.1. Locating the Modems

The modem should be located inside a building or a vehicle cabin, and should be fastened firmly to a permanent surface.

[picture: modem screwed on the base]

Fig. 2.8 Sequence DT10 installed

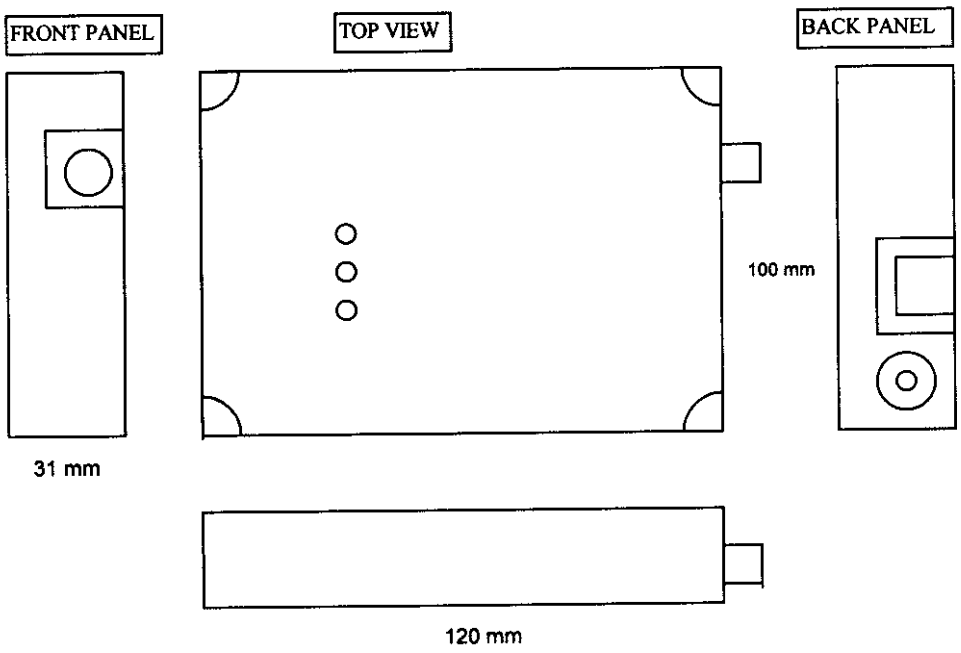

Fig 2.9 Mechanical dimensions of Sequence DT10

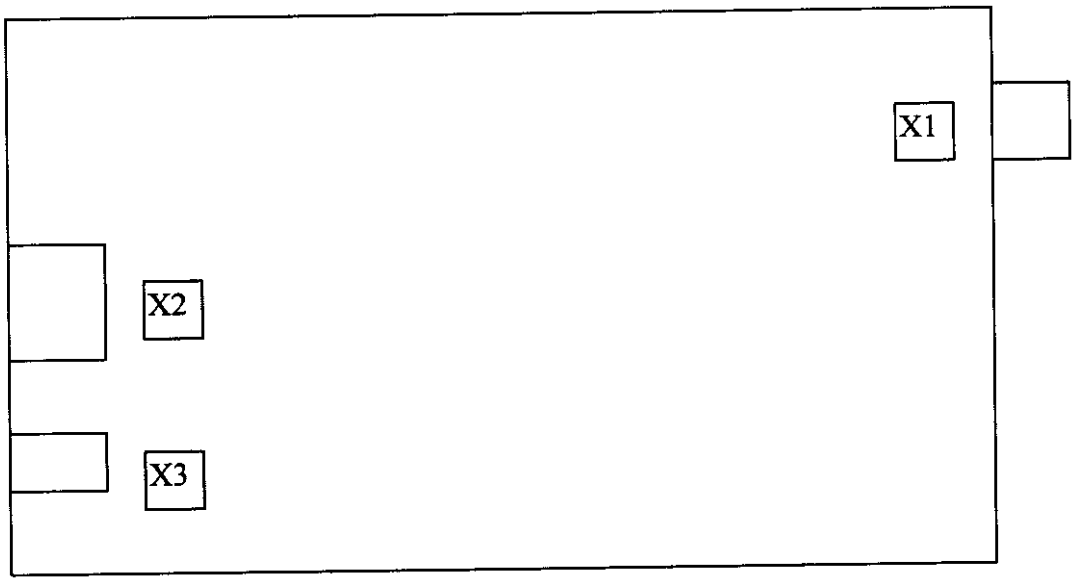

Fig 2.10 Connectors

Connector	Signal	Description
X1	ANT	RF in / out, 50 ohm TNC
X2	Interface	Modular connector 8 pin
X2-1 (next to conn. X3)	TXD_A	TX data RS-485 A
X2-2	TXD_B	TX data RS-485 B
X2-3	RXD_A	RX data RS-485 A
X2-4	RXD_B	RX data RS-485 B
X2-5	nc	
X2-6	VCC	+8V ... +16V
X2-7	GND	Ground
X2-8	GND	Ground
X3	Power	DC jack, 2.1 mm
X3-1 (outer contact)	VCC	+8V ... +16V
X3-2 (inner contact)	GND	Ground

Note that X3 is not used when power is supplied through the X2 pins, and vice versa.

2.4.2. Locating the Antennas

Try to locate the antenna so that there is line-of-sight to the remote modem's antenna. Fasten the antenna firmly to a permanent fixture.

[photo or picture: antenna fastened]

Fig. 2.11 Antenna fastened

2.4.3. Connecting the Antennas

The simplest antenna installation is to simply screw the omnidirectional antenna onto the modem body.

Sometimes the antenna must be located outside the building or vehicle cabin. To locate an antenna away from the modem, a cable is used between the modem and antenna.

2.4.4. Power Connection

There are three options for supplying power to the modem:

1. The standard plug-in net adapter with 2.1 mm DC Plug;
2. Supply DC power from a supply of your own, using a 2.1 mm DC Plug for the connection;
3. Supply the power via the 8 pin modular serial connector. (For the pin arrangement see section 2.4.)

There is no power on/off switch on the modem.

2.4.5. Use of RS-232 / RS-485 Adapters

If the host computer or terminal does not have RS-485 connector, an RS-232/RS-485 adapter may be required. See section 2.4 for the connector and pin description.

2.4.6. Connecting the Signal Cables

Connect the signal cables to the serial inputs of the modems.

3. START-UP

This chapter gives basic information how to set up a communication link with Sequence DT10 radio modems.

3.1. Factory Default Settings

The factory default settings are given in section 4.4. In order to set up an initial link, no changes for default values are necessary.

3.2. Point-to-Point Link with Two Modems

Before data can be sent and received with the modems, a connection must be established between them. See section 4.4 for further details.

If there is a single pair of modems in the area the communication is simple. Data is sent to the serial port of modem 1. This modem transmits the data to modem 2, then the data can be read from the serial port of modem 2.

3.3. Point-to-Multipoint Communication

If more sophisticated communication than just one link is desired, the user is responsible for the communication system design. Detailed information on how to use the modem for this purpose is available in chapter 4.

The communication system may treat one modem as a master and the others as slaves. In this scheme, the master is responsible for polling the system slaves. All modems sharing the same channel will receive poll messages. And the connection for a data transfer is established between the master and the slave with a specific address selected by the master.

3.4. Channels

It is possible to use different channels in order to build up separate modem networks in the same geographical area. See chapter 4 for further details.

4. MODEM OPERATION

This chapter provides the basic information necessary to operate and tune communication with the Sequence DT10 high data rate radio modems. The user should design an appropriate communication strategy and how to apply the modems within that framework. Thus, no detailed design directions are given here.

4.1. Functional Description

4.1.1 States of operation

The operation of the Sequence DT10 modem depends on its operational state. The states are as follows:

1. after hardware reset the modem goes to the Start-up state, where it conducts self-tests and prepares itself for operation;
2. when the start-up function is completed, the modem goes to the Off-line state, where it is ready to accept commands from the host and exchange handshaking messages with a remote modem;
3. when a connection to a remote modem is established, the modem enters the On-line state, during which it passes data between the host controller and the remote modem;
4. when the connection to the remote modem is aborted or lost, the modem returns to the Off-line state;
5. when in the Off-line state, the host is able to command the modem to the Test state for execution of various test scenarios.

These operational states are more precisely described in the following sections.

4.1.2. Start-up state

The modem enters the Start-up state immediately after hardware reset. The hardware reset may be caused by power application or by an internal watchdog timer.

The Sequence DT10 modem has start-up software in flash memory. This software is programmed to the flash memory during production and cannot be changed by software update process. The start-up code includes the following functions:

1. self-test of the modem;
2. verification of flash memory for operational software;
3. download of operational software from the host controller.

During the modem self-test, the green and red LEDs are off. After the self-test, the green LED turns on and the red LED indicates the result of the test. If the test fails, the red LED is turned on and the error code can be read by the host computer. If the test is passed, the

start-up code begins to check the flash memory for operational software. If the operational software is found, then control is passed to that software. However, if there is no operational software in the memory, the start-up software continues running and the host is able to download new operational software to the modem.

4.1.3. Off-line state

The modem enters the Off-line state when the operational software gains control after start-up or when returning from On-line state after a connection is aborted.

While in the Off-line state, the modem will accept commands from the host controller and is ready to receive messages from remote modems. The command set of the modem is a modified subset of Hayes "AT commands," which are widely used with telephone network modems. These commands are described in section 4.4. The messages passed between Sequence DT10 modems in the Off-line state are handshaking messages for connection set-up and broadcast messages, which are used by the master station to poll slave stations inside the coverage range. These messages are described in section 4.6.

4.1.4 On-line state

The modem enters the On-line state when a connection to the remote modem is successfully established. The connection set-up procedure is started when the host controller sends the Dial command or when the Call message is received from the remote modem.

While in the On-line state, the Sequence DT10 modem collects data from the host controller into data packets and sends the data packets to the remote modem. The packets are acknowledged by the receiving modem and the data is forwarded to the host controller. The Sequence DT10 modems are responsible for transmission of the data packets without errors over the radio interface. In case of transmission errors the packet is re-transmitted.

The On-line state is aborted and the modem is returned to the Off-line state when the host controller sends the escape sequence ("+++") or when the connection to the remote modem is lost.

4.1.5. Test state

The modem enters the Test state when the host controller sends the "&Tn" command to the modem. There are three kinds of tests:

1. Transmit test (&T1): the test modem transmits continuous test data to the radio interface;

2. Loopback test (&T3): the test modem retransmits all the data it receives from the radio interface;
3. Transmit/Receive test (&T4): the test modem sends packets of test data to the radio interface and receives the packets looped back by a remote modem. The test modem counts the transmitted packets and the errors from the received packets and sends the counter values to the host controller every 2 seconds.

The Test state is aborted by the host controller with "&T0" command.

4.2. Initialization

The microprocessor of the radio modem initializes the baseband signal processor to use a set of default (saved) parameters in its operation. So, after switching on the power, the modem is ready for operation without any external commands or explicit initialization. The host equipment is able to change these parameters by sending messages with new parameters to the radio modem. The parameters are saved, by command, in non-volatile memory.

4.3. Communication

The radio modem communicates with the host equipment using a modified set of standard "AT commands." With these commands, the host is able to change communication parameters, send broadcast messages and make calls to a remote modem. The host interface of the modem is described in section 4.4.

The communication between radio modems is based on packets. The physical layer of the communication is compatible with the IEEE 802.11 draft standard for wireless LAN's. The radio interface is described in section 4.6.

Transmission is not possible if the radio channel is occupied. If transmitting is requested while the channel is busy, the radio module will wait until the channel is free before starting the transmission.

4.4 Interface to the Host Controller

4.4.1 Physical interface

The interface between the Sequence DT10 modem and the host controller is an asynchronous serial interface using RS-485 signals. Only the data signals (TxD from host to modem, and RxD from modem to host) are used. The maximum data rate is 115.2 kbps. The data format is 8 data bits, no parity, and 1 stop bit. Hardware flow control cannot be used in this interface.

4.4.2 Command set

The Sequence DT10 modem is controlled with a modified set of Hayes "AT commands." These commands are allowed only in the Off-line state of operation (except the "+++" escape sequence which is used to abort the On-line state). Every command (except "+++") must begin with the "AT" prefix and be terminated by a Carriage Return (or keyboard Enter button) entry. The list of available commands is shown below. The default values are marked with an asterisk (*) where defined.

List of commands:

Command	Description
A	Manual answer
AT	Command prefix that precedes command line
C	Broadcast poll command C0 Send broadcast poll C1 Send poll answer (Both commands are followed by data to be sent.)
D	Dial command, followed by address ("phone number") of the called modem
En *	Off-line state local echo control E0 Echo OFF E1 Echo ON
Fn *	On-line state local echo control F0 Echo OFF F1 Echo ON
In	Information display I7 Display version number I8 Display self-test results
Qn *	Result codes displayed/suppressed Q0 Display result codes Q1 Quiet mode, display no result codes
Sr=n	Set S-register r to value n, see list of S-registers

Sr?	Display contents of S-register r
U	Start software update
Vn	Verbal/numeric result codes (see list of result codes below)
	V0 Numeric codes
*	V1 Verbal codes
Yn	Select power-on/reset default configuration
	Y0 default is &F0 - Factory default configuration
*	Y1 default is &F1- Configuration stored in non-volatile memory
&Fn	Load configuration
	&F0 Load factory default configuration
*	&F1 Load configuration stored in non-volatile memory
&Tn	Test modes (see section Test state in functional description)
	&T0 End testing
	&T1 Tx test
	&T3 Loopback test
	&T4 Tx/Rx test
&W	Store active configuration to non-volatile memory
+++	Escape from On-line state to Off-line state

List of S-registers:

Register	Default	Range	Function
S0	0	0-1	Auto-answer disabled(0)/enabled(1)
S2	43	0-127	ASCII code for escape character
S3	13	0-127	ASCII code for Carriage Return character
S4	10	0-127	ASCII code for Line Feed character
S5	8	0-127	ASCII code for Backspace character
S22	17	0-127	ASCII code for XON character
S23	19	0-127	ASCII code for XOFF character
S51	**	0-65535	Modem address
S52	65535	0-65535	Broadcast address
S53	0	0-4	Start of frame delimiter number

S54	8	1-13	Channel number
S55	0	0-4	Spreading sequence number
S56	0	0-4	Scrambling sequence number
S57	0	0-1	Modulation method DBPSK/DQPSK
S60	x	0-65535	hardware-reset counter
S61	x	0-65535	Tx packet counter
S62	x	0-65535	Re-transmit counter

**: The factory default value for the modem address is the last five digits of the modem's serial number.

Registers S53 - S57 are used to select parameters from predefined lists. These selections have to be same in all modems communicating with each other. The definitions for selections are given in the radio interface description (section 4.6).

Registers S60 - S62 are counters which are updated by the modem. These counters can be read and cleared by the host. Setting these registers to any value other than 0 is not allowed and will lead to an ERROR result code from the modem.

List of result codes:

Numeric	Verbal
0	OK
1	CONNECT
2	RING
3	NO CARRIER
4	ERROR
7	BUSY
8	NO ANSWER
9	POLL C REC
10	POLL A REC

4.4.3 Command and response formats

The "AT commands" are given in command lines starting with an "AT" prefix and ending with Carriage Return. The line may contain several commands, and the maximum length of a command line is 128 characters.

AT[cmd][cmd][cmd]... [cmd]<CR>

Commands may be either uppercase or lower case, not a combination. The Backspace character can be used to delete previous characters. Spaces may be used between commands, but is not required.

The modem parses the command line starting from the "AT" prefix. If an illegal command or value is found, the parsing is ended and an ERROR result code is returned. All commands prior to the illegal command are executed.

The broadcast poll commands "AT Cn" are followed by the data to be sent in the poll messages. The format for these commands is:

ATCn<data bytes><CR>

The result code is returned after the command line has been executed. The result code is sent in the format:

<CR><LF><result code><CR><LF>

The response for some commands (for example, "In") is textual information. In these cases the response is of the form

<CR><LF><info text><CR><LF><result code><CR><LF>

The information text itself can contain several lines separated by <CR>/<LF> characters.

4.5. Scenarios

4.5.1 Connection setup, originating call (i.e., source modem)

Host	Modem
AT D dest_addr ---------->	
	. Source modem calls destination modem, the destination modem acknowledges call and indicates RING to its host . . The called host answers (or auto-answer from the called modem)

CONNECT
<----------

Error conditions:
1. If errors in "AT D" command, ERROR response code is returned
2. If no acknowledgement from destination modem, NO CARRIER response code is returned
3. If no answer from destination modem, NO ANSWER response code is returned and call termination is indicated to the destination modem

4.5.2 Connection setup, terminating call (i.e., destination modem)

Host	Modem
	.
	Modem receives a call from another modem and acknowledges it
RING	
<----------	
.	If auto-answer is disabled, the RING indication
.	is repeated until Answer command is received
RING	or call terminated by calling modem
<----------	
.	
AT A	
---------->	
	.
	Modem sends answer to calling modem
CONNECT	
<----------	

If call termination is received from originating modem before the host answers, NO CARRIER response code is sent to the host.

4.5.3 Call termination

Host	Modem
.	
.	

Modem in On-line state passing data between the host and a remote modem.

. .

DATA
---------->
DATA
<----------
.
.

Host terminates call:

.
<silence 100 ms>
.
+++
---------->

<silence 100ms>

Modem sends call termination to remote modem, sends NO CARRIER response code and goes to Off-line state

NO CARRIER
<----------

The call is terminated when *either* of the hosts terminates call with the "+++" escape sequence or when the connection between modems is lost. In each case the NO CARRIER response code is sent to the host.

4.5.4 Poll broadcast

A poll broadcast is used by the master station to register new slave stations in its coverage area. The host controller of the slave station decides whether to answer the poll message or not, according to its need for service.

Host	Modem
AT C0 (data) ---------->	Modem sends broadcast poll.
. . .	When the poll answer is received, the address and data of the answered modem is sent to the host.
POLL A REC(address1, data) <----------	
. .	Answers may come from several modems

POLL A REC(addressN, data)
<----------

The maximum time between poll answers is 100 ms.

4.5.5 Poll answer

When the modem receives a poll message from radio interface, it indicates the message to the host with POLL C REC response code. If the host wants to answer, it sends the "AT C1" command with data to be included to the poll answer message.

Host	Modem
	Modem receives a poll message and indicates it to the host
POLL C REC (address, data) <----------	
.	
If the host wants to answer, it sends AT C1 command	
.	
AT C1(data) ---------->	Modem sends poll answer message

4.5.6 Software update

The operational software of the modem can be updated from the host controller. The scenario for a software update is as follows:

Host	Modem
AT U ---------->	
	Modem sends OK response code when ready to start downloading
OK <----------	
The host sends the file to the modem	
---------->	

---------->	
.	The modem checks the CRC of each file
.	record.
.	
---------->	
(end of file)	(If a checksum error was noticed during download,
	modem sends ERROR response code to the host
.	and returns to Off-line state)
.	
.	The modem starts to program the new software
.	to its flash memory. When the programming is
.	complete, OK result code is sent to the host
OK	
<----------	
	The modem starts to execute the new software

The software file is an ASCII file in Intel MCS-86 Hex format which includes checksums for each record. If a checksum is not correct, the modem returns an ERROR response code.

4.6 Radio Interface

The radio interface between the Sequence DT10 modems uses the direct sequence spread spectrum method in the 2.4 GHz ISM band. The requirements for transmission are set by the standards ETS 300 328 and IEEE 802.11. The characteristics of the interface are:

- frequency range: 2400 MHz - 2483.5 MHz
- symbol rate: 1 MHz
- DBPSK and DQPSK modulation
- data rate: 1 Mbps (DBPSK) or 2 Mbps (DQPSK)
- chip rate: 11 Mcps, 11-chip Barker sequence
- data scrambling with 127-bit scrambling sequence
- center frequency of the radio channel is programmed through register S54, the available channels are:

Channel Number	Frequency
[1	*2412 MHz]*
[2	*2417 MHz]*
3	2422 MHz
4	2427 MHz
5	2432 MHz
6	2437 MHz
7	2442 MHz

	8	2447 MHz
	9	2452 MHz
	10	2457 MHz
	11	2462 MHz
[	*12*	*2467 MHz]*
[	*13*	*2472 MHz]*

Note: ***Only channel numbers 3 - 11 are allowed according to ETS 300 328.***

Note: ***At very close geographical locations it is recommended to use parallel channel with 20 MHz minimum distance.***

The spreading sequence is programmed through register S55. The sequences are 11-bit Barker sequences which are numbered as follows:

Spreading sequence number	Sequence
0	10110111000 (0x05B8)
1 - 4	reserved for future use

The scrambling sequence, which is programmed through register S56, is a PN-sequence constructed using a 7-bit shift register with feedback from selected taps. The sequences are as follows:

Scrambling sequence number	Scrambling polynomial
0	$1 + x^{-4} + x^{-7}$
1 - 4	reserved for future use

5. TROUBLESHOOTING

This chapter gives some guidelines for testing the system and locating a problem.

5.1. Checklist for the Modem

1. Check that there is power connected on every unit.
2. Check that all cables are tightly connected.
3. Check the led indicators on the modem:
   - Yellow light indicates there is power to the unit.
   - Green light indicates normal functioning.
   - Red light indicates a hardware failure.

5.2. Troubleshooting the System

The communication systems which incorporate the modem differ according to customer's needs and design. Therefore no general directions for troubleshooting the communication system are given.

6. WARRANTY AND SERVICE

This chapter describes the warranty service policy of Elektrobit Ltd. for the Sequence DT10.

6.1. Limited Warranty

Elektrobit Ltd. warrants a registered Sequence DT10 radio modem (see section 2.1) to be free from defects in workmanship and materials, under normal use and service, for one year from the original date of purchase.

6.2. Service

The Sequence DT10 radio modem is a type tested and officially approved RF (radio frequency) device and no on site service is recommended.

Note: ***In order to maintain the Elektrobit replacement service policy, the unit should never be opened by unauthorized personnel.***