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### **DMR Overview**

In the ever ongoing effort to squeeze more capacity out of a finite resource, the electro-magnetic spectrum, a new digital standard — Digital Mobile radio (DMR) is becoming more and more popular. Whereas the older analogue PMR (Private Mobile Radio) requires 25 kHz channels or for newer systems 12.5 kHz, DMR offers two channels within 12.5 kHz. DMR offers both voice and data communications and interfacing to external networks. Voice communications offer features as call alert, emergency call, remote monitoring, silent worker, Push-to-Talk ID, radio check, all call, stunning etc. DMR has been standardized by ETSI. The standard describes three tiers of DMR services:

Tier I: Direct mode communication without infra-

#### structure

Tier II: Direct mode (unit-to-unit) or using a base station (BS) for repeating

Tier III: Trunking protocol with a controller managing communications, including simulcast and multicast

To distinguish between adjacent and repeater stations with overlapping coverage, DMR introduces the concept of Color Code. Interlinking of repeaters or base stations is outside the scope of the ETSI standard, but Motorola's implementation of DMR called Mototrbo allows this feature using an ordinary IP connection.



Fig. 1 DMR protocol stack

DMR uses 4FSK modulation at 4800 symbols/second with the dibits mapped to +1944 Hz, +648 Hz, -648 Hz and -1944 Hz in relation to the center frequency.

#### **DMR Protocol Stack**

The air interface physical layer is responsible for

- modulation and demodulation
- transmitter and receiver switching
- ♦ HF characteristics
- bits and symbol definition
- frequency and symbol synchronization
- burst building

The data link layer main functions are

- channel coding
- media access control
- Iink addressing
- interfacing of voice
- data bearer services
- ♦ acknowledgement mechanisms
- interleaving

The third layer is the call control layer in the control plane which provides

- base station activation and deactivation
- call setup, maintenance and tear-down
- destination addressing
- built-in services
- ♦ data call control
- announcement signaling

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#### **DMR Air Interface**

DMR supports 2-channel TDMA (Time Division Multiple Access). In fig. 2 below the outbound (from a base station) is labeled "BS TX" and the inbound (from a mobile station) "MS TX". Each burst is 30 ms long. Two bursts constitute a frame and 6 frames constitute a super frame used for voice transmissions.



Fig. 2 Two-frequency TDMA timing

The outbound channel is continuously transmitted when the BS (Base Station) is active, whereas the MS (Mobile Station) will stop transmission when it has no more traffic to transmit.

The outbound channel contains a Common Announcement Channel (CACH), between individual bursts, used for traffic channel management and signaling. The inbound channel has an empty guard time between the bursts to allow for propagation delays.

Finally a synchronization or signaling field is embedded in the centre of the burst.

The BS and MS burst and frame structures are shown in fig. 3, fig. 4 and fig. 5.



Fig. 3 DMR frame structure



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DMR also supports a Reverse Channel (RC) which is used for signaling. In the outbound direction the RC replaces the burst center sync field, whereas in the inbound direction a special short burst is used, see fig. 6.



For voice transmissions a super frame of use several burst and timeslots, see fig. 7. The individual voice bursts are labeled from A to F.



Fig. 7 Voice format

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DMR also has the ability for text messaging using either the Short Data Service, a SMS-like function or IP datagram's, see fig. 8. The ability to use IP facilitates the integration with other IP networks. A DMR terminal has its own IP address and contains a DHCP server, which allocates IP addresses to peripheral devices. These devices often connect physically via a USB connector.



Fig. 8 Fragmentation of IP datagram

### Wavecom DMR Decoder

Wavecom DMR decoder works with all equipments compatible to the ETSI standard, e.g., MOTOTRBO series from Motorola and Hytera DMR devices. The current implementation complies with the ETSI DMR standard series:

- ETSI TS 102 361-1 V2.3.1 (2013-7)
- ETSI TS 102 361-2 V2.2.1 (2013-7)
- ETSI TS 102 361-3 V1.2.1 (2013-7) and
- ETSI TS 102 361-4 V1.6.1 (2014-6).
- It covers all three layers of the DMR protocol stack:
- Layer 1: Air interface physical layer
- Layer 2: Air interface data link layer and
- Layer 3: Air interface call control layer.

Wavecom DMR mode covers all three tier services (Tier I: direct mode; Tier II: direct mode and base station communication; Tier III: trunking protocol). It decodes text, voice and service messages. Each data frame is output together with a time-stamp in a resolution of one millisecond, showing the time of receiving resp. decoding. In this way it is easy to verify if the decoder works correctly in real-time and no frame is missing in a long run.

All voice frames are decoded and assembled according to the vocoder standard. Audible voice is smoothly output to the speaker for live monitoring. At the same time all voice sessions are saved in WAV files. The two TDMA slots are sorted in two separate windows for clear display.

The following W-CODE screenshot shows a DMR data and voice decoding with the millisecond time-stamp in real-time communication.



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AR	UHF-SUB Satellite Fax & Moderns Options Demodulator Favorites Configuration Yiew Window Help	
	Format: Base Data, (Jdle) (CC 0x01) Carrier: -199:902 Hz NOR Traffic Confidence: 97 10:32:15	
1 🐸 🖬 🖻 🎯 🗛 🔍 🔘	Mode Analysis ↔ ▼ ↔ ₩ ₩ ₩ ▷ △ 團 ₩ ₩ ∞ ↔ ₩(④) → ↔ ₩₩₩₩₩ + ₩₩₩₩₩₩ + ₩₩₩₩₩₩	
Text Channel A - Card 4		
B Dec 2019, 10:32:15.439	Control Signalling Block (Slot 1)	
8 Dec 2019, 10:32:15.440	CSBK Opcode 0x29.	
B Dec 2019, 10:32:15.441	CSBK Data: 0x00 0x00 0x35 0x04 0xFC 0x00 0x00	
8 Dec 2019, 10:32:15.538	Receive Time : 10:32:15.529	
8 Dec 2019, 10:32:15.539	Idle Data. (216 bits, displayed in 27 Bytes, no interpretation)	
8 Dec 2019, 10:32:15.541	0x53 0x22 0x5E 0xAB 0xAB 0xA6 0x9D 0xA7 0x28 0x3B 0x3B 0x76 0x06 0x18 0x6B 0xF4 0xE4 0x65 0x17 0x9B 0x48 0xCA 0x4D 0x4F 0xE6 0x10 0xB4	
8 Dec 2019, 10:32:15.598	Receive Time : 10:32:15.589	
18 Dec 2019, 10:32:15.599	Idle Data. (216 bits, displayed in 27 Bytes, no interpretation)	
8 Dec 2019, 10:32:15.600	0x53 0x22 0x5E 0xAB 0xAB 0xA6 0x9D 0xA7 0x2C 0x3B 0xD8 0x76 0x06 0x18 0x6B 0xF4 0xE4 0x61 0x17 0x9B 0x58 0xCA 0x4D 0x4F 0xE6 0x10 0xB0	
8 Dec 2019, 10:32:15.638	Receive Time : 10:32:15.629	
8 Dec 2019, 10:32:15.639	Idle Data. (216 bits, displayed in 27 Bytes, no interpretation)	
8 Dec 2019, 10:32:15.641	0x53 0xc2 0x5E 0xAB 0xAB 0xA6 0x9D 0xA7 0x2C 0x3B 0xD8 0x76 0x06 0x18 0x6B 0xF4 0xE4 0x61 0x17 0x9B 0x48 0xcA 0x4D 0x4F 0xE6 0x10 0xB4	
8 Dec 2019, 10:32:15.688	Receive Time : 10:32:15.680	
8 Dec 2019, 10:32:15.688	Idle Data. (216 bits, displayed in 27 Bytes, no interpretation)	
8 Dec 2019, 10:32:15.689	0x53 0xC2 0x5E 0xAB 0xA6 0x96 0x97 0x2C 0x3B 0xD8 0x76 0x06 0x18 0x6B 0xF4 0xE4 0x61 0x17 0x9B 0x58 0xCA 0x4D 0x4F 0xE6 0x10 0xB0	
18 Dec 2019, 10:32:15.689		
•	111 III III III III III III III III III	
W. Test Channel B - Card 4		
8 Dec 2019, 10:32:15,442	Receive Time : 10:32:15.429	
8 Dec 2019, 10:32:15.443	Idle Data. (216 bits, displayed in 27 Bytes, no interpretation)	
8 Dec 2019, 10:32:15.444	0x13 0xC2 0x5E 0xAB 0xAB 0xA6 0x96 0xA7 0x2C 0x3B 0xD8 0x76 0x06 0x18 0x6B 0xF4 0xE4 0x61 0x17 0x9B 0x48 0xCA 0x4D 0x4F 0xE6 0x10 0xB4	
18 Dec 2019, 10:32:15.488	Receive Time : 10:32:15.480	
8 Dec 2019, 10:32:15.488	Idle Data, (216 bits, displayed in 27 Bytes, no interpretation)	
18 Dec 2019, 10:32:15,489	0x53 0x52 0x5E 0x4B 0x4B 0x66 0x9D 0x47 0x2C 0x3B 0x08 0x76 0x06 0x18 0x6B 0xF4 0x61 0x17 0x9B 0x58 0xcA 0x4D 0x4F 0x66 0x10 0x84	
8 Dec 2019, 10:32:15.544	Receive Time : 10:32:15.532	
8 Dec 2019, 10:32:15.545	Idle Data. (216 bits, displayed in 27 Bytes, no interpretation)	
	0x13 0x22 0x5E 0xA8 0xA8 0x66 0x9D 0xA7 0x2C 0x38 0xD8 0x76 0x06 0x18 0x68 0xF4 0xE4 0x61 0x17 0x98 0x58 0xcA 0x4D 0x4F 0xE6 0x10 0x84	
8 Dec 2019 10:32:15 546	Bacaive Time : 10:32:15.590	
8 Dec 2019, 10:32:15.603	Idle Data (216 bits, displayed in 27 Bytes, no interpretation)	
8 Dec 2019, 10:32:15.603 8 Dec 2019, 10:32:15.604	Tdle Data. (216 bits, displayed in 27 Bytes, no interpretation) 0x53 0xc2 0x55 0x38 0x66 0x90 0x37 0x28 0x38 0x76 0x06 0x18 0x65 0x74 0x65 0x17 0x98 0x48 0xc2 0x45 0xc6 0x10 0x84	
8 Dec 2019, 10:32:15.603 8 Dec 2019, 10:32:15.604 8 Dec 2019, 10:32:15.605	0x53 0xC2 0x58 0xAB 0xAB 0xA6 0x9D 0xA7 0x28 0x3B 0xD8 0x76 0x06 0x18 0x65 0xF4 0xE4 0x65 0x17 0x9B 0x48 0xCA 0x4D 0x4F 0xC6 0x10 0xB4	
<pre>8 Dec 2019, 10:32:15.603 8 Dec 2019, 10:32:15.604 8 Dec 2019, 10:32:15.605 8 Dec 2019, 10:32:15.605</pre>	0x53 0x22 0x55 0x88 0x88 0x66 0x9D 0x87 0x28 0x38 0x08 0x76 0x06 0x18 0x68 0x74 0x84 0x65 0x17 0x98 0x48 0x08 0x40 0x47 0x06 0x10 0x84 Receive Time : 10:32:15.678	
<ol> <li>B Dec 2019, 10:32:15.603</li> <li>B Dec 2019, 10:32:15.604</li> <li>B Dec 2019, 10:32:15.605</li> <li>B Dec 2019, 10:32:15.691</li> <li>B Dec 2019, 10:32:15.692</li> </ol>	ox33 0x22 0x58 0xA8 0x46 0x50 0xA7 0x28 0x38 0x08 0x76 0x06 0x18 0x68 0xF4 0xE4 0x65 0x17 0x98 0x48 0xCA 0x4D 0x4F 0xC6 0x10 0x84 Receiver Fime : 10:22:13.678 Tule Data. (16 bits, displayed in 27 Bytes, no interpretation)	
<ol> <li>Bec 2019, 10:32:15.603</li> <li>Bec 2019, 10:32:15.604</li> <li>Bec 2019, 10:32:15.605</li> <li>Dec 2019, 10:32:15.691</li> <li>Bec 2019, 10:32:15.692</li> <li>Dec 2019, 10:32:15.693</li> </ol>	0x53 0x22 0x55 0x88 0x88 0x66 0x9D 0x87 0x28 0x38 0x08 0x76 0x06 0x18 0x68 0x74 0x84 0x65 0x17 0x98 0x48 0x08 0x40 0x47 0x06 0x10 0x84 Receive Time : 10:32:15.678	
<ol> <li>Bec 2019, 10:32:15.603</li> <li>Bec 2019, 10:32:15.604</li> <li>Bec 2019, 10:32:15.605</li> <li>Dec 2019, 10:32:15.691</li> <li>Bec 2019, 10:32:15.692</li> <li>Dec 2019, 10:32:15.693</li> </ol>	ox33 0x22 0x58 0xA8 0x46 0x50 0xA7 0x28 0x38 0x08 0x76 0x06 0x18 0x68 0xF4 0xE4 0x65 0x17 0x98 0x48 0xCA 0x4D 0x4F 0xC6 0x10 0x84 Receiver Fime : 10:22:13.678 Tule Data. (16 bits, displayed in 27 Bytes, no interpretation)	
<pre>B Dec 2019, 10:32:15.546 B Dec 2019, 10:32:15.603 B Dec 2019, 10:32:15.603 B Dec 2019, 10:32:15.604 B Dec 2019, 10:32:15.691 B Dec 2019, 10:32:15.691 B Dec 2019, 10:32:15.693 B Dec 2019, 10:32:15.693 c</pre>	0x3 0x2 0x50 0xa8 0x46 0x50 0xa7 0x28 0x38 0x50 0x76 0x06 0x18 0x68 0xF4 0xE4 0x65 0x17 0x98 0x48 0xC8 0x4D 0x4F 0xC6 0x10 0x84 Receive Time : 10:32:15.678 Tale Data. (216 bits, displayed in 27 Bytes, no interpretation) Dx13 0xC2 0x55 0x88 0x86 0x66 0x50 0x87 0x2c 0x38 0xD8 0x76 0x66 0x18 0x65 0xF4 0xE4 0x61 0x17 0x95 0x88 0xC8 0x4D 0x4F 0xE6 0x10 0x84	

Fig. 9 W-CODE DMR decoding output with real time-stamp

### Wavecom DMR End-to-End Decryption Functionality

Wavecom DMR decoder decrypts secured text and voice transmission of Motorola MOTOTRBO series with the license of Motorola Solutions<sup>®</sup>. There are two kinds of encryption mode: *Basic* mode and *Enhanced* mode, covering ARC-4 and AES-256 encryption algorithms.

For basic mode the encryption is done by a scrambler. The decoder needs to use the same key ID (between 1 and 255) as the sender. The scrambler value to each key ID is predefined (hardcoded) by Motorola and is not sent over the air (OTA) for security reason.

The enhanced mode includes the Motorola propriatory ARC-4 algorithm with a 40-bit key and the Advanced Encryption Standard (AES) with a 256-bit key. Unlike the basic mode, the enhanced key list contains 255 editable keys for both ARC-4 and AES-256 encryptions with the key ID from 1 to 255. (Key ID = 0 is not used.) Each enhanced key is 40-bit (5 bytes) for ARC-4 or 256-bit (32 bytes) long for AES.

The decoder must use the same key list as the sending device. It reads (decodes) the key ID sent by the encrypting device over the air and use the corresponding key value for decryption. The 40-bit or 256-bit key value itself is not sent over the air for security reason.

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### Wavecom DMR Decryption Functionality

The decoder key list can be edited via a Graphic Useer Interface (GUI).

When the key ID for the basic mode or the key list for the enhanced mode matches to the one used by the sender, a secured text or voice transmission can be decoded to clear text or voice. Otherwise the text is unreadable and the voice is unaudible. Wavecom DMR decryption function has a "lateentry" feature: the user can enter the correct key ID or edit the key value during the decoding / decryption session and the output text or voice will get to be clear immediately.

Enha	inced	Basic
ARC-4	AES	Key ID
ID	Key A	1 *
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 <	01 02 03 0123456789abcdef0123456789abcdef0123456789abc 0 0 0 0 0 0 0 0 0	Hint The Basic Key is chosen by its Key ID a number between 1 and 255. The key value is hard coded. The 256 Enhanced Keys (ARC-4 and AES keys) can be set by the user. Each ARC-4 key value is 40-bit and each AES key value is 256-bit long. The input format of an enhanced key is hex decimal in byte in even numbers of hex with leading zero, for example "098ABC" instead of "98ABC".

Fig. 10 DMR decryption cipher key editor

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Since more than thirty years Wavecom Elektronik AG has developed, manufactured and distributed high quality devices and software for the decoding and retrieval of information from wireless data communication in all frequency bands. The nature of the data communication may be arbitrary, but commonly contains text, images and voice. The company is internationally established within this industry and maintains a longstanding, world-wide network of distributors and business partners.

#### **Product Information**

Products	http://www.wavecom.ch/product-summary.php	
Datasheets	http://www.wavecom.ch/brochures.php	
Specifications	http://www.wavecom.ch/product-specifications.php	
Documentation	http://www.wavecom.ch/manuals.php	
Online help	http://www.wavecom.ch/content/ext/DecoderOnlineHelp/default.htm	
Software warranty	One year free releases and bug fixes, update by DVD	
Hardware warranty	Two years hardware warranty	
Prices	http://www.wavecom.ch/contact-us.php	

#### **System Requirements**

	Minimum	Recommended
CPU	Core i5 or Core i7 2.8 GHz	Core i7-6700 3.4 GHz
Memory	4 - 8 GB RAM	16 - 32 GB RAM
OS	Windows 7	Windows 10 32-bit or 64-bit

#### **Distributors and Regional Contacts**

You will find a list of distributors and regional contacts at <a href="http://www.wavecom.ch/distributors.php">http://www.wavecom.ch/distributors.php</a>



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