Amateur Radio Digital Standards

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YAESU MUSEN CO., LTD.
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2 Overview

These standards and norms regulate the conditions regarding the use of digital communication systems as amateur radios. An overview of the system and the scope of application of these specifications are shown in Figure 2-1.

Direct communication between radio stations is carried out based on a half-duplex press-talk system. The communication system is either a simplex, half-duplex or broadcast system depending on the operation.

A relay station regenerates the bits of a carrier wave transmitted by a radio station and then sends out another carrier wave to another radio station.

Communication between radios is also carried out using the Continuous 4 Level Frequency Modulation (C4FM). Transmission rate is assumed to 9.6 kbps.
3 Technical Conditions of Radio Equipment

3.1 Requirements

(1) Radio Frequency Band
   A frequency band assigned to amateur radios is used.

(2) Modulation Scheme
   The modulation scheme used is the C4FM system.

(3) Communication System
   The communication system used is either a simplex, half-duplex or broadcast system based on SCPC (Single Channel Per Carrier).

(4) Antenna Power
   The antenna power must be less than the licensed value.

(5) Mode of Emission
   The type of radio wave shall be F1D (data) or F7W (data and voice).

(6) Channel Spacing
   The channel spacing shall be the channel spacing stipulated for amateur radios.

(7) Signal Transmission Rate
   The signal transmission rate shall be 9.6 kbps.

(8) Frame Length
   The frame length shall be 100 ms.

(9) Voice Encoding Method
   The voice encoding rate shall be 7.2 kbps or less including error correction.

(10) Concealment Function
   Concealment function is not provided.

3.2 Modulation Scheme Conditions

(1) Modem System
   The modem system shall be the C4FM system.

   The modulation procedure is shown in Figure 3-1 while the demodulation procedure is shown in Figure 3-2.
The binary data series of the serial input is entered into the modulation system after being converted into dibits starting from the leading bit of the signal format and then mapped onto the various symbols of the C4FM. The corresponding relationship between the dibit, symbol and frequency deviation is shown in Table 3-1.

<table>
<thead>
<tr>
<th>Dibit</th>
<th>Symbol</th>
<th>Frequency Deviations(Wide)</th>
<th>Frequency Deviations(Narrow)</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>+1</td>
<td>+900 Hz</td>
<td>+450 Hz</td>
</tr>
<tr>
<td>01</td>
<td>+3</td>
<td>+2700 Hz</td>
<td>+1350 Hz</td>
</tr>
<tr>
<td>10</td>
<td>-1</td>
<td>-900 Hz</td>
<td>-450 Hz</td>
</tr>
<tr>
<td>11</td>
<td>-3</td>
<td>-2700 Hz</td>
<td>-1350 Hz</td>
</tr>
</tbody>
</table>

For 4-level symbols, the baseband bandwidth is limited by the transmission filter \( H(f) \) specified below.

\[
H(f) = \int_{0}^{T} \cos \left( \frac{T}{4\alpha} \left[ 2\pi f - \pi (1 - \alpha) \right] \right) df
\]

\[
0 \leq |f| < \frac{(1-\alpha)}{2T}
\]

\[
\frac{(1-\alpha)}{2T} \leq |f| < \frac{(1+\alpha)}{2T}
\]

\[
\frac{(1+\alpha)}{2T} \leq |f|
\]

However, \( T \) (symbol spacing) must be equal to 1/4800 and \( \alpha \) (roll-off ratio) must be equal to 0.2.

For frequency-detected signals, the baseband bandwidth is limited by the transmission filter \( H(f) \) specified below.
\[ |H(f)| = \int_0^1 \cos \left( \frac{T}{4\alpha} \left( 2\pi f \right) - \pi \left( 1 - \alpha \right) / T \right) \]

However, \( T \) (symbol spacing) must be equal to 1/4800 and \( \alpha \) (roll-off ratio) must be equal to 0.2.

3.3 Transmission Device Conditions

(1) Frequency Tolerance
   The frequency shall comply with the regulations for radio station equipment.

(2) Occupied Frequency Bandwidth Tolerance
   The frequency shall comply with the regulations for radio station equipment.

(3) Permissible intensity of spurious emissions in the region outside the bandwidth
   The frequency shall comply with the regulations for radio station equipment.

(4) Permissible intensity of unwanted emissions in the spurious region
   The frequency shall comply with the regulations for radio station equipment.

(5) Antenna Power Tolerance
   The frequency shall comply with the regulations for radio station equipment.

(6) Enclosure Radiation
   Not specified.

(7) Transmission Rate Tolerance
   Must be within +/-5 ppm.

(8) Frequency Deviation
   Frequency deviation (maximum) must be less than \( \pm 4950 \)Hz.

(9) Modulation Accuracy
   Must be 10% or less.

3.4 Reception Equipment Conditions

FCC Part15, Subpart B, ANSI C63.4-2003

(1) Reference Sensitivity
   The bit error rate (BER) when bit transmitting a signal modulated by a binary pseudo noise
sequence with a bit period of code length 511 must be a value shown in Table 3-2.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Static</th>
</tr>
</thead>
<tbody>
<tr>
<td>BER</td>
<td>$1 \times 10^{-2}$</td>
</tr>
<tr>
<td>Reference Level</td>
<td>0.0 dBμV and below</td>
</tr>
</tbody>
</table>

(2) Strength of Secondary Emitting Radio Waves.
Not specified.

(3) 15.109 Radiated Spurious Emissions

Limits

<table>
<thead>
<tr>
<th>Frequency [MHz]</th>
<th>[dBuV/m]@3m</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 - 88</td>
<td>40.0</td>
</tr>
<tr>
<td>80 - 216</td>
<td>43.5</td>
</tr>
<tr>
<td>216 - 960</td>
<td>46.0</td>
</tr>
<tr>
<td>Above 960</td>
<td>54.0</td>
</tr>
</tbody>
</table>
4 Communication Control Method

4.1 Communication System Overview

(1) Radio Channel Configuration
The radio channel configuration is shown in Figure 4-1.

<table>
<thead>
<tr>
<th>HC (Header)</th>
<th>CC (Communication)</th>
<th>CC (Communication)</th>
<th>TC (Terminator)</th>
</tr>
</thead>
<tbody>
<tr>
<td>960 bits (100 mS)</td>
<td>960 bits (100 mS)</td>
<td>960 bits (100 mS)</td>
<td>960 bits (100 mS)</td>
</tr>
</tbody>
</table>

Figure 4-1 Radio Channel Configuration
During transmission, the Header Frame comes first, followed by the voice and data being sent via the CC Frame and finally the Terminator Frame comes last. The various frames are all defined by 960 bit (100 msec@9600 bps). The HC, CC and TC details will be provided later.

(2) Data Type
4 ways.
(a) V/D mode type 1 (simultaneous voice/data communication mode 1)
(b) V/D mode type 2 (simultaneous voice/data communication mode 2)
(c) Data FR mode (high-speed data transmission mode)
(d) Voice FR mode (high-quality voice full rate mode)

(3) Channel Type
The following four routes (Figure 4-2, Figure 4-3, Figure 4-4 and Figure 4-5) are assumed.

(a) Direct Wave (Direct) Communications (Figure 4-2)

(b) Communications via Repeater (Figure 4-3)
(c) Communication 1 via VoIP System (Figure 4-4)

![Diagram of Communication 1 via VoIP Network 1]

(d) Communication 2 via VoIP System (Figure 4-5)

![Diagram of Communication 2 via VoIP Network 2]

*The Source station is the signal transmission station while the Destination station is the signal reception station.
*VoIP AP is assumed to be a VoIP system base station (Access Point station).
*VoIP Relayed System is assumed to be a voice relay system existing in the Internet network.
*These channel types are determined from the MR value and VoIP value etc. in the FICH information (to be described later).
*In all cases from (a) to (d), communication reception by a third party is not precluded (receivable).
4.2 V/D mode (simultaneous voice/data communication mode)

4.2.1 V/D mode type 1 (simultaneous voice/data communication mode 1)

The frame composition is shown in Figure 4-6.

*Voice and superimposed data etc. is entered into the above-mentioned CC section and during transmission, this part is transmitted repeatedly.

*The repeating pattern of the CC section above changes depending on the volume of the transmission data you wish to send.

(1) HC (Header CH) and TC (Terminator CH)

The Header and Terminator basically have the same structure. The structural diagram is shown in Figure 4-7. (HC/TC is differentiated by the F1 value in FICH.)

<table>
<thead>
<tr>
<th>FS</th>
<th>FICH</th>
<th>DCH-1(0)</th>
<th>DCH-2(0)</th>
<th>DCH-1(1)</th>
<th>DCH-2(1)</th>
<th>DCH-1(2)</th>
<th>DCH-2(2)</th>
<th>DCH-1(3)</th>
<th>DCH-2(3)</th>
<th>DCH-1(4)</th>
<th>DCH-2(4)</th>
<th>Number of bits Total 960 bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>200</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>Total 960 bit</td>
</tr>
</tbody>
</table>

*Fill up using 0×20 (Space) when there is no information in CSD2. (during direct transmission)
(2) CC (Communication CH)

The structural diagram of the superimposed data and actual voice is shown in Figure 4-8.

<table>
<thead>
<tr>
<th>FS</th>
<th>FICH</th>
<th>DCH (0)</th>
<th>VCH (0)</th>
<th>DCH (1)</th>
<th>VCH (1)</th>
<th>DCH (2)</th>
<th>VCH (2)</th>
<th>DCH (3)</th>
<th>VCH (3)</th>
<th>DCH (4)</th>
<th>VCH (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>200</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
</tr>
</tbody>
</table>

Figure 4-8 CC Structural Drawing

Bit Breakdown within the Frame

- **FS** (Frame Sync): Synchronized symbol. (Refer to Section (3) for the details)
- **FICH** (Frame Information CH): Frame information channel. (Refer to Section (4) for the details)
- **DCH** (Data CH): CSD (Callsign Data) and text data to be superimposed and transmitted etc. is entered into DCH. (Total 360 bit) (Refer to Sections (5) and (6) for details)
- **VCH** (Voice CH): The Vocoder voice is entered into VCH. (Voice information totaling 100 msec is entered in 20 msec blocks for every 72 bits.) (Details are shown in Section (7))

This section is transmitted repeatedly during voice transmission. (Refer to Section (6) for the repeating pattern)

(3) FS (Frame Sync)

- Synchronized signal (40 bit) D471C9634D

(4) FICH (Frame Information CH)

- The FICH section is composed using 200 bit and includes actual data (32 bit) and check bit (168 bit). (Refer to Section 4.5 (1) for details on the check bit)

The structural drawing of the actual FICH data is shown in Figure 4-9.

Figure 4-9 FICH Actual Data Structure

The field composition of the actual FICH data is shown in Table 4-1.
<table>
<thead>
<tr>
<th>Field Name</th>
<th>Byte Length</th>
<th>Definition of Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame Type</td>
<td>2</td>
<td>Shows the radio channel type of the frame.</td>
</tr>
<tr>
<td>(FI: Frame Information)</td>
<td></td>
<td>00: Header Channel (HC)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>01: Communication Channel (CC)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10: Terminator Channel (TC)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11: Test Channel</td>
</tr>
<tr>
<td>Type of Callsign</td>
<td>2</td>
<td>Shows the callsign in the frame.</td>
</tr>
<tr>
<td>(CS: Callsign Information)</td>
<td></td>
<td>00: Reserve</td>
</tr>
<tr>
<td></td>
<td></td>
<td>01: Reserve</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10: Assign callsigns 1, 2 and 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11: Reserve</td>
</tr>
<tr>
<td>Type of Call</td>
<td>2</td>
<td>Shows an individual mode or Group/CQ mode.</td>
</tr>
<tr>
<td>(CM: Call Mode)</td>
<td></td>
<td>00: Group/CQ mode</td>
</tr>
<tr>
<td></td>
<td></td>
<td>01: Radio ID mode</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10: Reserve</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11: Individual mode</td>
</tr>
<tr>
<td>Block Number</td>
<td>2</td>
<td>Shows the block number when dividing and sending data.</td>
</tr>
<tr>
<td>(BN: Block Number)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block Total</td>
<td>2</td>
<td>Shows the block total when dividing and sending data.</td>
</tr>
<tr>
<td>(BT: Block Total)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frame number</td>
<td>3</td>
<td>Shows the frame number when dividing and sending data.</td>
</tr>
<tr>
<td>(FN: Frame Number)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frame Total</td>
<td>3</td>
<td>Shows the frame total when dividing and sending data.</td>
</tr>
<tr>
<td>(FT: Frame Total)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency Deviation</td>
<td>1</td>
<td>Specifies the frequency deviation of the transmit signal.</td>
</tr>
<tr>
<td>(Dev: Frequency Deviation)</td>
<td></td>
<td>0: Wide deviation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: Narrow deviation</td>
</tr>
<tr>
<td>Message Path</td>
<td>3</td>
<td>Shows the transmission path of the message.</td>
</tr>
<tr>
<td>(MR: Message Routing)</td>
<td></td>
<td>000: Direct wave communication</td>
</tr>
<tr>
<td></td>
<td></td>
<td>001: Downlink (uplink not busy)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>010: Downlink (uplink busy)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>011: Reserve</td>
</tr>
<tr>
<td></td>
<td></td>
<td>:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>111: Reserve</td>
</tr>
<tr>
<td>VoIP Path</td>
<td>1</td>
<td>Shows the VoIP communication path.</td>
</tr>
<tr>
<td>(VoIP)</td>
<td></td>
<td>0: Local (simplex)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1: via Internet (repeated)</td>
</tr>
<tr>
<td>Data Type</td>
<td>2</td>
<td>Shows the frame data type.</td>
</tr>
<tr>
<td>(DT: Data Type)</td>
<td></td>
<td>00: V/D mode type 1 (simultaneous voice/data communication mode 1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>01: Data FR mode (high-speed data transmission mode)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10: V/D mode type 2 (simultaneous voice/data communication mode 2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11: Voice FR mode (high-quality voice full rate mode)</td>
</tr>
<tr>
<td>SQL Type</td>
<td>1</td>
<td>0: SQL code enabled</td>
</tr>
<tr>
<td>(SQL type)</td>
<td></td>
<td>1: SQL code disabled</td>
</tr>
<tr>
<td>SQL Code</td>
<td>7</td>
<td>00000000: No value</td>
</tr>
<tr>
<td>(SC: Squelch Code)</td>
<td></td>
<td>00000001: SQL Code (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11111110: SQL Code (126)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11111111: Break Out code</td>
</tr>
</tbody>
</table>

In the V/D mode type 1 (simultaneous voice/data communication mode 1), the DT value (Data Type) is specified as 00.
(5) Breakdown of CSD (Callsign Data)

The Callsign Data is an area where the call sign information of an amateur radio station is entered. The information is shown in Table 4-2.

**Table 4-2 Call sign information of an amateur radio station**

<table>
<thead>
<tr>
<th>Callsign Data</th>
<th>bit</th>
<th>Call Sign Information</th>
<th>Information Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSD1</td>
<td></td>
<td>Dest</td>
<td>Address Callsign</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>Destination Callsign</td>
<td>Destination Callsign</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Source Callsign</td>
<td>Source Station’s Radio ID</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>Destination Radio ID</td>
<td>Destination Radio ID</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Source Radio ID</td>
<td>Source Station’s Radio ID</td>
</tr>
<tr>
<td>CSD2</td>
<td>80</td>
<td>Downlink Callsign</td>
<td>DownLink Station Callsign</td>
</tr>
<tr>
<td>Uplink</td>
<td>80</td>
<td>UpLink Callsign</td>
<td>Callsign of UpLink Station</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rem1</td>
<td>Callsign Supplementary Information 1</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>Remarks text 1</td>
<td>Callsign Supplementary Information 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rem2</td>
<td>Callsign Supplementary Information 3</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>Remarks text 2</td>
<td>Callsign Supplementary Information 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rem3</td>
<td>Callsign Supplementary Information 3</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>Remarks text 3</td>
<td>Callsign Supplementary Information 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rem4</td>
<td>Callsign Supplementary Information 4</td>
</tr>
</tbody>
</table>

The Callsign of the CSD1/CSD2 section is composed respectively of actual data in 10 byte (80 bit).
The Rem1 - Rem4 ID numbers of CSD3 are respectively composed in 5 byte (40 bit).

Callsign Data is handled in the Header, Terminator and DCH (Data CH) to be described later.

Radio ID: Device-specific identification number (5 byte).

When the repeater station sends (relays) the signal coming from the Uplink CH of your own station to the Downlink CH as it is, the Rem 1/2 information contains the Radio ID of your own station (repeater station).

When transmitting signals relayed via the Internet using the Downlink, the VoIP station ID information is also included.
The Callsign information to be sent by DCH (Data CH) is as follows.

CS=10 (bin)  CSD1 + CSD2 + CSD3 (Dest/Src/Down/Up/Rem1/2/3/4)

*By handling CSD information using the CC (Communication CH), the signal address can be located even if the signal is received midway.

(6) Breakdown of DCH (Data CH)
The DCH section is composed using 360 bit and includes actual data (160 bit) and check bit (200 bit). (Refer to Section 4.5 (2) for details on the check bit)

In the V/D mode (simultaneous voice/data communication mode), the information of the CC (Communication CH) is transmitted repeatedly during voice transmission using the PTT.

This repeating pattern changes as follows according to the DT (Data) volume that you wish to send.

The changes are shown in Table 4-3.

*The DT section can handle actual data totaling 800 bit (100 byte) for DT1 - DT5.

FT    Frame Total  The frame is transmitted repeatedly once every FT value.
FN    Frame Number The FN value is a serial number applied to the repeating Frame.
CS    Callsign Information  CS=10 (bin) fixed

(All values are defined in FICH.)

Table 4-3  V/D mode  type 1 case

<table>
<thead>
<tr>
<th>FT</th>
<th>FN=0</th>
<th>FN=1</th>
<th>FN=2</th>
<th>FN=3</th>
<th>FN=4</th>
<th>FN=5</th>
<th>FN=6</th>
<th>FN=7</th>
<th>Transmission data length (DT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>CSD1</td>
<td>CSD2</td>
<td>CSD3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>When there is not data</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rolling for every three frames</td>
</tr>
<tr>
<td>3</td>
<td>CSD1</td>
<td>CSD2</td>
<td>CSD3</td>
<td>DT1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>When DT=1-20 byte</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rolling for every four frames</td>
</tr>
<tr>
<td>4</td>
<td>CSD1</td>
<td>CSD2</td>
<td>CSD3</td>
<td>DT1</td>
<td>DT2</td>
<td></td>
<td></td>
<td></td>
<td>When DT=21-40 bytes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rolling for every five frames</td>
</tr>
<tr>
<td>5</td>
<td>CSD1</td>
<td>CSD2</td>
<td>CSD3</td>
<td>DT1</td>
<td>DT2</td>
<td>DT3</td>
<td></td>
<td></td>
<td>When DT=41-60 bytes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rolling for every six frames</td>
</tr>
<tr>
<td>6</td>
<td>CSD1</td>
<td>CSD2</td>
<td>CSD3</td>
<td>DT1</td>
<td>DT2</td>
<td>DT3</td>
<td>DT4</td>
<td></td>
<td>When DT=61-80 bytes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rolling for every seven frames</td>
</tr>
<tr>
<td>7</td>
<td>CSD1</td>
<td>CSD2</td>
<td>CSD3</td>
<td>DT1</td>
<td>DT2</td>
<td>DT3</td>
<td>DT4</td>
<td>DT5</td>
<td>When DT=81-100 bytes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rolling for every eight frames</td>
</tr>
</tbody>
</table>
(7) VCH (Voice CH) Breakdown

The transmission rate of the voice signal must be 3.6 kbps or less including the error correction code. Voice encoding follows the standards stipulated for a frame size of 20 ms (72 bit), voice code of 2.45 kbps, error correction code of 1.15 kbps Digital Voice Systems, Inc’s AMBE+2™ Enhanced Half-Rate (3600 bps).

49 bit voice encoded data and 23 bit error correction data is generated for each frame (20 ms) and bit assignment to the VCH is composed of five frames of (100 ms: 360 bit) voice encoded data. VCH bit allocation is as shown in Figure 4-10.

![Figure 4-10 VCH Bit Allocation](image-url)
4.2.2 V/D mode type 2 (simultaneous voice/data communication mode 2)

The frame composition is shown in Figure 4-11.

*Voice and simultaneously superimposed data etc. is entered into the above-mentioned CC section and during transmission, this part is transmitted repeatedly.

(1) HC (Header CH) and TC (Terminator CH)

The Header and Terminator are exactly the same as in the case for V/D mode type 1 (refer to Section 4.2.1 (1)).

(2) CC (Communication CH)

The structural diagram of the superimposed data and actual voice is shown in Figure 4-12.

<table>
<thead>
<tr>
<th>FS</th>
<th>FICH</th>
<th>DCH (0)</th>
<th>VCH (0)</th>
<th>VeCH (0)</th>
<th>DCH (1)</th>
<th>VCH (1)</th>
<th>VeCH (1)</th>
<th>DCH (2)</th>
<th>VCH (2)</th>
<th>VeCH (2)</th>
<th>DCH (3)</th>
<th>VCH (3)</th>
<th>VeCH (3)</th>
<th>DCH (4)</th>
<th>VCH (4)</th>
<th>VeCH (4)</th>
<th>Number of bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>200</td>
<td>40</td>
<td>72</td>
<td>32</td>
<td>40</td>
<td>72</td>
<td>32</td>
<td>40</td>
<td>72</td>
<td>32</td>
<td>40</td>
<td>72</td>
<td>32</td>
<td>40</td>
<td>72</td>
<td>32</td>
<td>960 bit</td>
</tr>
</tbody>
</table>

*This section is transmitted repeatedly during voice transmission. (Refer to Section (6) for the repeating pattern)*
(3) FS (Frame Sync)
   Same as Section 4.2.1 (3).

(4) FICH (Frame Information CH)
   Same as Section 4.2.1 (4).
   In V/D mode type 2, the DT value (Data Type) is specified as 10.

(5) Breakdown of CSD (Callsign Data)
   Same as Section 4.2.1 (5).
   *In V/D mode type 2, the data needs to be divided and sent in 20-byte packages as shown in Section (6).

(6) Breakdown of DCH (Data CH)
   The DCH section is composed using 200 bit and includes actual data (80 bit) and check bit (120 bit). (Bit configuration that is less than V/D mode type 1) (refer to Section 4.5 (2) for the check bit)
   Similar to V/D mode type 1 (simultaneous voice/data communication mode 1), the information of the CC (Communication CH) is transmitted repeatedly during voice transmission using the PTT.
   This repeating pattern changes as follows according to the DT (Data) volume that you wish to send.
   The changes are shown in Table 4-4.
   *The DT section can handle actual data totaling 160 bit (20 byte) for DT1 - DT2.

   FT   Frame Total       The frame is transmitted repeatedly once every FT value.
   FN   Frame Number   The FN value is a serial number applied to the repeating Frame.
   CS   Callsign Information       CS=10 (bin) fixed
   (All values are defined in FICH.)
Table 4-4  V/D mode  type 2 case

<table>
<thead>
<tr>
<th>FT</th>
<th>FN=0</th>
<th>FN=1</th>
<th>FN=2</th>
<th>FN=3</th>
<th>FN=4</th>
<th>FN=5</th>
<th>FN=6</th>
<th>FN=7</th>
<th>Transmission data length (DT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Dest</td>
<td>Src</td>
<td>Down</td>
<td>Up</td>
<td>Rem1+2</td>
<td>Rem3+4</td>
<td></td>
<td></td>
<td>When there is not data</td>
</tr>
<tr>
<td>6</td>
<td>Dest</td>
<td>Src</td>
<td>Down</td>
<td>Up</td>
<td>Rem1+2</td>
<td>Rem3+4</td>
<td>DT1</td>
<td></td>
<td>When DT=1-10 byte</td>
</tr>
<tr>
<td>7</td>
<td>Dest</td>
<td>Src</td>
<td>Down</td>
<td>Up</td>
<td>Rem1+2</td>
<td>Rem3+4</td>
<td>DT1</td>
<td>DT2</td>
<td>When DT=11-20 byte</td>
</tr>
</tbody>
</table>

(7) VCH (Voice CH) and VeCH (Voice Extend CH) Breakdown
Refer to Section 4.5 (3).

4.2.3 Switching between Type 1 and Type 2 V/D mode (simultaneous voice /data communication mode)
When text data needs to be added as transmission information during communication, switch between Type 1 and Type 2 modes depending on the data volume.
The frame composition is shown in Figure 4-13.

*Rolling is carried out during transmission until there is a request to switch the Type (make sure rolling is carried out at least once).
4.3 Data FR mode (high-speed data transmission mode)

The frame composition is shown in Figure 4-14.

<table>
<thead>
<tr>
<th>HC (Header)</th>
<th>CC (Communication CH)</th>
<th>TC (Terminator)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FN=0</td>
<td>FN=1</td>
<td>...</td>
</tr>
<tr>
<td>← 100 msec (960 bit) →</td>
<td>← 100 msec (960 bit) →</td>
<td>← 100 msec (960 bit) →</td>
</tr>
<tr>
<td>FN=7 (maximum)</td>
<td>...</td>
<td>← 100 msec (960 bit) →</td>
</tr>
</tbody>
</table>

Figure 4-14 Frame Composition Drawing

*Data is entered into the above-mentioned CC section. For large data volumes, block transfer (Section (7)) is supported.

(1) HC (Header CH) and TC (Terminator CH)

The Header and Terminator are exactly the same as in the case for V/D mode (refer to Section 4.2.1 (1)).

(2) CC (Communication CH)

The data structural diagram is shown in Figure 4-15.

<table>
<thead>
<tr>
<th>FS</th>
<th>FICH</th>
<th>DCH-1(0)</th>
<th>DCH-2(0)</th>
<th>DCH-1(1)</th>
<th>DCH-2(1)</th>
<th>DCH-1(2)</th>
<th>DCH-2(2)</th>
<th>DCH-1(3)</th>
<th>DCH-2(3)</th>
<th>DCH-1(4)</th>
<th>DCH-2(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>200</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
<td>72</td>
</tr>
</tbody>
</table>

Figure 4-15 CC Structural Drawing

Bit Breakdown within the Frame

<table>
<thead>
<tr>
<th>FS</th>
<th>FICH</th>
<th>DCH-1</th>
<th>DCH-2</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame sync.</td>
<td>Frame Information Channel</td>
<td>CSD (Callsign Data) and text data to be superimposed and transmitted etc. are entered in DCH.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DCH-1</td>
<td>Data CH-1</td>
<td>(Total 360 bit)</td>
<td>(Refer to Sections (5) and (6) for details)</td>
<td></td>
</tr>
<tr>
<td>DCH-2</td>
<td>Data CH-2</td>
<td>DCH-2 is also the same as DCH-1. (Total 360 bit)</td>
<td>(Refer to Sections (5) and (6) for details)</td>
<td></td>
</tr>
</tbody>
</table>

In this mode, no same data is repeated and sent.
(3) FS (Frame Sync)
   Same as Section 4.2.1 (3).

(4) FICH (Frame Information CH)
   Same as Section 4.2.1 (4).
   In the Data FR mode (data communication), the DT value (Data Type) is specified as 01.

(5) Breakdown of CSD (Callsign Data)
   Same as Section 4.2.1 (5).

(6) Breakdown of DCH (Data CH)
   The DCH section is composed using two 360 bit groups and includes actual data (160 bit) and check bit (200 bit) for each 360 bit. (Refer to Section 4.5 (2) for details on the check bit)
   *The DT section can handle actual data totaling 2080 bit (260 byte) for DT1 - DT13.
   The same data will not be transmitted repeatedly in the Data FR mode.
   The changes according to the DT (Data) volume you wish to send are shown in Table 4-5.

<table>
<thead>
<tr>
<th>FT</th>
<th>Frame Total</th>
<th>The frame is transmitted repeatedly once every FT value.</th>
</tr>
</thead>
<tbody>
<tr>
<td>FN</td>
<td>Frame Number</td>
<td>The FN value is a serial number applied to the repeating Frame.</td>
</tr>
<tr>
<td>CS</td>
<td>Callsign Information</td>
<td>CS=10 (bin) fixed</td>
</tr>
</tbody>
</table>

(All values are defined in FICH.)
### Table 4-5 For Data FR mode

<table>
<thead>
<tr>
<th>FT</th>
<th>FN</th>
<th>Transmission data length (DT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>CSD1, CSD2, CSD3, DT1</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>CSD1, CSD2, CSD3, DT1, DT2, DT3</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>CSD1, CSD2, CSD3, DT1, DT2, DT3, DT4, DT5</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>CSD1, CSD2, CSD3, DT1, DT2, DT3, DT4, DT5, DT6, DT7</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>CSD1, CSD2, CSD3, DT1, DT2, DT3, DT4, DT5, DT6, DT7, DT8, DT9</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>CSD1, CSD2, CSD3, DT1, DT2, DT3, DT4, DT5, DT6, DT7, DT8, DT9, DT10, DT11</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>CSD1, CSD2, CSD3, DT1, DT2, DT3, DT4, DT5, DT6, DT7, DT8, DT9, DT10, DT11, DT12, DT13</td>
</tr>
</tbody>
</table>

#### 7) Block management of DCH (Data CH)

Continuous transmission of a maximum of four blocks is stipulated with the above mentioned CC (FN=0-7) taken as a single block.

The block structural diagrams are shown in Figure 4-16, Figure 4-17, Figure 4-18 and Figure 4-19.

<table>
<thead>
<tr>
<th>BT</th>
<th>Block Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>BN</td>
<td>Block Number</td>
</tr>
</tbody>
</table>

(All values are defined in FICH.)

* A maximum of 260*4=8320 bit (1040 byte) of actual data for four blocks in total can be handled.

<table>
<thead>
<tr>
<th>HC (Header)</th>
<th>CC [BN = 0]</th>
<th>TC (Terminator)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

←100 msec→ ←←←← 800 msec →→→→ ←100 msec→ (Maximum: 1.0 sec transmission)

**Figure 4-16** Block Structural Drawing (BT=0)
Figure 4-17  Block Structural Drawing (BT=1)

Figure 4-18  Block Structural Drawing (BT=2)

Figure 4-19  Block Structural Drawing (BT=3)
4.4 Voice FR mode (High-quality voice full rate mode)

The frame composition is shown in Figure 4-20.

<table>
<thead>
<tr>
<th>HC (Header)</th>
<th>CC0 (Communication CH)</th>
<th>TC (Terminator)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FN=0 (Sub Header)</td>
<td>FN=1 (maximum)</td>
<td>FN=0</td>
</tr>
</tbody>
</table>

![Figure 4-20 Frame Composition Drawing](image)

As not all Call sign information can be sent using HC alone, only the first frame just after the HC shall have a special structure. Specifically, FT is assumed to be 1 just after the HC only and only the FT=1/FN=0 frame (CC0) at that time shall have a special structure that includes CSD3. Thereafter, all transmissions shall be at AMBE full rate.

Under this pattern, when the initial HC and initial CC (Sub header (CSD3)) cannot be received, the Call sign information can not be obtained. No CSD3 information can be obtained from other frames except the FT=1/FN=0 frame.

(1) HC (Header CH) and TC (Terminator CH)

The Header and Terminator are exactly the same as in the case of V/D mode (refer to Section 4.2.1 (1)).

(2) CC (Communication CH)

The structural drawing of the CC0 (Sub Header CH) actual voice and superimposed data is shown in Figure 4-21.

![Figure 4-21 CC0 Structural Drawing](image)

The structural drawing of the CC actual voice is shown in Figure 4-22.

![Figure 4-22 CC Structural Drawing](image)
Bit Breakdown within the Frame

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS</td>
<td>Frame sync. Synchronized symbol. (Refer to Section (3) for details)</td>
</tr>
<tr>
<td>FICH</td>
<td>Frame Information CH Frame Information Channel (Refer to Section (4) for details)</td>
</tr>
<tr>
<td>DCH</td>
<td>Data CH Send all Callsign information by HC and CC0. (Refer to Sections (5) and (6) for details)</td>
</tr>
<tr>
<td>VCH</td>
<td>Voice CH The Vocoder voice is entered into VCH. (All AMBE Full Rate) (refer to Section (7) for details)</td>
</tr>
</tbody>
</table>

(3) FS (Frame Sync)

Same as Section 4.2.1 (3).

(4) FICH (Frame Information CH)

Same as Section 4.2.1 (4).

(5) Breakdown of CSD (Callsign Data)

Send all Callsign information using the DCH of HC and CC0.

(6) Breakdown of DCH (Data CH)

Text cannot be transmitted.

(7) VCH (Voice CH) Breakdown

The transmission rate of the voice signal must be 7.2 kbps or less including the error correction code. Voice encoding follows the standards stipulated for a frame size of 20 ms (144 bit), voice code of 4.4 kbps, error correction code of 2.8 kbps Digital Voice Systems, Inc's AMBE+2™ Enhanced Full-Rate (7200 bps).
88 bit voice encoded data and 56 bit error correction data is generated for each frame (20 ms) and bit assignment to the VCH is composed of five frames of (100 ms: 720 bit) voice encoded data. VCH bit allocation is as shown in Figure 4-23.
4.5 Details of the Error Check Bit

(1) FICH Section

Frame Information Channel (FICH: Frame Information CH)

(a) Encoding Procedure

The FICH encoding procedure is shown in Figure 4.24.

![Figure 4.24 FICH Encoding Procedure](image)

(b) Error Detection Code

16 bit CRC

Generator polynomial: $x^{16}+x^{12}+x^5+1$

The configuration of the CRC encoder must be as shown in Figure 4.25. The initial values of all the shift registers $S_{15}$-$S_{00}$ shall be zero and all bits must be inverted at the end.

![Figure 4.25 CRC16 Encoder Configuration](image)

(c) Golay Coding (refer to Appendix A)

The input bit must be divided into 12 bit segments starting from the top and extended Golay coding (Golay (24, 12, 8)) must be carried out for each segment.

(c) Trellis Coding (refer to Appendix B)

The convoluted coding shown below must be carried out using a sequence with four fixed bits (All 0) added at the end of an input bit string as input. The output bit must be read alternately in the order of $G_1$ followed by $G_2$.

- Coding rate $R = 1/2$
- Constraint length $K = 5$
- Generator polynomial:
  - $G_1 = x^4 + x^3 + 1$
  - $G_2 = x^4 + x^2 + x + 1$

(e) Interleave

After reading the input bit in 2 bit segments and then after making a dibit, an interleave with block length $M = 5$ dibits and depth $N = 10$ must be carried out.

(f) Encoding Details

The encoding details of the frame information channel is shown in Figure 4.26.
Figure 4-26 Frame Information Channel (FICH) Coding Method
(2) DCH Section
Data Communication Channel (DCH: Data Channel)

(a) Encoding Procedure

The encoding procedure for a single unit is shown in Figure 4-27.

![Figure 4-27 Single Unit Encoding Procedure]

(b) Whitening

This is used for whitening of the data series. The whitening pattern assumes the PN (9,5) shown in Figure 4-28 as output, and the respective XOR bits starting from the top bit of the unit as whitening output. The shift register shall be initialized for each unit.

![Figure 4-28 Configuration of PN (9,5) used in Unit Whitening]

(c) Error Detection Code

16 bit CRC

Generator polynomial: \( x^{16} + x^{12} + x^5 + 1 \)

The configuration of the CRC encoder must be as shown in Figure 4-29. The initial values of all the shift registers \( S_{15} - S_{00} \) shall be zero and all bits must be inverted at the end.

![Figure 4-29 CRC16 Encoder Configuration]

(c) Trellis Coding (refer to Appendix B)

The convoluted coding shown below must be carried out using a sequence with four fixed bits (All 0) added at the end of an input bit string as input. The output bit must be read alternately in the order of \( G_1 \) followed by \( G_2 \).

Coding rate \( R = 1/2 \)
Constraint length \( K = 5 \)

Generator polynomial:
\[ G_1 = x^4 + x^3 + 1 \]
\[ G_2 = x^4 + x^2 + x + 1 \]
(e) Interleave
After reading the input bit in 2 bit segments and then after making a dibit, an interleave with block length \( M = 9 \) dibits and depth \( N = 20 \) must be carried out.

(f) Encoding Details
The encoding details of a single unit are shown in Figure 4-30 and Figure 4-31.

---

**Figure 4-30 Data Communication Channel (DCH: HC (Header CH), TC (Terminator CH), V/D mode type 1CC and Data FR mode CC) Coding Method**
Figure 4-31 Data Communication Channel (DCH: V/D mode type 2 CC) Coding Method
(3) VCH Section and VeCH Section

In the case of V/D mode type 2, error correction for the purpose of improving the connectivity of a weak electric field is carried out (separately from the error correction function of the voice encoder). The 49 bit voice encoded data is split into 27 and 22 blocks in order to use the majority method as error correction. The 27 data bits in the first half are further divided into 3 bits each (81) which are then combined with the 22 bits in the divided second half (103). 1 bit (0) is added (104). The same whitening as the DCH is applied, and then an interleave with block length M = 26 bit and depth N = 4 is carried out to divide it into VCH (72) and VeCH (32).

The encoding details of the V/D mode type 2 (simultaneous data communication mode 2) is shown in Figure 432.

![Diagram](image-url)
4.6 Communication Channel Start-up / Keep / Stop Conditions

(1) Communication Channel Start-up Procedure
Before transmitting in the communication channel (CC), the radio must continuously transmit the head channel (HC) a prescribed number of times ($N_0$: Recommended value is 1).

(2) Communication Channel Keep Condition
If the frame synchronization is out-of-sync during communication or when there is a failure in migrating from the head channel to the communication channel, autonomous synchronization capture must be carried out in the reception communication channel.

(3) Communication Channel Stop Condition
Not specified.

4.7 Frame Synchronization

(1) Synchronization Establishment Conditions
When frame synchronization symbols are received $N_1$ times continuously (recommended value 1).

(2) Out-of-Sync Conditions
When frame synchronization symbols cannot be received $N_2$ times continuously (recommended value 4).
Appendix

A. Extended Golay Code (24, 12, 8)

The txd coded data is obtained by applying the Golay (24, 12, 8) generation matrix on the original 12 bit data.

\[ txd = [d_{11} \quad d_{10} \quad d_{9} \quad d_{8} \quad d_{7} \quad d_{6} \quad d_{4} \quad d_{3} \quad d_{2} \quad d_{1} \quad d_{0}]. \]

\[
\begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & 0 & 1 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & 1 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & 1 & 0 & 1 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & 1 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & 1 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & 1 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & 1 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & 1 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & 1 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & 1 & 0 & 1 & 0 \\
\end{bmatrix}
\]

Encoded data is

\[ txd = [d_{11} \quad d_{10} \quad d_{9} \quad d_{8} \quad d_{7} \quad d_{6} \quad d_{5} \quad d_{4} \quad d_{3} \quad d_{2} \quad d_{1} \quad d_{0} \quad p_{11} \quad p_{10} \quad p_{9} \quad p_{8} \quad p_{7} \quad p_{6} \quad p_{5} \quad p_{4} \quad p_{3} \quad p_{2} \quad p_{1} \quad p_{0}]. \]
B. Trellis encoder Coding rate R = 1/2 Constraint length K = 5

The configuration of the Trellis encoder is shown in Figure B-1.

\[ G_1 = x^4 + x^3 + 1 \]
\[ G_2 = x^4 + x^2 + x + 1 \]

In the figure above, the initial encoder registers D are all set to 0 and data is then entered while shifting through them. The output switches between G1 and G2 for every shift.