Digital Selective Calling

A Project Report

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THESIS CERTIFICATE

This is to certify that the thesis entitled **Digital Selective Calling**, submitted by **YCS JANARDHANA**, to the Indian Institute of Technology Madras, for the award of the degree of **Master of Technology**, is a bona fide record of the research work carried out by him under my supervision. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

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ABSTRACT

KEYWORDS: GMDSS, DSC

Many ships travel the seas far from land with so many lives and valuable cargo on board. Any small problem can be potentially disastrous. Quick Information and reliable communication systems are very important assets on seas. So Global Maritime Distress and Safety System (GMDSS) is developed. It is an internationally agreed-upon set of safety procedures, types of equipment, and communication protocols used to increase safety and make it easier to rescue distressed ships and pass on information reliably.

This project is an attempt to understand Global Maritime Distress and Safety System and implement Digital Selective Calling (DSC) a standard for sending predefined digital messages via the medium frequency (MF), high frequency (HF) and very high frequency (VHF) maritime radio systems. DSC is a core part of the Global Maritime Distress Safety System.

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ABBREVIATIONS

GMDSS	Global Maritime Distress and Safety System
DSC	Digital Selective Calling
MSI	Maritime Safety Information
EPIRB	Emergency Position Indicating Radio Beacon
SART	Search And Rescue Transponder
GPS	Global Positioning System
MMSI	Maritime Mobile Service Identity
EOS	End Of Sequence
ECC	Error Check Character
FSK	Frequency Shift Keying
VHF	Very High Frequency
HF	High Frequency
MF	Medium Frequency
ITU	International Telecommunication Union

CHAPTER 1

INTRODUCTION

The aim of this project is to understand the GMDSS and implement Digital Selective calling(DSC). GMDSS is an internationally agreed set of safety procedures, types of equipment, and communication protocols used to increase safety on sea. DSC is a core part of GMDSS. It a standard for sending predefined digital messages and to send automatic distress alerts in case of emergency. In this project we source code the predefined messages as per the DSC standards and modulation is done using FSK.

1.1 Organisation of the thesis

In chapter 2, we begin by introducing GMDSS and explain its basic functions. Then we discuss the type of Equipment used in GMDSS.

In chapter 3, we begin by introducing the DSC, its general characteristics. Then we define the DSC standards and look into the technical format of different types of calls.

In chapter 4, we discuss how to implement DSC and we explain how FSK modulation and demodulation is done.

In chapter 5, we discuss results of the project.

CHAPTER 2

Global Maritime Distress and Safety System

2.1 Introduction

The Global Maritime Distress and Safety System (GMDSS) is an internationally agreed upon set of safety procedures, types of equipment, and communication protocols used to increase safety and make it easier to rescue distressed ships, boats and aircraft. The system is intended to perform the following functions: alerting (including position determination of the unit in distress), search and rescue coordination, locating (homing), maritime safety information broadcasts, general communications, and bridge-to-bridge communications. It also provides redundant means of distress alerting, and emergency sources of power.

2.2 Basic concept of the GMDSS

2.2.1 Equipment carriage

A major difference between the GMDSS and the previous Wireless Telegraphy (W/T) and Radio Telephony (R/T) systems is that the equipment to be carried by a ship should be determined by its area of operation rather than by its size.

2.2.2 Search and rescue

The GMDSS uses modern technology, including satellite and Digital Selective Calling techniques on the MF, HF and VHF bands enabling a distress alert to be transmitted and received automatically over short and long distances. The system allows search and rescue authorities ashore, as well as ships in the vicinity of the ship in distress to be rapidly alerted to a distress incident so that they can assist in a coordinated search and rescue operation with the minimum of delay.

2.2.3 Maritime Safety Information

Additionally, the GMDSS provides for urgency and safety communications, and the dissemination of Maritime Safety Information (MSI) - navigational and meteorological information to ships.

2.3 Areas of operation under the GMDSS

Because the different radio systems incorporated into GMDSS have individual limitations with respect to range and service provided, the equipment required to be carried by a ship is determined by the ship's area of operation. The GMDSS has divided the world's oceans into four distinct areas. All vessels are required to carry equipment appropriate to the sea area or areas in which they trade.

GMDSS operational areas:

Area A1: An area within the radiotelephone coverage of at least one VHF coast station in which continuous DSC (Ch.70/156.525 MHz) alerting and radiotelephony services are available. Such an area could extend typically upto 30 to 40 nautical miles (56 to 74 km) from the Coast Station.

Area A2: An area, excluding Sea Area A1, within the radiotelephone coverage of at least one MF coast station in which continuous DSC (2187.5 kHz) alerting and radiotelephony services are available. For planning purposes, this area typically extends to up to 180 nautical miles (330 km) offshore, but would exclude any A1 designated areas.

Area A3: An area, excluding sea areas A1 and A2, within the coverage of an Inmarsat geostationary satellite. This area lies between about latitude 76 Degrees North and South, but excludes A1 and/or A2 designated areas.

Area A4: An area outside Sea Areas A1, A2 and A3 is called Sea Area A4. This is essentially the polar regions, north and south of about 76 degrees of latitude, excluding any A1, A2 and A3 areas.

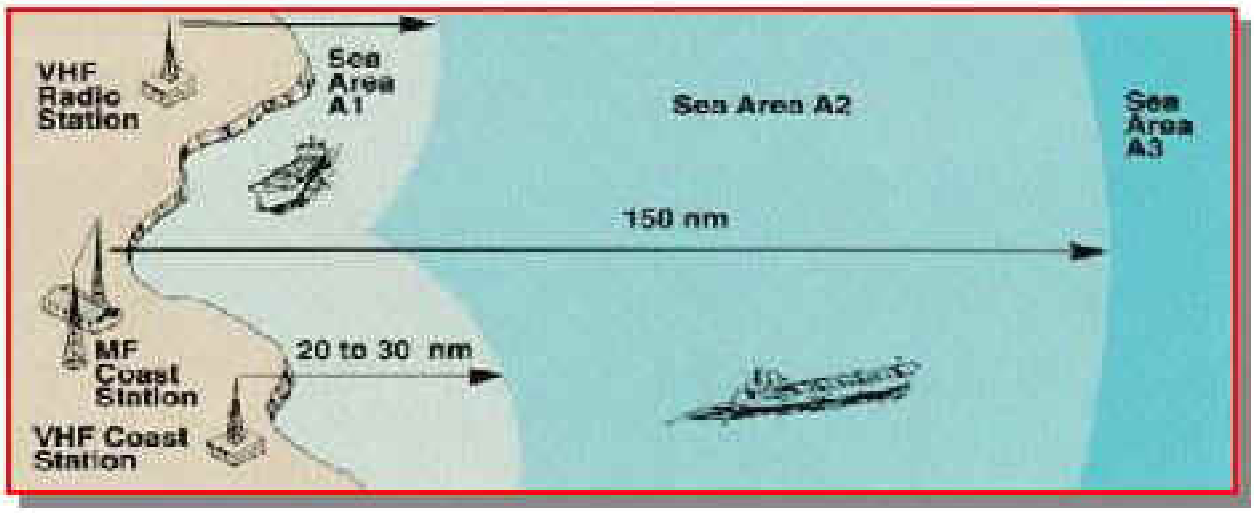


Figure 2.1: GDMSS Sea Areas

2.4 Components of GMDSS

The main types of equipment used in GMDSS are:

2.4.1 Emergency Position Indicating Radio Beacon

Cospas-Sarsat is an international satellite-based search and rescue system. The 406 MHz Emergency Position-Indicating Radio Beacon (EPIRB), an element of the GMDSS designed to operate with Cospas-Sarsat system. These automatic activating EPIRBs, now required on SOLAS ships, commercial fishing vessels, and all passenger ships, are designed to transmit to alert rescue coordination centres via the satellite system from anywhere in the world. The GPS incorporated EPIRBs transmit highly accurate positions (within about 20 metres) of the distress position. 406 MHz EPIRB's transmit a registration number which is linked to a database of information about the vessel.

2.4.2 Digital Selective Calling

Digital Selective Calling or DSC is a standard for sending predefined digital messages via the medium frequency (MF), high frequency (HF) and very high frequency (VHF) maritime radio systems. DSC is used to automate distress alerts, which allows for faster and more reliable way for signalling distress.

2.4.3 NAVTEX

Navtex is an international, automated system for instantly distributing maritime safety information (MSI) which includes navigational warnings, weather forecasts and weather warnings, search and rescue notices and similar information to ships. A small, low-cost and self-contained smart printing radio receiver is installed on the bridge, or the place from where the ship is navigated, and checks each incoming message to see if it has been received during an earlier transmission, or if it is of a category of no interest to the ship's master. The messages are coded with a header code identified by the using single letters of the alphabet to represent broadcasting stations, type of messages, and followed by two figures indicating the serial number of the message.

2.4.4 Inmarsat

Satellite systems operated by the Inmarsat company, are also important elements of the GMDSS. The types of Inmarsat ship earth station terminals recognized by the GMDSS are: Inmarsat B, C and F77. Inmarsat B and F77, provide ship/shore, ship/ship and shore/ship telephone, telex and high-speed data services, including a distress priority telephone and telex service to and from rescue coordination centres. Fleet 77 fully supports the Global Maritime Distress and Safety System (GMDSS) and includes advanced features such as emergency call prioritisation. The Inmarsat C provides ship/shore, shore/ship and ship/ship store-and-forward data and email messaging, the capability for sending preformatted distress messages to a rescue coordination centre.

2.4.5 High frequency

A GMDSS system may include high-frequency (HF) radiotelephone and radiotelex (narrow-band direct printing) equipment, with calls initiated by digital selective calling (DSC). Worldwide broadcasts of maritime safety information can also made on HF narrow-band direct printing channels.

2.4.6 Search And Rescue Transponder

The GMDSS installation on ships include one or two Search and Rescue Locating device(s) called Search and Rescue Radar Transponders (SART) which are used to locate survival craft or distressed vessels by creating a series of twelve dots on a rescuing ship's 3 cm radar display. The detection range between these devices and ships, dependent upon the height of the ship's radar mast and the height of the Search and Rescue Locating device, is normally about 15 km (8 nautical miles).

CHAPTER 3

Digital Selective Calling

3.1 Introduction

Digital selective calling or DSC is a standard for sending predefined digital messages via the medium frequency (MF), high frequency (HF) and very high frequency (VHF) maritime radio systems. DSC is primarily intended to initiate ship-to-ship, ship-to-shore and shore-to-ship radiotelephone and MF/HF radiotelex calls. DSC calls can also be made to individual stations, groups of stations, or all stations in one's radio range. Each DSC equipped ship, shore station and group is assigned a unique 9 digit Maritime Mobile Service Identity. DSC distress alerts, which consist of a preformatted distress message, are used to initiate emergency communications with ships and rescue coordination centres. DSC was intended to eliminate the need for persons on a ship's bridge or on shore to continuously guard radio receivers on voice radio channels. DSC signal uses a stable signal with a narrow bandwidth and the receiver has no squelch, it has a slightly longer range than analog signals.

3.2 General characteristics

The system is a synchronous system using characters composed from a ten bit error detecting code as listed in Table 3.1. The first seven bits of the ten bit code of Table 3.1 are information bits. Bits 8, 9 and 10 indicate, in the form of a binary number, the number of B elements that occur in the seven information bits, a Y element being a binary number 1 and a B element a binary number 0,this is used as parity check for information bits. The seven information bits of the primary code express a symbol number from 00 to 127, as shown in Table 3.1. The symbols from 00 to 99 are used to code two decimal figures according to Table 3.2. The symbols from 100 to 127 are used to code service commands according to Table 3.3.

Each character is transmitted twice in a time-spread mode; the first transmission (DX) of a specific character is followed by the transmission of four other characters before the retransmission (RX) of that specific character takes place, allowing for a time-diversity as in Figure 3.1.

In VHF channels Modulation used is frequency shift keying (FSK) with two tones 1300 Hz and 2100 Hz, with the sub-carrier being at 1700 Hz, frequency tolerance is ± 10 Hz.The bit rate is 1200 B/s (bit/s).The higher frequency corresponds to the B state and the lower frequency corresponds to the Y state of the signal elements.

3.3 DSC call categories

The DSC system supports a number of call categories. These categories mirror the standard maritime prioritisation of message traffic.

DISTRESS

URGENCY

SAFETY

ROUTINE

Distress alerts are automatically addressed to all stations. Urgency, safety and routine calls can be addressed to all stations, an individual station, or a group of stations.

3.4 Technical format of call sequence.

The technical format of the call sequence is:

Dot pattern	Phasing sequence	Call content	Closing sequence

3.4.1 Dot pattern and phasing sequence

The phasing sequence provides information to the receiver to permit correct bit phasing and unambiguous determination of the positions of the characters within a call sequence. The phasing sequence consists of specific characters in the DX and RX positions transmitted alternatively. Six DX characters are transmitted. The phasing character in the DX position is symbol No. 125. The phasing characters in the RX position specify the start of the information sequence(i.e. the format specifier) and consist of the symbol Nos. 111, 110, 109, 108, 107, 106, 105 and 104 of Table 3.1, consecutively. The phasing sequence is preceded by a dot pattern for call initiation.

3.4.2 Format specifier

Format specifier is used to determine the nature of call, and coded according to Table 3.3. The format specifier characters which are transmitted twice in both the

DX and RX positions (see Figure 3.1). It is considered that receiver decoders must detect the format specifier character twice for distress alerts and all ships calls to effectively eliminate false alerting. For other calls, the address characters provide additional protection against false alerting and, therefore, single detection of the format specifier character is considered satisfactory.

3.4.3 Address

For a selective call directed to an individual ship, to a coast station or to a group of stations having a common interest, the address consists of the characters corresponding to the station's maritime mobile service identity, the sequence consisting of characters coded in accordance with Table 3.2.

3.4.4 Category

The category information is coded as shown in Table 3.3 and defines the degree of priority of the call sequence. For a distress alert the priority is defined by the format specifier and no category information is included in the call sequence. For distress relays, distress relay acknowledgements and distress acknowledgements the category is distress. For safety related calls, the category is urgency or safety. For other calls, the category is routine.

3.4.5 Maritime Mobile Service Identity

The MMSI is an address assigned to the calling station, coded as indicated in 3.4.3, is used for self-identification.

3.4.6 Message

The messages that are included in a call sequence contain the following message elements. All message formats are explicitly defined in Table 3.4.

3.4.7 Distress coordinates

Distress coordinates message, consisting of ten digits indicating the location of the vessel in distress, coded on the principles described in Table 3.2, in pairs starting from the first and second digits. The first digit indicates the quadrant in which the incident has occurred, as follows:

Quadrant NE is indicated by the digit 0.

Quadrant NW is indicated by the digit 1.

Quadrant SE is indicated by the digit 2.

Quadrant SW is indicated by the digit 3.

The next four figures indicate the latitude in degrees and minutes. The next five figures indicate the longitude in degrees and minutes. If distress coordinates cannot be included, or if the position information has not been updated for 23½ h, the 10 digits following the nature of distress should be automatically transmitted as the digit 9 repeated 10 times.

3.4.8 Time

Time message, consisting of four digits indicating the time, coded on the principles described in Table 3.2, in pairs starting from the first and second digits. The first two digits indicate the time in hours. The third and fourth digits indicate the part of the hours in minutes. If the time cannot be included the four time indicating digits should be transmitted automatically as "8 8 8 8".

3.4.9 Telecommand message

For calls other than distress, telecommand information is passed for subsequent communication. Telecommand information and consists of 2 characters (first and second telecommand) coded as shown in Table 3.3. If no information additional to that conveyed by the first telecommand character is required, then the second telecommand signal should be symbol No. 126 (no information).

3.4.10 Frequency message

For calls other than distress, Frequency message is passed for subsequent communication. Frequency message may contain two channel or frequency message elements, each of which always consists of three characters, character 1, character 2 and character 3, indicating the proposed working frequency (in the F1B/J2B mode the assigned frequency should be used) in multiples of 100 Hz or the channel number (coded in accordance with Table 3.5) or the ship's position. The first frequency element (the RX field) in the call indicates the called station receive frequency and the second frequency element (the TX field) indicates the called station transmit frequency. In acknowledgements the RX and TX fields indicate the receiver and transmit frequency of the acknowledging station respectively.

3.4.11 End of Sequence

The End of Sequence (EOS) character is transmitted three times in the DX position and once in the RX position (see Figure 3.1). It is one of the three unique characters corresponding to symbol Nos. 117, 122 and 127. Symbol No. 117 is used if the call requires acknowledgement (Acknowledge RQ), used for individual and automatic/semiautomatic calls only. Symbol No. 122 is used if the sequence is an answer to a call that requires acknowledgement (Acknowledge BQ), used for individual and automatic/semiautomatic calls and all distress relay acknowledgements. Symbol No. 127 is used for all other calls as in Table 3.3.

3.4.12 Error Check Character

The Error check character (ECC) is the final character transmitted and it serves to check the entire sequence for the presence of errors which are undetected by the ten-unit error-detecting code and the time diversity employed.

The seven information bits of the ECC shall be equal to the least significant bit of the modulo-2 sums of the corresponding bits of all information characters (i.e. even vertical parity). The format specifier and the EOS characters are considered to be information characters. The phasing characters and the retransmission (RX) characters shall not be considered to be information characters. Only one format specifier character and one EOS character should be used in constructing the ECC. The ECC shall also be sent in the DX and RX positions.

Automatic acknowledgement transmissions should not start unless the ECC is received and decoded correctly. A received ECC which does not match that calculated from the received information characters may be ignored if this was due to an error detected in the ten-unit error-detecting code of the information characters which was correctable by use of the time diversity code.

Table 3.1

Ten-bit error-detecting code

Symbol No.	Emitted signal and bit position 1 2 3 4 5 6 7 8 9 10	Symbol No.	Emitted signal and bit position 1 2 3 4 5 6 7 8 9 10	Symbol No.	Emitted signal and bit position 1 2 3 4 5 6 7 8 9 10
00	BBBBBBBYYY	43	YYBYBYBBYY	86	BYYBYBYBYY
01	YBBBBBBYYB	44	BBYYBYBYBB	87	YYYBYBYBYB
02	BYBBBBBYYB	45	YBYYBYBBYY	88	BBBYYBYYBB
03	YYBBBBBYBY	46	BYYYBYBBYY	89	YBBYYBYBYY
04	BBYBBBBYYB	47	YYYYBYBBYB	90	BYBYYBYBYY
05	YBYBBBBYBY	48	BBBBYYBYBY	91	YYBYYBYBYB
06	BYYBBBBYBY	49	YBBBYYBYBB	92	BBYYYBYBYY
07	YYYBBBBYBB	50	BYBBYYBYBB	93	YBYYYBYBYB
08	BBBYBBBYYB	51	YYBBYYBBYY	94	BYYYYBYBYB
09	YBBYBBBYBY	52	BBYBYYBYBB	95	YYYYYBYBBY
10	BYBYBBBYBY	53	YBYBYYBBYY	96	BBBBBYYYBY
11	YYBYBBBYBB	54	BYYBYYBBYY	97	YBBBBYYYBB
12	BBYYBBBYBY	55	YYYBYYBBYB	98	BYBBBYYYBB
13	YBYYBBBYBB	56	BBBYYYBYBB	99	YYBBBYYBYY
14	BYYYBBBYBB	57	YBBYYYBBYY	100	BBYBBYYYBB
15	YYYYBBBBYY	58	BYBYYYBBYY	101	YBYBBYYBYY
16	BBBBYBBYYB	59	YYBYYYBBYB	102	BYYBBYYBYY
17	YBBBYBBYBY	60	BBYYYYBBYY	103	YYYBBYYBYB
18	BYBBYBBYBY	61	YBYYYYBBYB	104	BBBYBYYYBB
19	YYBBYBBYBB	62	BYYYYYBBYB	105	YBBYBYYBYY
20	BBYBYBBYBY	63	YYYYYYBBBY	106	BYBYBYYBYY
21	YBYBYBBYBB	64	BBBBBBYYYB	107	YYBYBYYBYB
22	BYYBYBBYBB	65	YBBBBBYYBY	108	BBYYBYYBYY
23	YYYBYBBBYY	66	BYBBBBYYBY	109	YBYYBYYBYB
24	BBBYYBBYBY	67	YYBBBBYYBB	110	BYYYBYYBYB
25	YBBYYBBYBB	68	BBYBBBYYBY	111	YYYYBYYBBY
26	BYBYYBBYBB	69	YBYBBBYYBB	112	BBBBYYYYBB
27	YYBYYBBBYY	70	BYYBBBYYBB	113	YBBBYYYBYY
28	BBYYYBBYBB	71	YYYBBBYBYY	114	BYBBYYYBYY
29	YBYYYBBBYY	72	BBBYBBYYBY	115	YYBBYYYBYB
30	BYYYYBBBYY	73	YBBYBBYYBB	116	BBYBYYYBYY
31	YYYYYBBBYB	74	BYBYBBYYBB	117	YBYBYYYBYB
32	BBBBBYBYYB	75	YYBYBBYBYY	118	BYYBYYYBYB
33	YBBBBYBYBY	76	BBYYBBYYBB	119	YYYBYYYBBY
34	BYBBBYBYBY	77	YBYYBBYBYY	120	BBBYYYYBYY
35	YYBBBYBYBB	78	BYYYBBYBYY	121	YBBYYYYBYB
36	BBYBBYBYBY	79	YYYYBBYBYB	122	BYBYYYYBYB
37	YBYBBYBYBB	80	BBBBYBYYBY	123	YYBYYYYBBY
38	BYYBBYBYBB	81	YBBBYBYYBB	124	BBYYYYYBYB
39	YYYBBYBBYY	82	BYBBYBYYBB	125	YBYYYYYBBY
40	BBBYBYBYBY	83	YYBBYBYBYY	126	BYYYYYYBBY
41	YBBYBYBYBB	84	BBYBYBYYBB	127	YYYYYYYBBB
42	BYBYBYBYBB	85	YBYBYBYBYY		

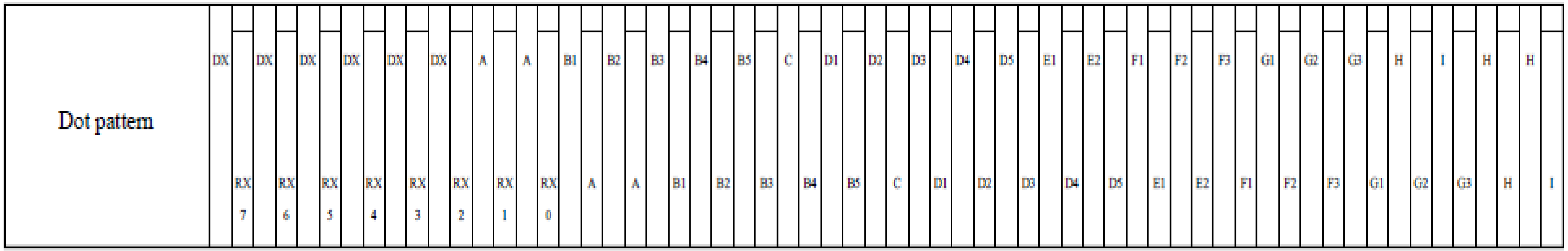
B = 0
Y = 1

Order of bit transmission: bit 1 first.

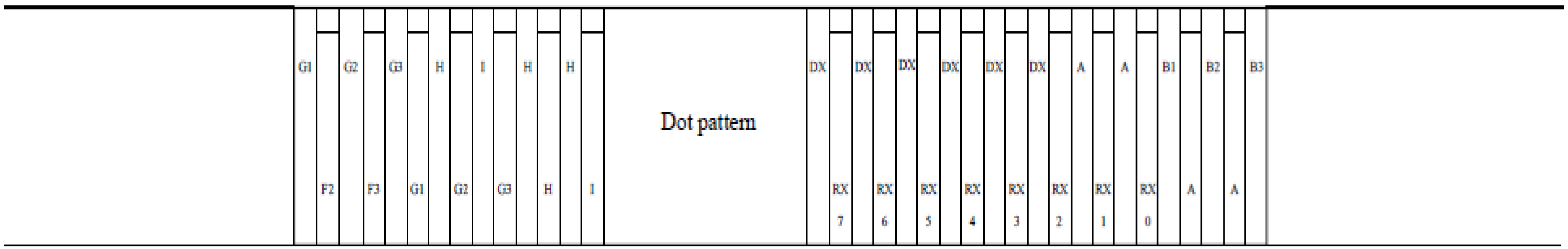
Figure 3.1

Dot pattern	DX/RX Phasing sequence	A Format specifier 2 identical characters	B Called party address 5 characters	C Category 1 character	D Self-identification 5 characters	E Telecommand message 2 characters	F Frequency message 3 characters	G Frequency message 3 characters	H End of sequence 3 identical DX characters 1 RX character	I Error-check character 1 character

a) Technical format of a typical routine message



b) Transmission sequence corresponding to a



c) Transmission sequence for repetition of a distress call

Table 3.2

Packing table for decimal numbers into ten-bit characters

The digits for the									
Thousands of millions D2	Hundreds of millions D1	Tens of millions D2	Millions D1	Hundreds of thousands D2	Tens of thousands D1	Thousands D2	Hundreds D1	Tens D2	Units D1
Character 5		Character 4		Character 3		Character 2		Character 1	

NOTE 1 – Character 1 is the last character transmitted.

The digit sequence D2-D1 varies from 00 to 99 inclusive in each character (character 1 to 5 inclusive). The character that represents a particular two-decimal figure is transmitted as the symbol number (see Table 1) that is identical to that particular two-decimal figure.

When the number consists of an odd number of decimal digits, a zero shall be added in front of the most significant position to provide an integral number of ten-bit characters.

Table 3.3

Use of symbol Nos. 100 to 127

Symbol No.	Phasing and unique functions	Format specifier(1)	Category(1)	Nature of distress(1)	First telecommand(1)	Second telecommand(1)
100			Routine	Fire, explosion	F3E/G3E All modes TP	No reason given(2)
101				Flooding	F3E/G3E duplex TP	Congestion at maritime switching centre
102		Geographical area		Collision		Busy(2)
103		(3)	(3)	Grounding	Polling	Queue indication(2)
104	Phasing RX-0 position			Listing, in danger of capsizing	Unable to comply	Station barred(2)
105	Phasing RX-1 position			Sinking	End of call(4)	No operator available(2)
106	Phasing RX-2 position		(6)	Disabled and adrift	Data	Operator temporarily unavailable(2)
107	Phasing RX-3 position			Undesignated distress		Equipment disabled(2)
108	Phasing RX-4 position		Safety	Abandoning ship		Unable to use proposed channel(2)
109	Phasing RX-5 position			Piracy/armed robbery attack	J3E TP	Unable to use proposed mode(2)
110	Phasing RX-6 position	(5)	Urgency	Man overboard	Distress acknowledgement	Ships and aircraft of States not parties to an armed conflict

(continued)

Symbol No.	Phasing and unique functions	Format specifier[1]	Category[1]	Nature of distress[1]	First telecommand[1]	Second telecommand[1]
111	Phasing RX-7 position				[6]	Medical transports (as defined in 1949 Geneva Conventions and additional Protocols)
112		Distress	Distress	EPIRB emission	Distress relay	Pay-phone/public call office
113					F1B/J2B TTY-FEC	Facsimile/data according to Recommendation ITU-R M.1081
114		Ships having common interest				
115					F1B/J2B TTY-ARQ	[6]
116		All ships[7]			[6]	[6]
117	Ack. RQ (EOS)				[6]	[6]
118					Test	[6]
119					[6]	[6]
120		Individual stations			[6]	[6]
121		Reserved for national non-calling purposes e.g. Report ITU-R M.1159			Ship position or location registration updating	[6]
122	Ack. BQ (EOS)				[6]	[6]
123		Individual station semi-automatic/ automatic service			[6]	[6]
124		[5]			[6]	[6]
125	Phasing DX position				[6]	[6]
126	*				No information	No information
127	EOS				[6]	[6]

TP: Telephony
TTY: Direct printing
ARQ: Rec. ITU-R M.476 or Rec. ITU-R M.625 equipment

[1] Unassigned symbols should be rejected. The DSC equipment should take no action.

[2] Currently unassigned when used with first telecommands other than symbol No. 104 – for future use.

[3] Used for selective call to a group of ships in a specified VTS area (Rec. ITU-R M.825). Reception of calls having format specifier 103, for (or) category shall not activate any alarms on shipborne DSC controller. Should not be used in any future expansion.

[4] Only used for semi-automatic/automatic service.

[5] Used in the automatic VHF/UHF service (Rec. ITU-R M.586). Should not be used in any future expansion.

[6] Should not be used in any future expansion.

[7] MF/HF used only for distress alert acknowledgment and coast station receive (see Table 4).

Table 3.4: Technical format of call sequence

Distress alerts

	Format specifier (2 identical)	Self-ID (5)	Message 1: Nature of distress (1)	Message 2: Distress coordinates (5)	Message 3: Time (2)	Message 4: Subsequent communications (1)	EOS (1)	ECC (1)	EOS (2 identical)
Distress (RT)	112	MMSI	100 to 111	Pos1	UTC	100	127	ECC	127

Distress acknowledgements

	Format specifier (2 identical)	Category (1)	Self-ID (5)	Telecommand (1)	Message 0: Distress MMSI (5)	Message 1: Nature of distress (1)	Message 2: Distress coordinates (5)	Message 3: Time (2)	Message 4: Subsequent communications (1)	EOS (1)	ECC (1)	EOS (2 identical)
Distress acknowledgement (RT)	116	112	MMSI	110	MMSI	100 to 111	Pos1	UTC	100	127	ECC	127

Distress relays

	Format specifier (2 identical)	Address (5)	Category (1)	Self-ID (5)	Telecommand (1)	Message 0: Distress MMSI (5)	Message 1: Nature of distress (1)	Message 2: Distress coordinates (5)	Message 3: Time (2)	Message 4: Subsequent communications (1)	EOS (1)	ECC (1)	EOS (2 identical)
Individual (RT)	120	MMSI	112	MMSI	112	MMSI	100 to 111	Pos1	UTC	100	117	ECC	117
Geographic area (RT)	102	Zone	112	MMSI	112	MMSI	100 à 111	Pos1	UTC	100	127	ECC	127
All ships (RT)	116	n/a	112	MMSI	112	MMSI	100 to 111	Pos1	UTC	100	127	ECC	127

Distress relay acknowledgements

	Format specifier (2 identical)	Address (5)	Category (1)	Self-ID (5)	Telecommand (1)	Message 0: Distress MMSI (5)	Message 1: Nature of distress (1)	Message 2: Distress coordinates (5)	Message 3: Time (2)	Message 4: Subsequent communications (1)	EOS (1)	ECC (1)	EOS (2 identical)
Individual (RT)	120	MMSI	112	MMSI	112	MMSI	100 to 111	Pos1	UTC	100	122	ECC	122
All ships (RT)	116	n/a	112	MMSI	112	MMSI	100 to 111	Pos1	UTC	100	122	ECC	122

Urgency and safety calls – All ships

	Format specifier (2 identical)	Category (1)	Self-ID (5)	Message 1: 1st tele-command (1)	Message 1: 2nd tele-command (1)	Message 2: Frequency (6)	EOS (1)	ECC (1)	EOS (2 identical)
All modes RT	116	108 or 110	MMSI	100	126	Frequency	127	ECC	127
Duplex RT	116	108 or 110	MMSI	101	126	Frequency	127	ECC	127
Medical transports	116	110	MMSI	100	111	Frequency	127	ECC	127
Ships and aircraft	116	110	MMSI	100	110	Frequency	127	ECC	127

Urgency and safety – Individual calls and their acknowledgements

	Format specifier (2 identical)	Address (5)	Category (1)	Self-ID (5)	Message 1: 1st tele-command (1)	Message 1: 2nd tele-command (1)	Message 2: Frequency or pos number (6)	Message 3: Time (2)	EOS (1)	ECC (1)	EOS (2 identical)
All modes RT	120	MMSI	108 or 110	MMSI	100	126	Frequency	n/a	117	ECC	117
Duplex RT	120	MMSI	108 or 110	MMSI	101	126	Frequency	n/a	117	ECC	117
RT acknowledgement	120	MMSI	108 or 110	MMSI	100	126	Frequency	n/a	122	ECC	122
Unable to comply acknowledgement	120	MMSI	108 or 110	MMSI	104	100 to 109	Frequency	n/a	122	ECC	122
Position request	120	MMSI	108	MMSI	121	126	Pos3	n/a	117	ECC	117
Position acknowledgement	120	MMSI	108	MMSI	121	126	Pos4	UTC	122	ECC	122
Test	120	MMSI	108	MMSI	118	126	126	n/a	117	ECC	117
Test acknowledgement	120	MMSI	108	MMSI	118	126	126	n/a	122	ECC	122

Routine group calls

	Format specifier (2 identical)	Address (5)	Category (1)	Self-ID (5)	Message			EOS (1)	ECC (1)	EOS (2 identical)
					1		2			
					1st tele-command (1)	2nd tele-command (1)	Frequency (6)			
All mode RT	114	MMSI	100	MMSI	100	126	Frequency	127	ECC	127
Duplex RT	114	MMSI	100	MMSI	101	126	Frequency	127	ECC	127

Routine individual calls and their acknowledgements

	Format specifier (2 identical)	Address (5)	Category (1)	Self-ID (5)	Message			EOS (1)	ECC (1)	EOS (2 identical)
					1		2			
					1st tele-command (1)	2nd tele-command (1)	Frequency or pos number (6)			
All mode RT	120	MMSI	100	MMSI	100	126	Frequency	117	ECC	117
Duplex RT'	120	MMSI	100	MMSI	101	126	Frequency	117	ECC	117
RT acknowledgement	120	MMSI	100	MMSI	100	126	Frequency	122	ECC	122
Data	120	MMSI	100	MMSI	106	126	Frequency	117	ECC	117
Data acknowledgement	120	MMSI	100	MMSI	106	126	Frequency	122	ECC	122
Unable to comply acknowledgement	120	MMSI	100	MMSI	104	100 to 109	Frequency	122	ECC	122
Polling	120	MMSI	100	MMSI	103	126	126	117	ECC	117
Polling acknowledgement	120	MMSI	100	MMSI	103	126	126	122	ECC	122

n/a-This field is not included in this call.

Table 3.5

Frequency or channel information

Frequency	0 1 2	X X X	X X X	X X X	X X X	X X X	The frequency in multiples of 100 Hz as indicated by the figures for the digits HM, TM, M, H, T, U. This should be used for MF, HF equipment.
Channels	3	X	X	X	X	X	The HF/MF working channel number indicated by the values of the digits TM, M, H, T and U. This should be used for backward compatibility in receive only mode.
	8	X	X	X	X	X	Only used for Recommendation ITU-R M.586 equipment.
	9	0	X[(1)]	X	X	X	The VHF working channel number indicated by the values of the digits M, H, T and U.
	HM	TM	M	H	T	U	
	Character 3		Character 2		Character 1[(2)]		

(1) If the M digit is 1 this indicates that the ship stations transmitting frequency is being used as a simplex channel frequency for both ship and coast stations. If the M digit is 2 this indicates that the coast stations transmitting frequency is being used as a simplex channel frequency for both ship and coast stations. If the M digit is 0, this indicates the frequency being used is in accordance with RR Appendix 18 for both single and two frequency channels.

(2) Character 1 is the last character transmitted.

Table 3.6

Position information

	Quadrant digit	Latitude				Longitude				
	NE = 0 NO = 1 SE = 2 SO = 3	Tens of degrees	Units of degrees	Tens of minutes	Units of minutes	Hundreds of degrees	Tens of degrees	Units of degrees	Tens of minutes	Units of minutes
55	X	X	X	X	X	X	X	X	X	X
Character 6	Character 5		Character 4		Character 3		Character 2		Character 1[(1)]	

(1) Character 1 is the last character transmitted.

CHAPTER 4

Implementation

4.1 Introduction

In this chapter we discuss how Digital Selective Calling (DSC) feature of GMDSS is implemented. The system is divided into two parts transmitter and receiver, which are defined below. Frequency shift keying (FSK) is used to modulate carrier wave. 1300Hz and 2100Hz are the two tones used with buad rate of 1200 bits/sec.

4.2 Transmitter

In transmitter, Message text is coded to message bits by the encoder as per the DSC standards mentioned in chapter 3 and coded message bits are modulated onto carrier wave by the modulator and transmitted.

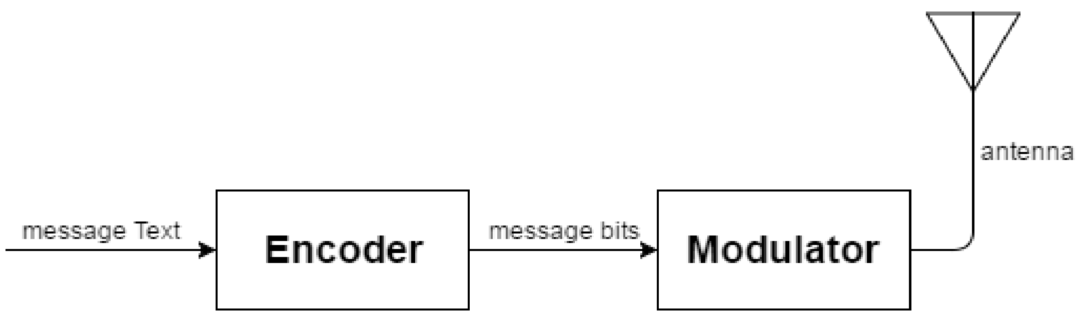


Figure 4.1: Transmitter

4.2.1 Encoder

Upon initiating the call, the nature of call (distress alerts, distress acknowledgements, distress relays, distress relay acknowledgements, urgency and safety calls, routine calls) is determined and relevant information characters are sought from the input as defined in Table 3.4 and the message is translated to information characters as defined in Table 3.3, Error-check character (ECC) is calculated as said in 3.4.12 and added to information characters. Phasing and time diversification is done by adding DX and RX0-7 phasing characters to information characters for more redundancy (see Figure 3.1) and is coded to bit sequence as defined in Table 3.1, Dot pattern is prefixed to bit sequence to form message bits, to be modulated and transmitted as in Figure 4.2.

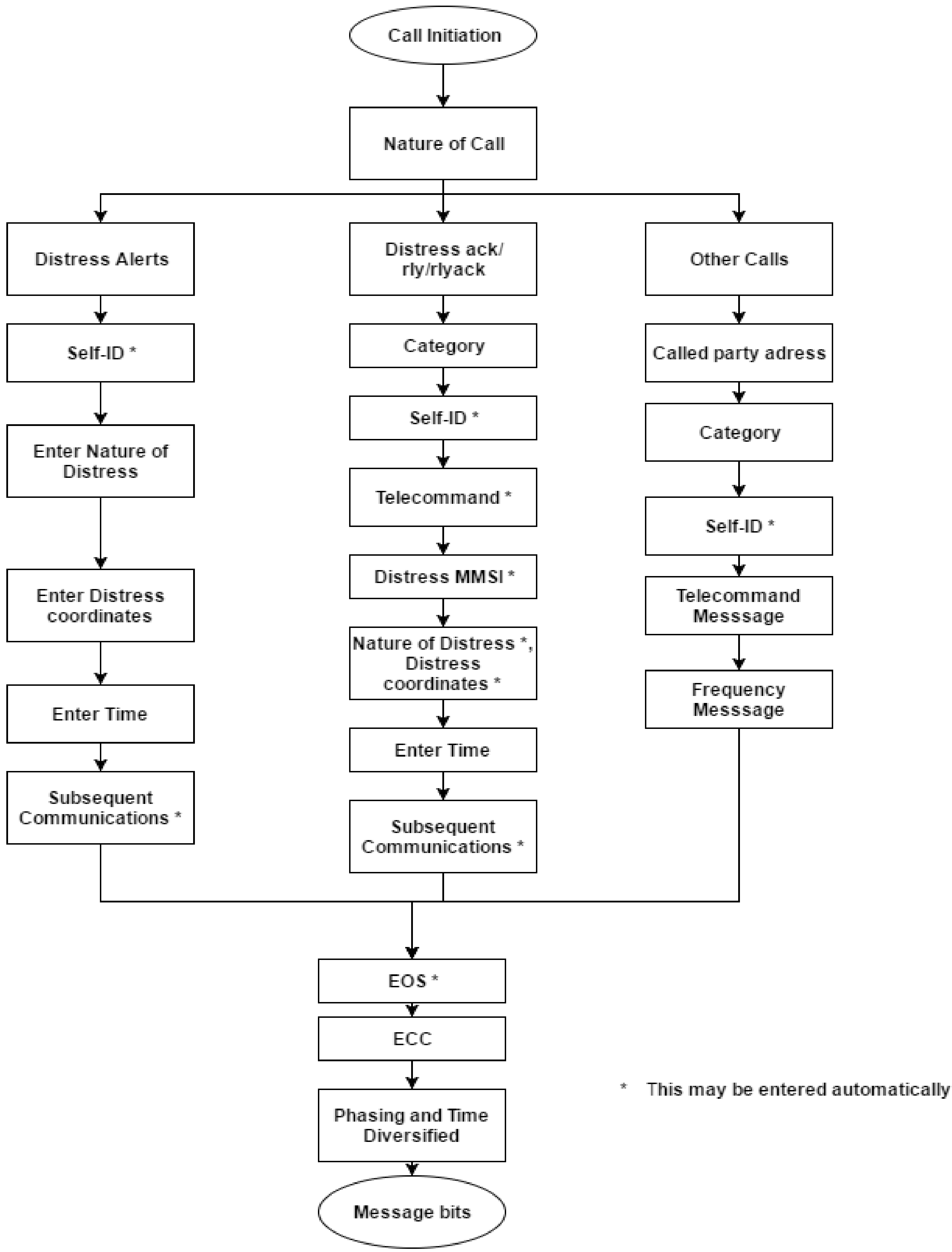


Figure 4.2: Encoder

4.2.2 Modulator

Here we use FSK system to modulate message bits onto carrier wave. The signals transmitted for marks (binary ones) and spaces (binary zeros) are,

$$S_1(t) = A\cos(2\pi f_1 t) \quad 0 < t \leq T$$

$$S_2(t) = A\cos(2\pi f_2 t) \quad 0 < t \leq T$$

$$m(t) = \begin{cases} S_1(t) & if\, bit = 0 \\ S_2(t) & if\, bit = 1 \end{cases}$$

The phase of the signal is discontinuous at the switching times. Then the signal is up-converted to carrier wave frequency by multipling with $\sqrt{2}\cos(2\pi f_c t)$ and transmitted.

$$Transmitted\, Signal = \sqrt{2} m(t) \cos(2\pi f_c t)$$

4.3 Receiver

In receiver the received signal is in passband which is down-converted and then the signal is demodulated to message bits using synchronous FSK demodulator. The message bits are then decoded to message text by decoder and displayed to screen.

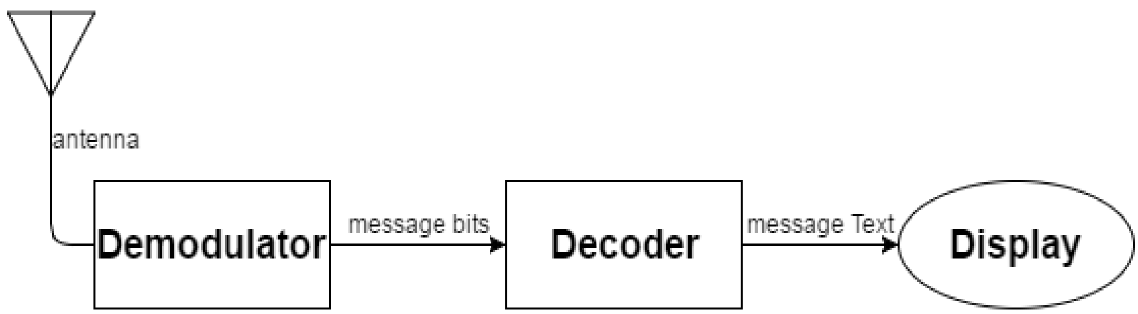


Figure 4.3: Receiver

4.3.1 Demodulator

In demodulator the received signal is down-converted. Due to the difference in carrier frequency at transmitter and receiver sides and sampling time instant a frequency offset and phase offset are introduced to the signal, upon down conversion this leads to inphase $I(t)$ and quadrature phase $Q(t)$ components. Using inphase and quadrature phase components timing instant and frequency offset are determined. The signal is frequency offset corrected and used to determine message bits.

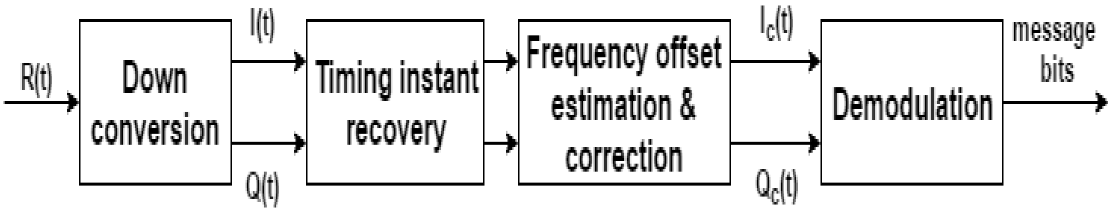


Figure 4.4: Demodulator

Down conversion

The received signal, R(t) is multiplied with $\sqrt{2}\cos(2\pi f_c t)$ and $\sqrt{2}\sin(2\pi f_c t)$ and passed through low pass filter to get inphase and quadrature phase components respectively as shown below.

$$R(t) = \sqrt{2}m(t)\cos\left(2\pi f_c t + 2\pi\Delta f t + \phi\right)$$

Let $\phi_f(t) = 2\pi\Delta f t$.

$$R(t) \times \sqrt{2}\cos(2\pi f_c t) = 2m(t)\cos\left(2\pi f_c t + 2\pi\Delta f t + \phi\right)\cos(2\pi f_c t)$$

$$= 2m(t)\left(\cos^2(2\pi f_c t)\cos\left(\phi_f(t) + \phi\right) - \cos(2\pi f_c t)\sin(2\pi f_c t)\sin\left(\phi_f(t) + \phi\right)\right.$$

$$= m(t)\cos\left(\phi_f(t) + \phi\right) + m(t)G(f_c)$$

where $G(f_c) = \cos(4\pi f_c t)\cos\left(\phi_f(t) + \phi\right) - \sin(4\pi f_c t)\sin\left(\phi_f(t) + \phi\right)$

Low pass filtering is done to eliminate higher frequency components $G(f_c)$ to get inphase component.

$$I(t) = m(t)\cos\left(\phi_f(t) + \phi\right)$$

$$R(t) \times \sqrt{2}\sin(2\pi f_c t) = 2m(t)\cos\left(2\pi f_c t + 2\pi\Delta f t + \phi\right)\sin(2\pi f_c t)$$
$$= 2m(t)\left(\cos(2\pi f_c t)\sin(2\pi f_c t)\cos\left(\phi_f(t) + \phi\right) - \sin^2(2\pi f_c t)\sin\left(\phi_f(t) + \phi\right)\right.$$
$$= -m(t)\sin\left(\phi_f(t) + \phi\right) + m(t)H(f_c)$$

where $H(f_c) = \cos(4\pi f_c t)\sin\left(\phi_f(t) + \phi\right) + \sin(4\pi f_c t)\cos\left(\phi_f(t) + \phi\right)$

Low pass filtering is done to eliminate higher frequency components $H(f_c)$and the output is multiplied with -1 to get quadrature phase component.

$$Q(t) = m(t)\sin\left(\phi_f(t) + \phi\right)$$

$$r(t) = I(t) + jQ(t) = m(t)\exp\left(j\left(\phi_f(t) + \phi\right)\right)$$

Timing instant recovery

Since all DSC message signals have dot pattern prefix we use that information to recover timing instant, I(t) and Q(t) are both multiplied with S_1 and integrated over the symbol duration, square and add them to obtain T1. Similarly I(t) and Q(t) are both multiplied with S_2 and integrated over the symbol duration, square and add them to obtain T2. Now T1 and T2 are compared to determine the bit sequence (see Figure 4.5). Then the bit sequence are checked for a partial dot pattern (example:1010101010), if not found, signals are shifted, if partial dot pattern is detected then the signals are checked maximum energy detection for the next bit interval to get best timing instant(see Algorithm 1).

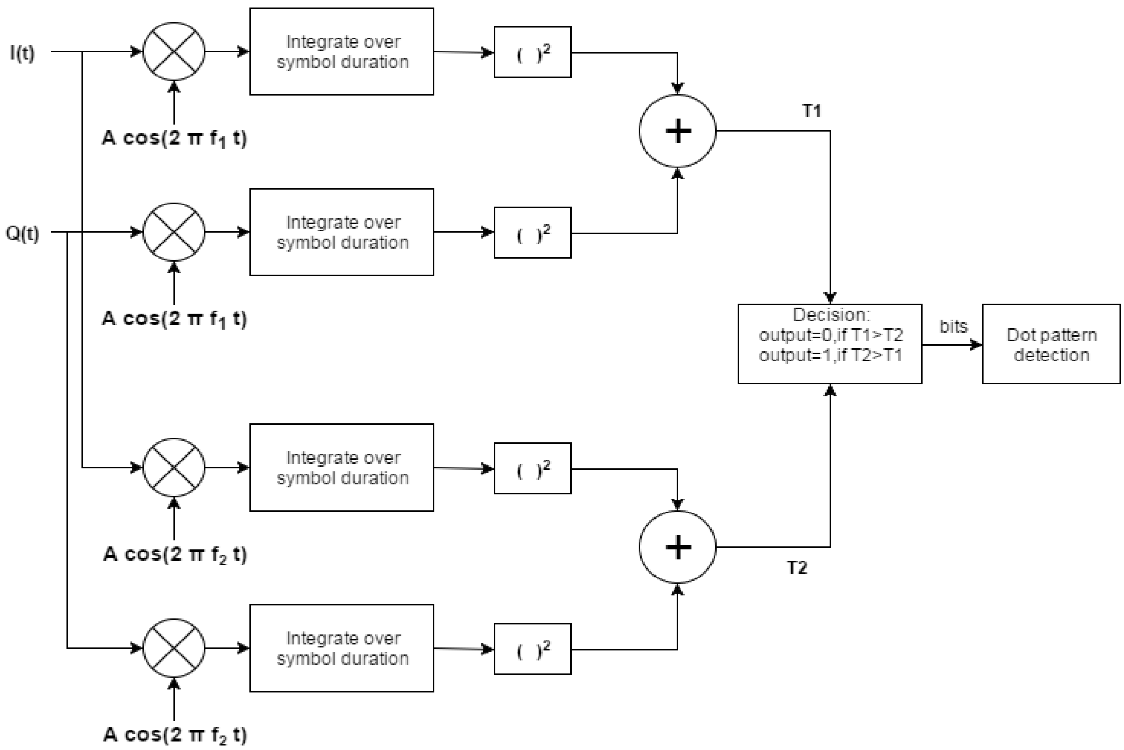


Figure 4.5: Timing recovery

Frequency offset estimation & correction

Once the timing instant is determined, frequency offset can be estimated using dot pattern. Since in dot pattern bits are repeated alternately,

$$m(t+2T) = m(t)$$

$$r(t) = m(t)\exp\left(j\left(2\pi\Delta f t + \phi\right)\right)$$

$$\begin{aligned} r(t+2T) &= m(t+2T)\exp\left(j\left(2\pi\Delta f(t+2T) + \phi\right)\right) \\ &= m(t)\exp\left(j\left(2\pi\Delta f t + \phi + 4\pi\Delta f T\right)\right) \end{aligned}$$

$$K = \frac{r(t+2T)}{r(t)} = \exp\left(j\left(4\pi\Delta f T\right)\right)$$

$$\arg(K) = 4\pi\Delta f T$$

$$\Delta f = \frac{\arg(K)}{4\pi T}$$

```
Require: I(t), Q(t) and N
 1: generate y1(t), a coswave with frequency f_1
 2: generate y2(t), a coswave with frequency f_2
 3: initialize check=0 and j=1
 4: Loop1:
 5: while check ≠ 1 do
 6:    initialize count=0
 7:    initialize sum=0
 8:    checkwave1 = I(j : j + N × 10 − 1)
 9:    checkwave2 = Q(j : j + N × 10 − 1)
10:    generate a sequence Y = y1, y2, y1, y2, y1, y2, y1, y2, y1, y2 · · · · · · (oflengthN)
11:    multiply checkwave1 with Y, integrate the results over symbol duration and
       save them in Sum1.
12:    multiply checkwave2 with Y, integrate the results over symbol duration and
       save them in Sum2.
13:    Thr(symbol)= square and add the Inphase(in Sum1(symbol)) and
       quadraturephase(in Sum2(symbol))
14:    for every symbol do
15:       if Thr(symbol) > Bit_Threshold then
16:          count=count+1
17:       end if
18:       sum=sum+Thr(symbol)
19:    end for
20:    if count=N then
21:       timinginstant=j
22:       check=1
23:    end if
24: end while
25: initialize priviousssum=0
26: for j = timinginstant → timinginstant + 20 do
27:    repeat the steps in Loop1 from 6 to 19
28:    if count=N and sum>previoussum then
29:       timinginstant=j
30:       previoussum=sum
31:    end if
32: end for
```

Algorithm 1: Timing recovery

For better accuracy, frequency offset value is estimated from $\arg(K)$ values taken over a period(see Algorithm 2). Let the estimated frequency offset value be $f^{'}$, when the signal is corrected for frequency offset, there will still be residual frequency offset $f^{''}$ left in the signal.

$$f^{''} = \Delta f - f^{'}$$

$$r_c(t) = r(t)\exp\left(-j\left(2\pi f^{'} t\right)\right)$$
$$= m(t)\exp\left(j\left(2\pi f^{''} t + \phi\right)\right)$$

$$I_c(t) = real(r_c(t)) = m(t)\cos\left(2\pi f^{''} t + \phi\right)$$

$$Q_c(t) = imag(r_c(t)) = m(t)\sin\left(2\pi f^{''} t + \phi\right)$$

Require: timinginstant and $r(t)$
1: $r(timinginstant : timinginstant + 10N - 1)$ where N is number of bits
2: $A_r = angle(r(timinginstant : timinginstant + 10N - 1))$
3: $\hat{A}_r = A_r(timinginstant : timinginstant + 10N - 20) - A_r(timinginstant + 20 : timinginstant + 10N)$
4: estimating $\arg(K)$ with the help of $\hat{A}_r$
5: estimating $f^{'}$ using $f^{'} = \frac{\arg(K)}{4\pi T}$

Algorithm 2: Frequency offset estimation

Demodulation

The frequency offset corrected signal has two components real part Ic(t) and imaginary part Qc(t). Ic(t) and Qc(t) are both multiplied with S_1 and integrated over the symbol duration, square and add them to obtain T1. Similarly Ic(t) and Qc(t) are both multiplied with S_2 and integrated over the symbol duration, square and add them to obtain T2. Now T1 and T2 are compared to determine bit sequence (see Figure 4.6). The residual frequency offset left in the signal, which is very small compared to symbol frequency, won't affect the demodulation since we are using both inphase and quadrature phase components of the signal (see Algorithm 3).

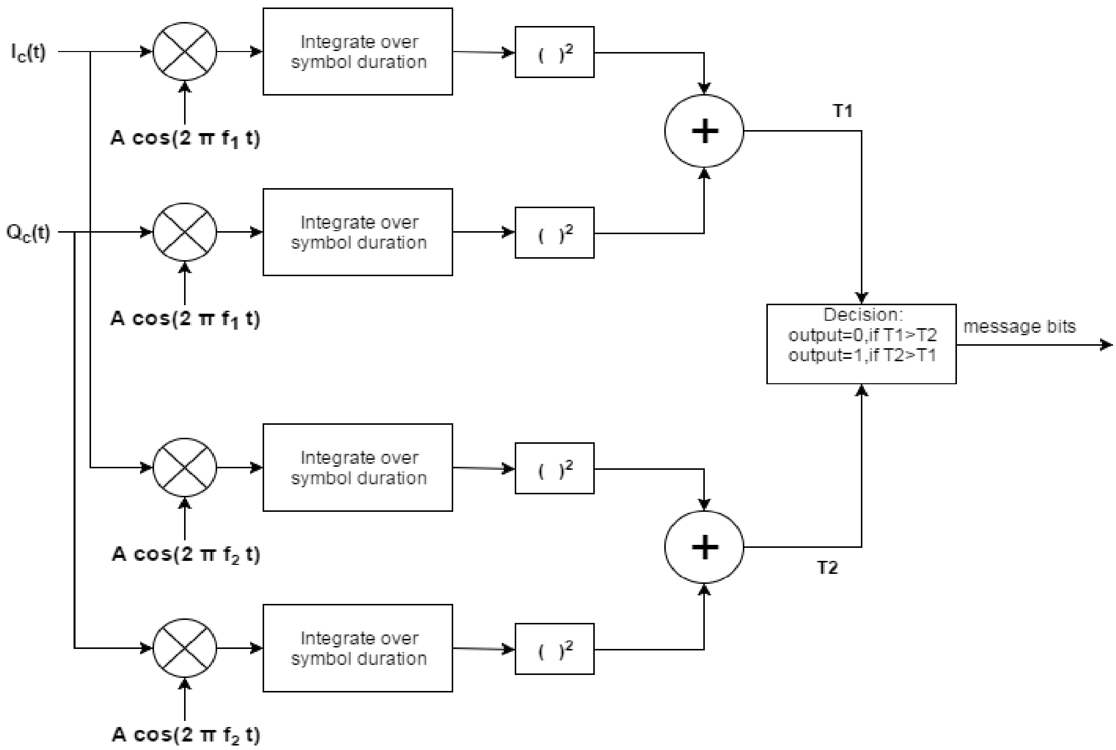


Figure 4.6: Demodulation

Require: $I_c(t)$, $Q_c(t)$, $y1(t)$ and $y2(t)$

for i= 1→n **do**
  $k = timinginstant + (i-1) \times 10$
  $checkwave1 = I_c(k : k+9)$
  $checkwave2 = Q_c(k : k+9)$
  multiply *checkwave*1 and *checkwave*2 with $y1$, integrate the results over symbol duration.
  square and add them to obtain T1
  multiply *checkwave*1 and *checkwave*2 with $y2$, integrate the results over symbol duration.
  square and add them to obtain T2
  if T2>T1 and T2>$Bit_{Threshold}$ **then**
    Bit=1
  else
    Bit=0
  end if
end for

Algorithm 3: Demodulation

4.3.2 Decoder

The incoming bit stream continuously checked for dot pattern by dot pattern detector, if dot pattern is detected then the handle is passed to phasing sequence detector, if phasing is achieved, format specifier is determined and handle is passed to specific decoders to retrieve the message (see Figure 4.7).

Phasing is considered to be achieved when two DXs and one RX, or two RXs and one DX, or three RXs in the appropriate DX or RX positions, respectively, are successfully received. These three phasing characters may be detected in either consecutive or non-consecutive positions but in both cases all bits of the phasing sequence should be examined for a correct 3-character pattern. A call should be rejected only if a correct pattern is not found anywhere within the phasing sequence.

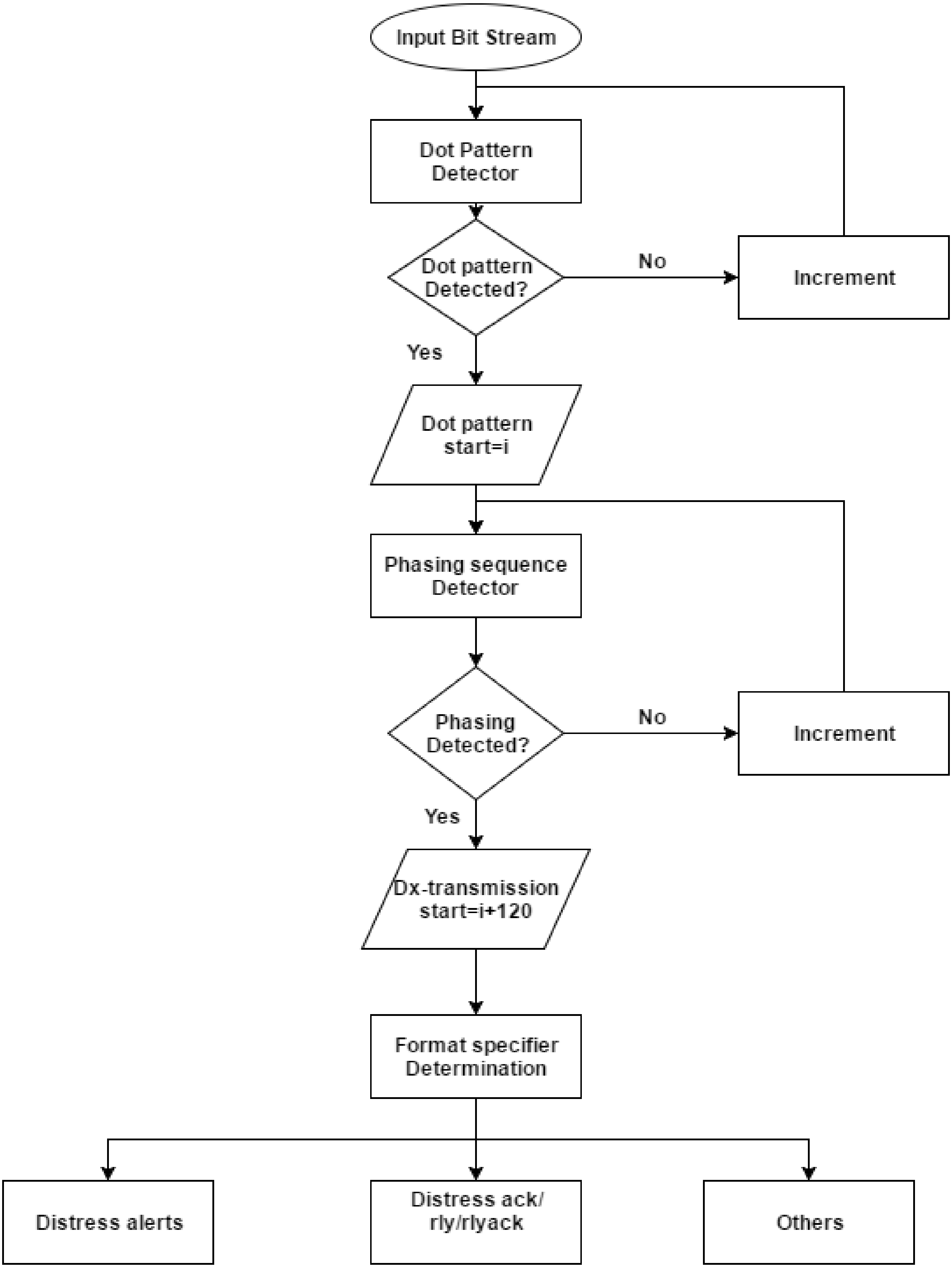


Figure 4.7: Decoder

In specific decoders for each nature of call(distress alerts, distress acknowledgements, distress relays, distress relay acknowledgements, urgency and safety calls, routine calls) the first transmission characters, retransmission characters and Error-check character (ECC) can be determined from received bits since we have the phasing information and all message formats are explicitly defined see Table 3.4. Then we perform parity check on first transmission characters if it fails we perform parity check retransmission characters, parity checked characters are stored in information characters. Error-check character (ECC) is calculated from Dx-transmission characters and rx-transmission characters and validated with received ECC as defined in 3.4.12. If it is passed, Information characters are decoded to message text as defined by Table 3.1 and Table 3.3. The decode message is displayed on screen.

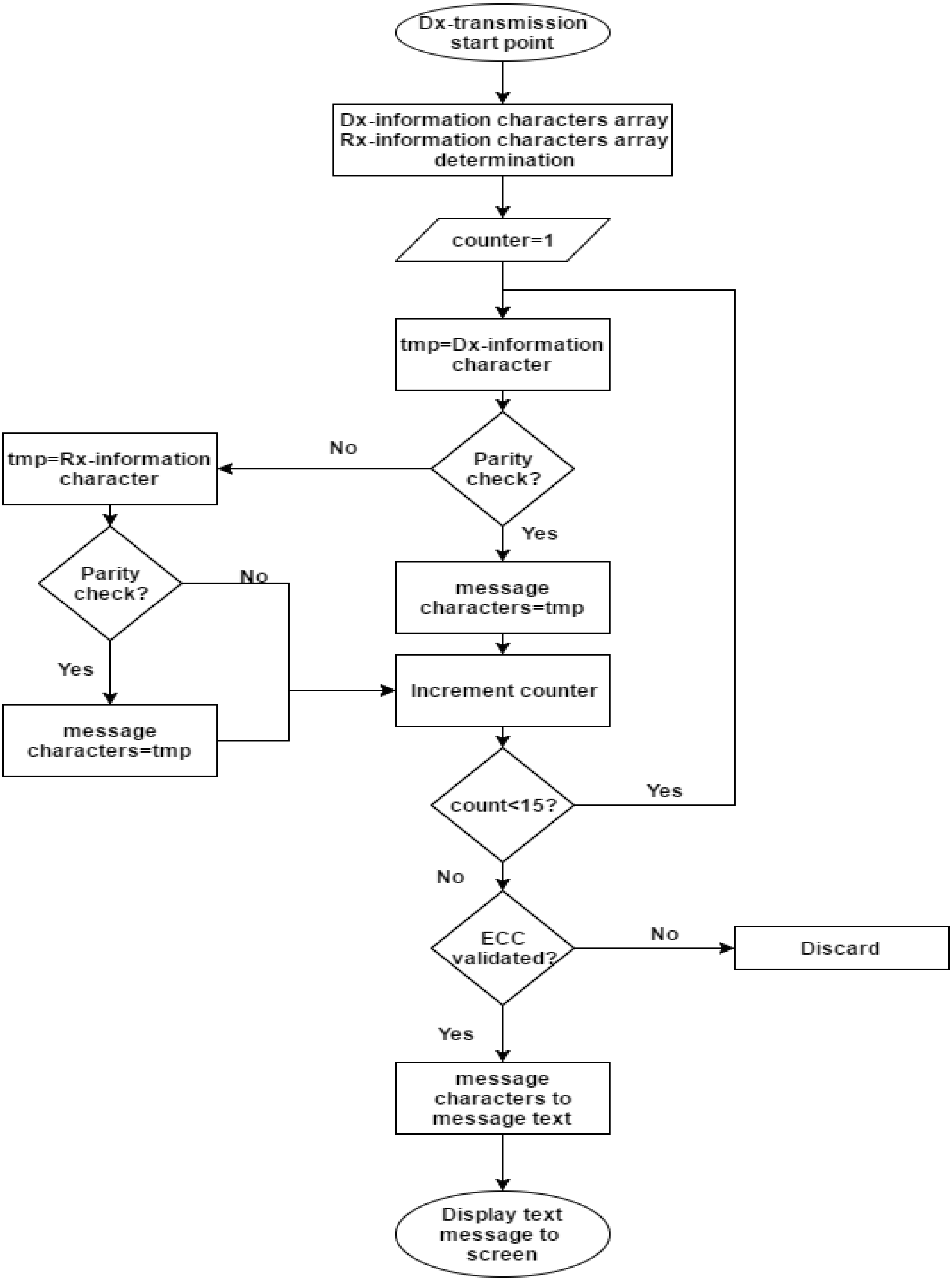


Figure 4.8: Distress decoder

CHAPTER 5

Conclusion

This project is an attempt to understand the GMDSS and implement DSC. As per the standards defined in chapter 3, we source coded the predefined messages and then implemented DSC using FSK as discribed in chapter4. This DSC feature has an ability to send distress alerts automatically in case of emergency with information about location and time of distress. The message is transmitted twice with ECC and every infomation character has parity check bits, this leads to a more reliable communication. The physical layer modulation and demodulation was done using FSK. Since FSK is used, the signal is more resilient to noise and signal strength variations but this leads to more bandwidth requirement and less spectral efficiency. Practical implementation of FSK involves synchronization (timing recovery , correction of Carrier Frequency Offset) before symbol recovery. This system was successfully implemented using WiComm kits at a carrier frequency of 70MHz. At the receiver, we successfully decoded the message(see Figure 5.1).

Figure 5.1

(a) Transmitted message

Command Window

```
Tranmitter
Type of call : distress
Enter Nature of Distress : fire
enter distress coordinates : 25566788888
enter time: 084050
enter subsequent comm  : 100
```

(b) Received message

Command Window

```
Receiver
Distress
MMSI:1010101010
nature of distress:fire
position:2556678888
time:084050
subseq_comm:100
```

APPENDIX A

REFERENCES

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