FM^{3}TR
Technology Group

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Test Waveform Specifications
Issue 1.0

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1. FOREWORD

1.1 Scope

This document defines the FM3TR parametric test waveform. It specifies only the parameters necessary for interoperability between two different platforms. This waveform shall be implemented on the different national demonstrators of FM3TR TG members and tested in (a benign) laboratory environment.

1.2 Objectives of the FM3TR Test waveform

Since programmability is the major objective of the FM3TR, the test waveform shall be designed in order to illustrate this concept.

Legacy systems are dedicated to one or at most four or five waveforms. Progress towards a fully programmable radio depends upon extended capacities or range in frequency band coverage, hop rate, modulation rate, linearity and bandwidth. Those improvements will result mostly from new designs of the analog subsystem and the analog / digital interface of the FM3TR. No dual technology will emerge from the civilian market that will tackle those technological and technical problems because they are specific to the military applications (no infrastructures, high mobility, enforced security...) and frequency bands (from HF to UHF). Those capacities are thus critical for the FM3TR.

The FM3TR test waveform shall then address those critical points. The mandatory test waveform specified hereafter only demonstrates two out of five critical capacities: hop rate programmability, extended frequency band coverage over the 30 - 400 MHz range.

It should be noted that both linearity and bandwidth variability are not taken into account by this test waveform. A supplementary set of waveforms could be designed to demonstrate those capacities.

2. FREQUENCY BAND OF OPERATION

2.1 Frequency range

TW#1 shall be available over the 30 - 400 MHz frequency range.

2.2 Channel spacing

Channel spacing for TW#1 shall be 25 kHz over the frequency range.

2.3 Frequency accuracy

Frequency accuracy shall be better than 10^{-6} over the frequency range at room temperature.

3. MODULATION

3.1 Modulation type

The modulation used for TW#1 shall be Continuous Phase Frequency Shift Keying (CPFSK). Optional waveforms may be considered in the future.

3.2 Modulation index

The modulation index shall be 0,5.

3.3 Modulation rate

The modulation rate shall be 25 kbits/s.

3.4 Modulated signal definition

a_k denotes the information bits to be transmitted, where k is the bit number. The information bits shall be mapped onto a sequence of modulation symbols b_k, where k is the corresponding symbol number. The equations below define the relationship between information bits and modulation symbols.

$$a_k = 1 \text{ or } 0$$
$$b_n = \begin{cases} 1 & \text{when } a_n = 1 \\ -1 & \text{when } a_n = 0 \end{cases}$$

The mathematical expression for the transmitted signal is:

$$s(t) = A\cos\left(2\pi f_0 t + \varphi(t, b_n)\right)$$

where A is the amplitude, f_0 is the carrier frequency, and $\varphi(t, b_n)$ is the phase function, which carries the message. The phase function has the form:

$$\varphi(t, b_n) = 2\pi h \sum_{i}^{n} b_i \int^{t} g(x - iT)\,dx$$

where h is a constant called the *modulation index*, g(t) represents a pulse, T is the bit duration, b_n is the modulation simple sequence, and $b_i = \pm 1$.

g(t) is a rectangular pulse such that:

$$g(t) = \begin{cases} \dfrac{1}{2T}, & 0 \le t \le T \\ 0, & \text{otherwise} \end{cases}$$

This expression for the transmitted signal produces a phase increase when a 0 symbol is transmitted and a phase decrease when a 1 symbol is transmitted. In terms of frequency, a 0 symbol produces the higher frequency and a 1 symbol produces the lower frequency. For the FM3TR waveform where: $h \quad \frac{1}{2}$ and $T \quad \frac{1}{25KHz}$

$$f_0 \quad f_1 \quad \frac{h}{T} \quad \frac{1/2}{40x10^{\ 6}\sec} \quad 12{,}500Hz$$

Therefore a 1 symbol is a shift of frequency 6250Hz below the carrier frequency and a 0 symbol is a shift of frequency 6250Hz above the carrier.

3.4.1 Special Test Mode Modulation

The special test mode modulation is actually the same modulation described in section 3.4 with the exception that the value of b_n always equals 1 (for all n) for special test mode 1 and -1 for special test mode 0. The special test modes are included for the purpose of verification of RF frequency of the demonstrator during carrier modulation. When the frequency table has only one frequency entered, invocation of either of the special test modes will result in a single frequency transmission with on and off patterns consistent with the hop framing.

Implementation of special test mode 1 may be accomplished by driving the modulator with a fixed pattern of 1 data (a_n = 1). Implementation of the special test mode 0 may be accomplished by driving the modulator with a fixed pattern of 0 data (a_n = 0).

4. HOP DEFINITION

4.1 Hop rate

The nominal hop rate for TW#1a and TW#1b shall be respectively 250 and 500 hops per second and shall be variable up to 2000 hops per second.

4.2 Hop timings

Timings are given in modulation bits (e.g. number of 40 µs intervals).

The dwell time, representing the nominal duration of relevant information, shall last N_{inf} modulation bits. The dwell-off time, includes the tuning, the rise and release time and shall last N_{dot} modulation bits.

The tuning time shall not exceed N_{tt} modulation bits.

The representation of the timings in a hop is given in figure 1.

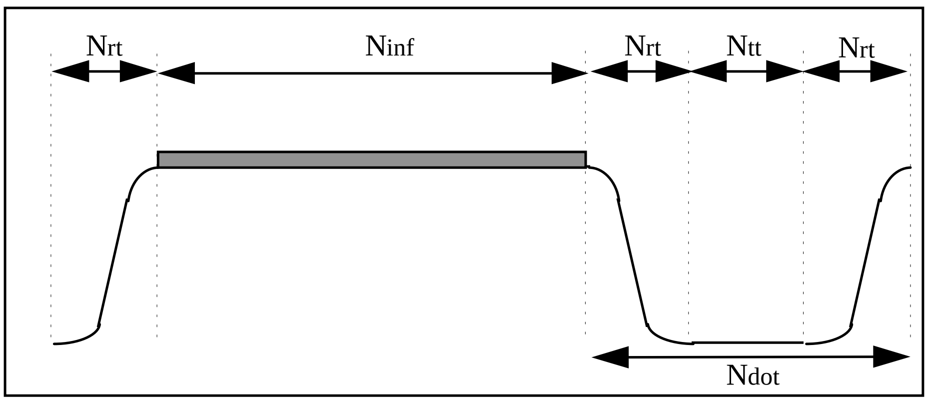


Figure 1 : Hop representation

Values of those timings for TW#1a and TW#1b shall be compliant with table 1.

Timings in bits	**TW#1a**	**TW#1b**
N_{inf}	80	40
N_{rt}	5	2,5
N_{tt}	10	5
N_{dot}	20	10

Table 1 : Hop timings

5. HOP SETS DEFINITION

5.1 Hopping sub-bands

Hopping sub-bands (HSB) define specific bands within the frequency range as specified in 2.2.1. Frequency hop sets shall be selected within a given hopping sub-band.

The HSB available for TW#1 shall be :
HSB1 : 30 - 100 MHz
HSB2 : 100 - 150 MHz
HSB3 : 225 - 400 MHz

5.2 Initial hop set

5.2.1 Nominal mode

The initial hop set used during the synchronization sequence is limited to a single frequency selected within one of the HSBs.

5.2.2 Robust mode (optional)

The initial hop set used during the synchronization sequence of the robust mode comprises 16 frequencies : f0...f15 selected within one of the HSBs.

5.3 Traffic hop set

The traffic hop set used during transmission of user information nominally shall comprise 128 frequencies variable to the maximum number within the selected within one of the HSBs. *As an option this maximum could be extended to 8192*.

6. SYNCHRONIZATION

6.1 Synchronization hop

A synchronization hop is defined as a nominal hop containing a specific N_s-bit pattern centered within the dwell time as given in figure 2.

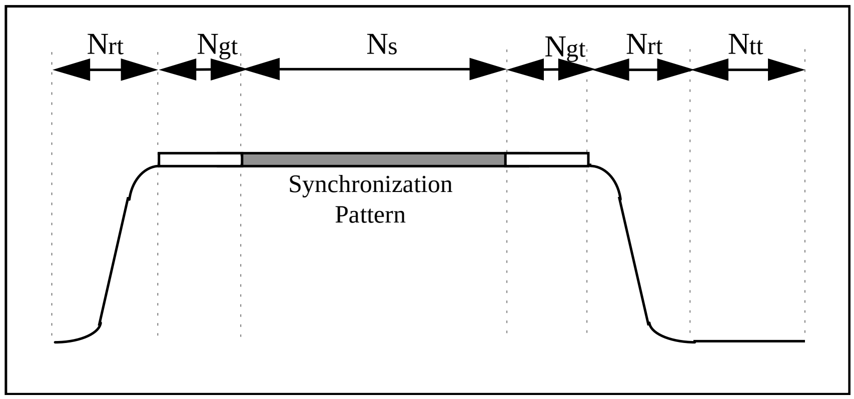


Figure 2 : Synchronization hop

Values of those timings for TW#1a and TW#1b shall be compliant with table 2.

Timings in bits	**TW#1a**	**TW#1b**
N_s	64	32
N_{gt}	8	4
N_{rt}	5	2,5
N_{tt}	10	5

Table 2 : Synchronization Hop timings

6.2 Nominal synchronization call

6.2.1 General description

A synchronization call is emitted after each push to talk e.g. before any transmission of useful information (data or voice). The synchronization preamble is composed of phasing and synchronisation patterns followed by a carrier-free guard time. The synchronization call shall be transmitted at a single frequency. This frequency shall be the first frequency among the traffic hopset.

6.2.2 Preamble Synchronisation Pattern

The preamble shall consist of a Phasing Pattern (comprising bit reversals) followed by a 256 symbol Synchronisation Pattern and a carrier free Guard Time.

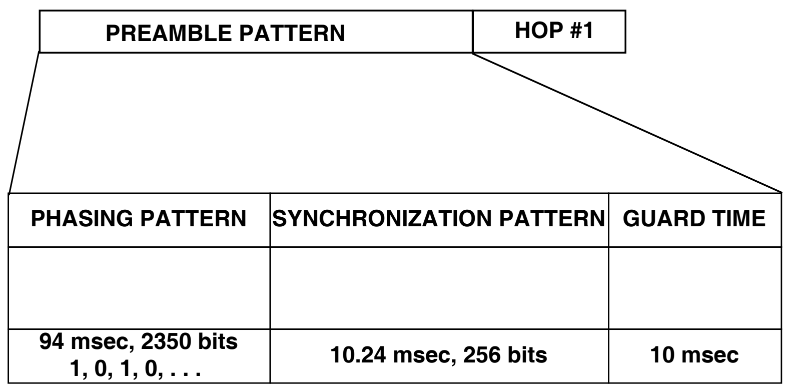
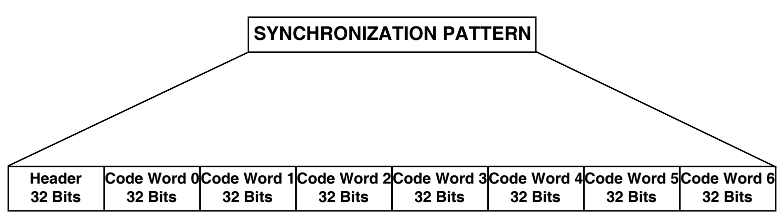


Figure 3. *Preamble Waveform Specification*

6.2.3 Synchronisation Pattern

The 256-symbol Synchronisation Pattern shall consist of eight 32-bit symbol periods.



SIB(n) : Service Indicator Bit = Output of 32-symbol correlation

Figure 4. *Synchronisation Pattern Details*

These eight periods shall be coded according to the following Table:

Period	Name	No. Bits	Contents
1	Acquisition Header	32	32-Bit Code A
2-8	Code Words 0-6 (Code Word (0) is first and is the LSB)	32	32-Bit Code S or Code S’

Table 3. 256-Bit Preamble Format

The Acquisition Header is a 32-bit code with good auto-correlation properties, as specified below:

Code A : 0000 0001 0101 1010 1100 1111 1001 1110

This header is used for all hop rates and voice and data modes.

Code Words 0-6 are determined by the hop rate and mode (voice or data)

Table 4 provides the mapping of the code word sequences to the synchronization pattern for all hop rates and voice and data modes. The synchronization pattern which is transmitted declares the hop rate and the voice or data mode. Correlation of each received code word with Code S identifies the transmitted code as Code S if the correlation is positive and Code S’ if negative. The four unused Code Words (Code Word(6,5,4,3)) are reserved for future growth (data/code rates, net I.D. etc.)

Each Code Word is a 32-bit code, defined by :

Code S: 0110 1101 1110 1010 0111 0111 0001 1110 or
Code S’: 1001 0010 0001 0101 1000 1000 1110 0001

Hop Rate	Voice/Data	Code Word 2	Code Word 1	Code Word 0
250 h/s	Voice	S’	S’	S’
250 h/s	Data	S’	S’	S
500 h/s	Voice	S’	S	S’
500 h/s	Data	S’	S	S
1000 h/s	Voice	S	S’	S’
1000 h/s	Data	S	S’	S
2000 h/s	Voice	S	S	S’
2000 h/s	Data	S	S	S

Table 4: Radio Mode Code Word Mapping

The four unused Service Indicator Bits (SIB(6,5,4,3)) are reserved for future growth (data/code rates, net I.D. etc.).

6.3 Robust Synchronization call (optional)

6.3.1 General description

A call cycle is defined as a sequence of synchronization hops transmitted over the 16 frequencies of the initial hop set. The initial hop set is read in the natural order from f0 to f15.

The synchronization call of the robust mode shall contain 17 different call cycles. A diagrammatic description of the synchronization call is given in figure 3.

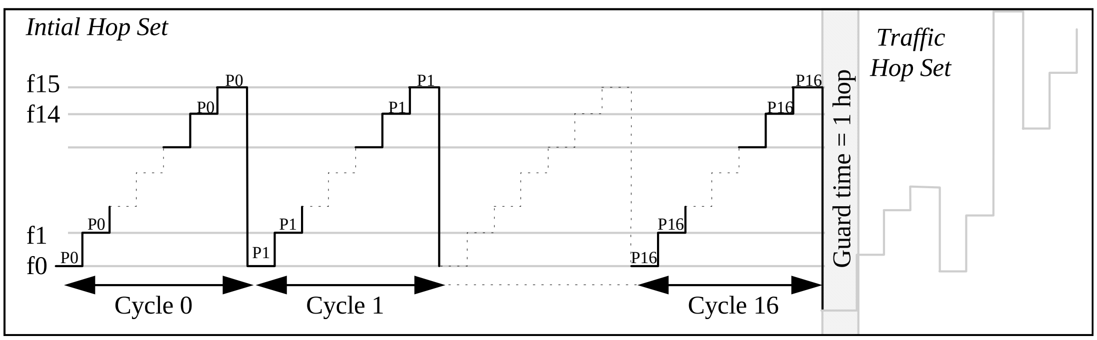


Figure 5 : Synchronization call of the robust mode

A guard time of 1 hop shall separate the synchronization call from the beginning user data transmission in order to enable synchronization on the last hop of cycle 16.

6.3.2 Synchronization patterns

The seventeen different N_s-bit patterns P0...P16 emitted respectively on cycle 0 to 16 shall be extracted from a 255 bit sequence S with the following rule (shift of one bit per cycle) :

P0j = Sj for j =0 to N_s-1

Pij = Sj+i for j = 0 to N_s-1

where i is the cycle number and j the bit number inside the pattern.

The 255 bit sequence shall be
For TW#1a : TBD (FR Action 8.6)
For TW#1b : TBD

6.4 Traffic synchronization

6.4.1 Frame definition

A frame is defined as five consecutive hops. The 4 first hops of a frame shall be used for user data transmission. The last hop of a frame shall be a synchronization hop. Consequently the available bit rate for data transmission is 16 kbits/s.

6.4.2 Frame synchronization hop

The frame synchronization hop is identical to the synchronization hop defined in 6.1.

The N_S-bit pattern Pi contained in each synchronization hop shall be the Code S 32-bit symbol as defined at Table 1 in section 6.2.3. It shall be used for the 32-bit word required for the TW#1b (500 hop/s) waveform, and shall be repeated to form the 64 bit pattern required for the TW#1a 250 hop/s waveform, as shown below :

TW#1a Frame synchronisation Pattern :-

0110 1101 1110 1010 0111 0111 0001 1110

0110 1101 1110 1010 0111 0111 0001 1110

TW#1b Frame synchronisation Pattern :-

0110 1101 1110 1010 0111 0111 0001 1110

7. CHANNEL CODING

7.1 16 kbits/s transparent channel

This nominal mode is dedicated to CVSD voice transmission. There is no channel coding in this mode.

7.2 Data channel coding (optional)

The useful bit rate shall be 9600 bits/s. The code scheme shall be compliant with the following table :

Waveform	**Hop coding**	**Block coding**
TW#1a	RS (16,14,5)	RS (105,72,7)
TW#1b	RS (10,8,4)	RS (252,189,8)

RS (Total symbols, useful symbols, symbol size in bits)

Table 5 : Channel coding

The generator polynomials and the precise composition of the RS coded frames are defined by the following tables.

	TW#1a		TW#1b	
Coding	Hop	Block	Hop	Block
RS Code *)	(16,14,5)	(105,72,7)	(10,8,4)	(252,189,8)
d_{min} **)	3	34	3	64
Galois Field	$GF(2^5)$	$GF(2^7)$	$GF(2^4)$	$GF(2^8)$
Primitive Element	00010 (MSB-LSB)	0000010 (MSB-LSB)	0010 (MSB-LSB)	00000010 (MSB-LSB)
Primitive Polynomial	D^5+D^2+1	D^7+D^3+1	D^4+D+1	$D^8+D^4+D^3+D^2+1$

*) RS (total symbols, useful symbols, symbol size in bits)

**) minimum distance

Table 6 : RS Code Properties

The construction of a generator polynomial g(D) shall be performed according to the following equation:

$$g(D) = \prod_{i=1}^{i=2t} (D - \alpha^{i}) ,$$

with 2t = number of parity-check symbols.

This leads to Table 7:

RS(16,14,5)	$g(D)$	${}^{3} \quad {}^{19} D \quad D^{2}$
RS(105,72,7)	$g(D)$	${}^{53} \quad {}^{73} D \quad {}^{82} D^{2} \quad {}^{45} D^{3} \quad {}^{17} D^{4} \quad {}^{7} D^{5}$ ${}^{104} D^{6} \quad {}^{64} D^{7} \quad {}^{99} D^{8} \quad {}^{116} D^{9} \quad {}^{111} D^{10}$ ${}^{43} D^{11} \quad {}^{61} D^{12} \quad {}^{116} D^{13} \quad {}^{37} D^{14} \quad {}^{61} D^{15}$ ${}^{16} D^{16} \quad {}^{126} D^{17} \quad {}^{10} D^{18} \quad {}^{79} D^{19} \quad {}^{124} D^{20}$ ${}^{35} D^{21} \quad {}^{110} D^{22} \quad {}^{17} D^{23} \quad {}^{115} D^{24} \quad {}^{64} D^{25}$ ${}^{122} D^{26} \quad D^{27} \quad {}^{124} D^{28} \quad {}^{100} D^{29} \quad {}^{94} D^{30}$ ${}^{97} D^{31} \quad {}^{54} D^{32} \quad D^{33}$
RS(10,8,4)	$g(D)$	${}^{3} \quad {}^{5} D \quad D^{2}$
RS(252,189,8)	$g(D)$	${}^{231} \quad {}^{198} D \quad {}^{176} D^{2} \quad {}^{78} D^{3} \quad {}^{50} D^{4} \quad {}^{190} D^{5}$ ${}^{48} D^{6} \quad {}^{217} D^{7} \quad {}^{92} D^{8} \quad {}^{235} D^{9} \quad {}^{113} D^{10}$ ${}^{217} D^{11} \quad {}^{179} D^{12} \quad {}^{12} D^{13} \quad {}^{250} D^{14} \quad {}^{110} D^{15}$ ${}^{170} D^{16} \quad {}^{156} D^{17} \quad {}^{7} D^{18} \quad {}^{156} D^{19} \quad {}^{30} D^{20}$ ${}^{98} D^{21} \quad {}^{96} D^{22} \quad {}^{16} D^{23} \quad {}^{61} D^{24} \quad {}^{127} D^{25}$ ${}^{75} D^{26} \quad {}^{113} D^{27} \quad {}^{109} D^{28} \quad {}^{180} D^{29} \quad {}^{216} D^{30}$ ${}^{153} D^{31} \quad {}^{121} D^{32} \quad {}^{120} D^{33} \quad {}^{20} D^{34} \quad {}^{140} D^{35}$ ${}^{80} D^{36} \quad {}^{233} D^{37} \quad {}^{221} D^{38} \quad {}^{91} D^{39} \quad {}^{237} D^{40}$ ${}^{253} D^{41} \quad {}^{191} D^{42} \quad {}^{59} D^{43} \quad {}^{121} D^{44} \quad {}^{163} D^{45}$ ${}^{248} D^{46} \quad {}^{198} D^{47} \quad {}^{74} D^{48} \quad {}^{150} D^{49} \quad {}^{103} D^{50}$ ${}^{206} D^{51} \quad {}^{180} D^{52} \quad {}^{12} D^{53} \quad {}^{70} D^{54} \quad {}^{118} D^{55}$ ${}^{179} D^{56} \quad {}^{201} D^{57} \quad {}^{24} D^{58} \quad {}^{75} D^{59} \quad {}^{39} D^{60}$ ${}^{73} D^{61} \quad {}^{31} D^{62} \quad D^{63}$

Table 7: Generator Polynomials

These polynomials are used to generate the code words x(D) based on the information symbols u(D). The following equation presents the coding scheme for a systematic encoder:

$$x(D) \quad D^{2t} \quad u(D) \quad D^{2t} u(D) \bmod g(D),$$

with the second term being the remainder of the division

$$(D^{2t}\ \ u(D))/g(D)\,.$$

7.2.1 Code concatenation:

The code concatenation is described using TW#1a as example waveform.

Block coding shall be performed by partitioning the data stream in symbols consisting of seven consecutive bits. One block code word consists of 105x7=735 bits. With the next step, the bit stream produced by the block code shall be partitioned into symbols consisting of 5 bits. A number of 14 symbols (=70 bit) shall be encoded by the hop code. Due to the code parameters, ten symbols of the block code in addition to the parity-check symbols of the hop code form a hop.

Table 8 shows the relations between block and hop code. The bit streams of both waveforms are shown in Table 9 and Table 10. Note that for TW#1a it is necessary to transmit two block codes to end up on a hop boundary.

	TW#1a	TW#1b
Number Of Bits Of One Block Code Word	735	2,016
Ratio Of Hop Code Words vs. Block Code Word	10.5	63
Number Of Hops Per Block Code Word	10.5	63

Table 8 : Relation of Block and Hop Code

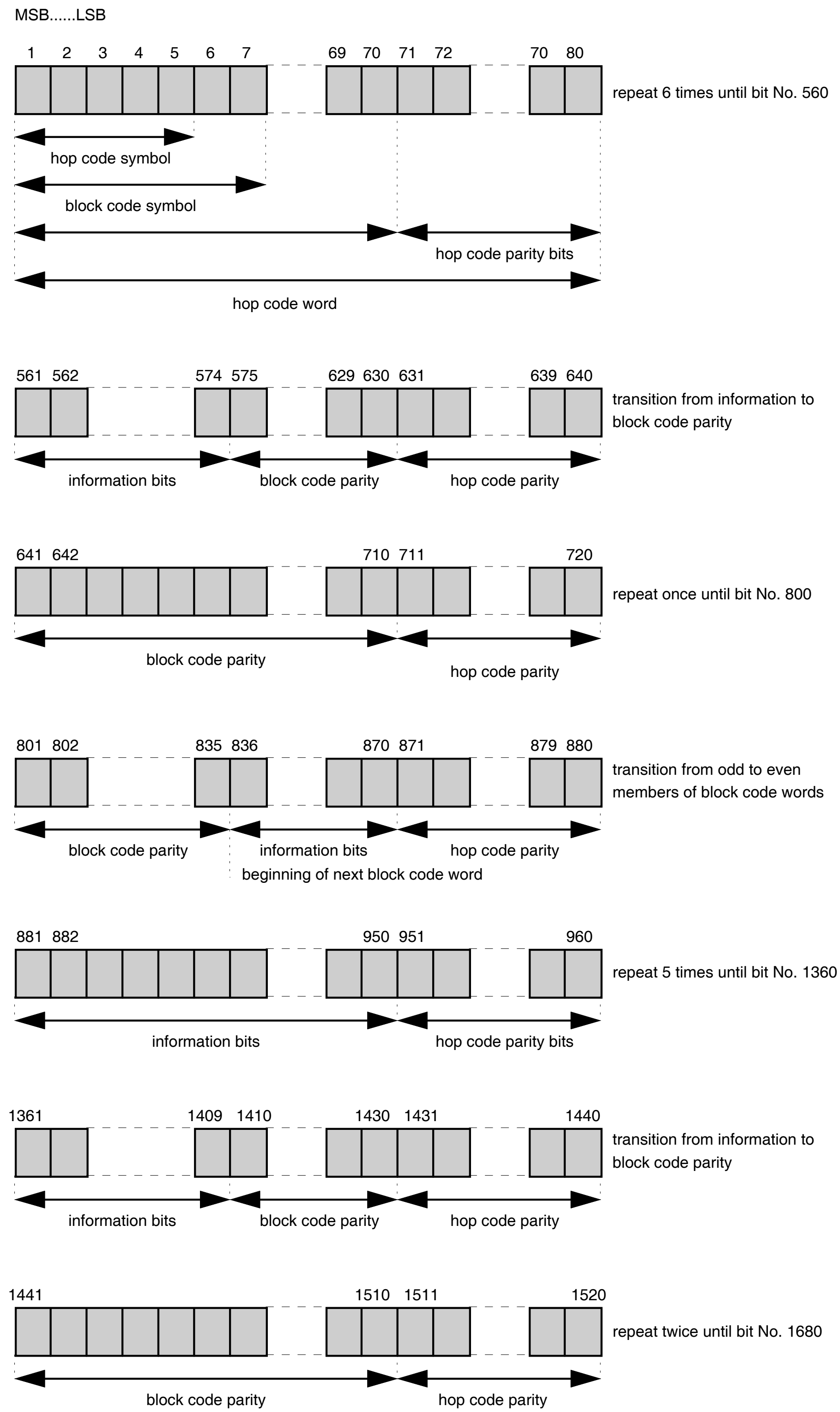


Table 9 : Bit Stream of TW#1a

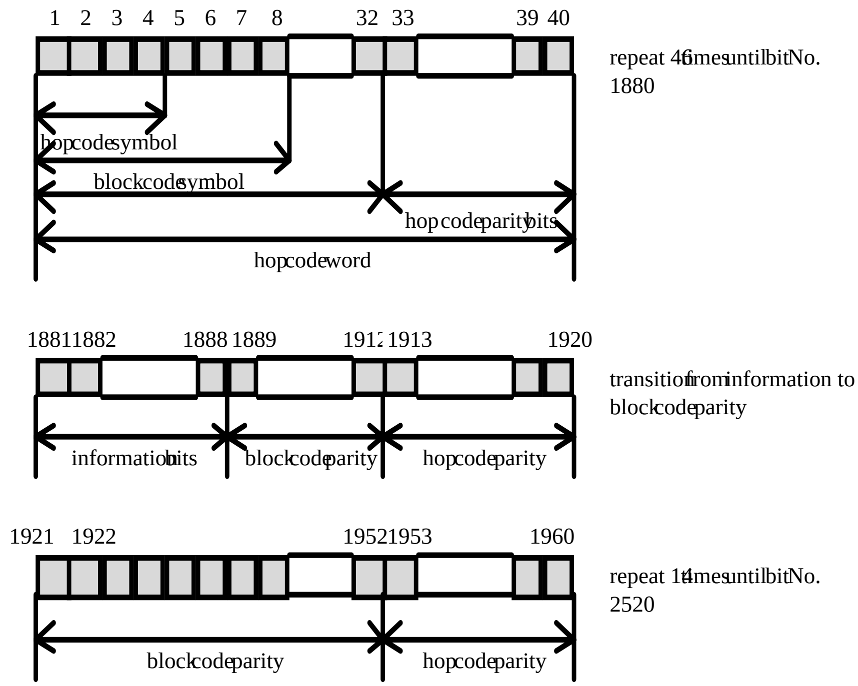


Table 10 : Bit Stream of TW#1b

8. VOICE TRANSMISSION

8.1 Source coding

Source coding shall be compliant with STANAG 4209 and 4380 (CVSD at 16 kbit/s).

8.2 Voice push-to-talk

Voice transmission shall start with a synchronization call and end with an End-Of-Message (EOM).

The synchronization call is described in paragraph 6.1.2.

The EOM shall be the inverse of the S pattern defined at section 6.2.3:

Inverse S : 1001 0010 0001 0101 1000 1000 1110 0001

This shall be transmitted once during each of the two frame synchronisation hop periods which follow the end of the information hops.

9. DATA TRANSMISSION (OPTIONAL)

9.1 General description

Transmission of short text messages is the basic service offered.

Text messages shall be coded in ASCII.

A text message shall not exceed 48 180 bytes.

Each message shall be preceded by a header identifying the message as defined in 2.7.2.

Each transmission of a text message shall begin with a synchronization call.

9.2 Header

The header contains :

Calling platform address :	1 byte
Called platform address :	1 byte
Message ID :	11 bytes
Message length :	2 bytes byte #1 number of blocks in the text message following the header byte #2 number of bytes in the last block

10. MAC EXTENSIONS (OPTIONAL)

10.1 General Description

FM^{3}TR specification has some Medium Access Control (MAC) layer functionality, however it is very limited as the waveform is half-duplex by nature. This section specifies an optional full-duplex mode for the data transmission only, where the return path is used for control feedback, and not for data traffic.

It is intended that the FM^{3}TR transceivers that implement the MAC layer extensions be backward compatible with the transceivers that do not. For this purpose, the transmitting set shall listen to the hop frequency (5th frequency in the hop set) that is allocated as the receiver feedback frequency channel. If the receiver is not sending any feedback, that means the receiver has not implemented the MAC extensions, and the transmitter should use the receiver feedback frequency as one of its transmission frequencies.

On the other hand, if the receiver has implemented the MAC extensions, after it receives a synchronization call, it shall acknowledge (send ACK) by responding in the receiver feedback frequency channel. After this, the receiver shall wait before sending any other feedback in the receiver feedback frequency channel to see if the transmitter will skip the frequency slot that is allocated as the receiver feedback frequency channel. If the transmitter skips that channel, it means that the transmitter has also implemented the MAC layer extensions, and the receiver can send flow control related feedback information to the transmitter on the receiver feedback channel. If not, the receiver shall not send any feedback to the transmitter.

10.2 Receiver Feedback Channel

After the transmitter has been verified to have implemented the MAC extensions, the receiver can use the receiver feedback channel to send traffic related feedback to the transmitter. For this purpose, the 5th frequency in the hop traffic set shall be used as the receiver feedback channel. The transmitter's traffic hop set will inherently reduce to 127 frequencies in case of a 128 frequency hop set, since the 5th frequency will not be used for data traffic transmission. This frequency is chosen on purpose to support the backward compatibility with the original FM^{3}TR specification.

The receiver shall send feedback on the receiver feedback channel at the same time slot the transmitter is sending a synchronization frame, as specified in section 6.4. This would mean that a feedback data packet will be sent to the transmitter once every 5 frames.

10.3 MAC Signalling Functionality

By having the capability of sending feedback to the transmitter, the receiver will be able to communicate flow control related information to the transmitter. In order to do this, the receiver tells the transmitter about its watermark levels, i.e, how full its input buffers are. Supported flow control messages are:

1. LOW_WATERMARK: Low watermark will be sent when the receiver's input buffer has reached the low watermark level. The value of low watermark is implementation dependent, since the developer of the receiver has the flexibility of specifying as much input buffer as he wants. This message will serve as an indication to the transmitter that the input buffer of the receiver is at a safe level.

   If the transmission had been stopped due to a HIGH_WATERMARK signal, the transmitter shall resume transmission after a LOW_WATERMARK signal has been received.

2. HIGH_WATERMARK: High watermark will be sent when the receiver's input buffer has reached the high watermark level. The value of high watermark is implementation dependent, since the developer of the receiver has the flexibility of specifying as much input buffer as he wants. This message will serve as a warning to the transmitter to considerably slow down the transmission as some packets may be lost.

   After receiving the HIGH_WATERMARK message, the transmitter shall stop sending data until LOW_WATERMARK or EMPTY signal has been received, whichever occurs first. When transmission is stopped, transmitter shall not increment the hop frequency index. After that, the transmitter shall resume transmission from the frequency it stopped transmission.

3. EMPTY: The transmitter shall send the EMPTY message to indicate that the receiver has finished consuming all of the packets at its input buffer.

4. NOOP: The transmitter shall send a NOOP message to indicate that it is alive and listening, but has nothing to report at the given instant.

The receiver can also acknowledge the receipt of the last four frames of data by sending either one of the two signals:

1. ACK: The transmitter shall send an ACK message if the last 4 frames were received without an error.

2. NAK: The transmitter shall send a NAK message if there was an error in the reception of the last 4 frames. The transmitter shall re-transmit the last 4 frames in that case. The receiver has to decode the incoming frames and check if there was a decoding error in the reed-solomon code.

10.4 MAC Signalling Frame Structure

The feedback frame that will be sent on the receiver feedback channel shall consist of 100 bits total. There will be no dwell-off time allocated in the frame, since the receiver feedback channel does not have frequency hopping nature. The receiver will start sending the feedback frame as soon as it starts receiving the synchronization frame from the transmitter. In case of TW#1a, the feedback frame will finish by the time the synchronization frame finishes. In case of TW#1b, the feedback frame wil finish one frame after the synchronization frame finished.

The first 4 bits of the feedback frame shall be a phasing header that will be {1,0,1,0}. The rest 96 bits is partitioned into 3 words, 32 bits each.

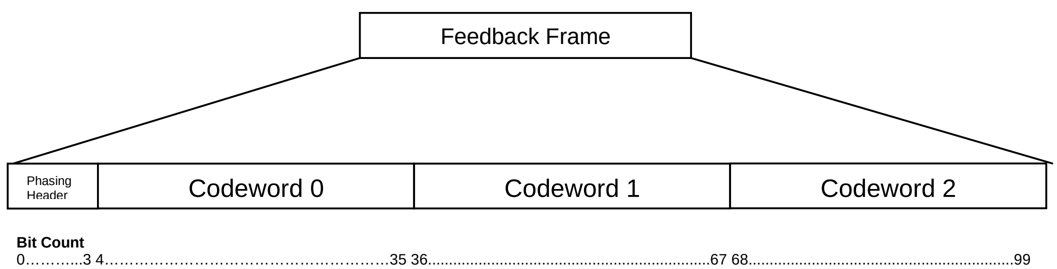


Figure 3 – Receiver Feedback Frame

Codeword 0 is used for acknowledging the transmission, whereas codewords 1 and 2 are used for flow control information. Each codeword is a 32 bit word, and can only have two values defined by:

Code S: 0110 1101 1110 1010 0111 0111 0001 1110 or
Code S’: 1001 0010 0001 0101 1000 1000 1110 0001

Correlation of each received code word with Code S identifies the transmitted code as Code S if the correlation is positive and Code S’ if negative. Decoding tables for the incoming MAC signals are given in Table 4 and Table 4.

MAC Signal	Code Word 0
ACK	S
NAK	S’

Table 3 : Acknowledgement Signals

MAC Signal	Code Word 2	Code Word 1
LOW_WATERMARK	S’	S’
HIGH_WATERMARK	S’	S
EMPTY	S	S’
NOOP	S	S

Table 4 : Flow Control Signals

10.5 MAC Management Functionality

Both a receiver and a transmitter shall provide an interface for an application to manage the MAC layer functionalities. This interface shall only be accessable internally, and not over the air with an incoming data packet. The interface shall provide capabilities to:

1. Set the hop rate
2. Set the hopping sub-band
3. Set the frequency hop set
4. Turn flow control signaling on/off

11. LLC EXTENSIONS (OPTIONAL)

This section specifies a Logical Link Control (LLC) layer functionality that can be optionally implemented on top of the MAC layer specified in the previous section, for the data mode only. The push-to-talk mechanism in FM^{3}TR already provides the waveform with a connection oriented LLC capability. For the purposes of implementing a simple LLC layer, the following capabilities can be supported by the LLC controller:

1. Establish Stream: When the user application wants to initiate a transmission, it shall first establish a stream by calling an interface provided by the LLC controller. User application shall provide the header information given in section 9.2 in order to establish a call.
2. Start stream: After establishing a valid stream, the user application shall start the stream. This interface shall translate into a nominal synchronization call as specified in section 6.2.
3. Stop stream: When the end of message transmission has been reached, the user application shall stop the stream. This will signal the system that there is no more data to be sent, however it should keep sending NULL values to the receiver since there may be more data to be sent soon.
4. Release stream: After calling the stop stream, user application can call a release stream, which will translate into sending an EOM meesage to the receiver and exiting the transmission mode.