A INTRODUCTION

Modern maritime communications demand increased reliability and performance. Teleprinted communications have several advantages over Morse telegrams and radio telephone since they are faster and produce hard copy. The performance of HF radio channels depends on many factors, such as congestion, interference, radio propagation etc. Several methods have been devised to overcome many of these difficulties.

Teleprinters operate with a code consisting of zeroes and ones which are sent in sequence in the teleprinter circuit. The information or data is surrounded by start and stop bits which indicate to the teleprinter when to start and stop printing. Loss of start and stop information will result in loss of synchronism and garbled copy.

A method for protecting teleprinted information on radio circuits has been used in other services for many years. This method is based on the principle that the receiving station checks the validity of each received character and governs the sending station by Automatic Repetition reQuests, ARQ.

In an effort to standardize maritime direct-printing communications, the International Radio Consultative Committee (CCIR) has drafted its Recommendation 476.

Recommendation 476 details the function of a simplex-mode ARQ system with built-in selective calling facilities, mode A. In addition, it also specifies a 7-unit forward acting, errorcorrecting and indicating, time-diversity system, FEC, mode B (broadcast), which has two versions, collective and selective.

On the radio channel, signals are transmitted in a synchronous 7-bit code. A binary 7-bit code allows $2^7 = 128$ combinations. Of these, the 35 combinations which contain 4 ones and 3 zeroes have been selected since they have a common denominator, the 4:3 ratio, which is used to check the validity of a character.

Equipment built to CCIR Recommendation 476 uses the 4:3 ratio for error detection, on a go-no go basis. The 5-bit asynchronous teleprinter code or CCITT-2-code is converted into a 7-bit synchronous ARQ code with a constant bit ratio of 4:3, and is then transmitted. After demodulation at the receiving station, the received bitstream is checked, using the 4:3 criterion, reconverted to CCITT-2 code and printed, if accepted. Otherwise, a request for repetition is issued.

In broadcast, or B-mode, each character is transmitted twice with a 210 ms interval. The 4:3 ratio is also used here, and the character is printed, if accepted, either in the first or the second period. If the character cannot be accepted, an error character (i.e. a space) is printed instead.

The complete CCIR Recommendation 476 follows below.

2. TABLE OF CONVERSION

2.1 Traffic information signals

No.	Letters	Figures	International Alphabet No. 2 Code	Emitted 7-unit signal (1)
1	A	–	ZZAAA	BBBYYYB
2	B	?	ZAAZZ	YBYYBBB
3	C	:	AZZZA	BYBBBYY
4	D	WRU	ZAAZA	BBYYBYB
5	E	3	ZAAAA	YBBYBYB
6	F	Ä	ZAZZA	BBYBBYY
7	G	Ä	AZAZZ	BYBYBBY
8	H	Ö	AAZAZ	BYYBYBB
9	I	8	AZZAA	BYBBYYB
10	J	BELL	ZZAZA	BBBYBYY
11	K	(	ZZZZA	YBBBBYY
12	L	)	AZAAZ	BYBYYBB
13	M	.	AAZZZ	BYYBBBY
14	N	,	AAZZA	BYYBBYB
15	O	9	AAAZZ	BYYYBBB
16	P	0	AZZAZ	BYBBYBY
17	Q	1	ZZZAZ	YBBBYBY
18	R	4	AZAZA	BYBYBYB
19	S	'	ZAZAA	BBYBYYB
20	T	5	AAAAZ	YYBYBBB
21	U	7	ZZZAA	YBBBYYB
22	V	=	AZZZZ	YYBBBBY
23	W	2	ZZAAZ	BBBYYBY
24	X	/	ZAZZZ	YBYBBBY
25	Y	6	ZAZAZ	BBYBYBY
26	Z	+	ZAAAZ	BBYYYBB
27	Carriage return		AAAZA	YYYBBBB
28	Line feed		AZAAA	YYBBYBB
29	Letter shift		ZZZZZ	YBYBBYB
30	Figure shift		ZZAZZ	YBBYBBY
31	Space		AAZAA	YYBBBYB
32	Unperforated tape		AAAAA	YBYBYBB

(1) B represents the higher emitted frequency and Y the lower.

2.2 Service information signals

Mode A (ARQ)	Emitted signal	Mode B (FEC)
Control signal 1	BYBYYBB	
Control signal 2	YBYBYBB	
Control signal 3	BYYBBYB	
Idle signal β	BBYYBBY	
Idle signal α	BBBBYYY	Phasing signal 1
Signal repetition	YBBYYBB	Phasing signal 2

3. CHARACTERISTICS

3.1 **Mode A** (ARQ) (see Figs. 1 and 2)

A synchronous system, transmitting blocks of three characters from an information sending station (ISS) towards an information receiving station (IRS), which stations can, controlled by the control signal 3, interchange their functions.

3.1.1 ***Master and slave arrangements***

3.1.1.1 The station that initiates the establishment of the circuit (the calling station) becomes the "master" station, and the station that has been called will be the "slave" station;

this situation remains unchanged during the entire time in which the established circuit is maintained, regardless of which station at any given time is the Information Sending Station (ISS) or Information Receiving Station (IRS);

3.1.1.2 the clock in the master station controls the entire circuit (see circuit timing diagram, Fig 1);

3.1.1.3 the basic timing cycle is 450 ms and for each station consists of a transmission period followed by a transmission pause during which reception is effected;

3.1.1.4 the master station transmitting time distributor is controlled by the clock in the master station;

3.1.1.5 the slave station receiving time distributor is controlled by the received signal;

3.1.1.6 the slave station transmitting time distributor is phase-locked to the slave station receiving time distributor; i.e. the time interval between the end of the received signal and the start of the transmitted signal (t_E in Fig 1) is constant.

3.1.1.7 the master station receiving time distributor is controlled by the received signal.

3.1.2 ***The Information Sending Station (ISS)***

3.1.2.1 Formats the information to be transmitted into blocks of three characters (3×7 signal elements);

3.1.2.2 emits a "block" in 210 milliseconds after which a transmission pause of 240 milliseconds becomes effective, retaining the emitted block in memory until the appropriate control signal confirming correct reception by the Information Receiving Station (IRS) has been received;

3.1.2.3 numbers successive blocks alternately "Block 1" and "Block 2" by a local numbering device, the numbering being interrupted at the reception of:
(a) a request for repetition; (b) a mutilated signal; (c) a control signal;

3.1.2.4 emits the information of Block 1 on receipt of control signal 1;

3.1.2.5 emits the information of Block 2 on receipt of control signal 2;

3.1.2.6 emits a block of three "signal repetitions" on receipt of a mutilated signal.

3.1.3 ***The Information Receiving Station (IRS)***

3.1.3.1 Numbers the received blocks of three characters alternately "Block 1" and "Block 2" by a local numbering device, the numbering being interrupted at the reception of (a) a block in which one or more characters are mutilated, (b) a block containing at least one "signal repetition": (3.1.2.3 and 3.1.2.5).

3.1.3.2 after the reception of each block, emits one of the control signals of 70 milliseconds duration after which a transmission pause of 380 milliseconds becomes effective;

3.1.3.3 emits the control signal 1 at the reception of:
- an unmutilated "Block 2",
- a mutilated "Block 1",
- a "Block 1" containing at least one "signal repetition";

3.1.3.4 emits the control signal 2 at reception of:
- an unmutilated "Block 1",
- a mutilated "Block 2",
- a "Block 2" containing at least one "signal repetition".

3.1.4 ***Phasing***

3.1.4.1 When no circuit is established, both stations are in the "stand-by" position. In this stand-by position no ISS or IRS and no master or slave position is assigned to either of the stations;

3.1.4.2 the station desiring to establish the circuit emits the "call" signal. This "call" signal is formed by two blocks of three signals;

3.1.4.3 the call signal contains:
- in the first block: "signal repetition" in the second character place and any combination of information signals in the first and third character place,
- in the second block: "signal repetition" in the third character place preceded by any combination of the 32 information signals in the first and second character place.

3.1.4.4 on receipt of the appropriate call signal the called station changes from stand-by to the IRS position and emits the control signal 1 or the control signal 2;

3.1.4.5 on receipt of two consecutive identical control signals, the calling station changes into ISS and operates in accordance with §§ 3.1.2.4 and 3.1.2.5.

3.1.5 ***Rephasing***

3.1.5.1 When reception of information blocks or of control signals is continuously mutilated, the system reverts to the "stand-by" position after a predetermined time (32×450 ms) of continuous repetition that is master station at the time of interruption immediately initiates rephasing along the same lines as laid down in § 3.1.4;

3.1.5.2 however, if, at the time of interruption, the slave station was in the ISS position, it emits, after rephasing, the control signal 3;

3.1.5.3 if rephasing has not been accomplished within the timeout interval of § 3.1.8.1, the system reverts to the stand-by position and no further rephasing attempts are made.

3.1.6 ***Change over***

3.1.6.1 The Information Sending Station (ISS)
- emits, to initiate a change in the direction of the traffic flow, the information signal sequence "Figure Shift", "Plus" ("Z"), "Question Mark" ("B") followed, if necessary, by one or more "Idle Signals β" to complete a "Block";
- emits, on receipt of a control signal 3, a block containing the signals "Idle Signal β", "Idle Signal α", "Idle Signal β";
- changes subsequently to IRS after the reception of a "signal repetition".

3.1.6.2 The Information Receiving Station (IRS)
- emits the control signal 3:
  (a) when the station wishes to change over to ISS,
  (b) on receipt of a block in which the signal information sequence "Figure Shift", "Plus", "Question Mark" terminates or on receipt of the following block, whether one or more characters in that block are mutilated or not;
- changes subsequently to ISS after reception of a block containing the signal sequence "$\beta\alpha\beta$";
- emits one "signal repetition" as a master station, or a block of three "signal repetitions" as a slave station, after being changed into ISS;

3.1.7 ***Output to line***

3.1.7.1 the signal offered to the line output terminal is a 5-unit start-stop signal at a modulation rate of 50 bauds.

3.1.8 ***End of communication***

3.1.8.1 when reception of information blocks or of control signals is continuously mutilated, the system reverts to the "stand-by" position after a predetermined time of continuous repetition, which causes the termination of the established circuit;

3.1.8.2 the station that wishes to terminate the established circuit transmits an "end of communication signal";

3.1.8.3 the "end of communication signal" consists of a block containing three "Idle Signal α" signals;

3.1.8.4 the "end of communication signal" is transmitted by the ISS;

3.1.8.5 if an IRS wishes to terminate the established circuit it has to change over to ISS in accordance with § 3.1.6.2;

3.1.8.6 the IRS that receives an "end of communication signal" emits the appropriate control signal and reverts to the "stand-by" position;

3.1.8.7 on receipt of a control signal that confirms the unmutilated reception of the "end of communication signal", the ISS reverts to the "stand-by" position;

3.1.8.8 when after a predetermined number of transmissions of the "end of communications" signal no control signal has been received confirming the unmutilated reception of the "end of communication signal" the ISS reverts to the stand-by position and the IRS times out in accordance with § 3.1.8.1.

3.2 **Mode B** forward error correction (FEC) (see Figs 3 and 4)

A synchronous system, transmitting an uninterrupted stream of characters from a station sending in the collective B-mode (CBSS) to a number of stations receiving in the collective B-mode (CBRS), or from a station sending in the selective B-mode (SBSS) to one selected station receiving in the selective B-mode (SBRS).

3.2.1 ***The station sending in the collective or in the selective B-mode (CBSS or SBSS):***

3.2.1.1 emits each character twice: the first transmission (DX) of a specific character is followed by the transmission of four other characters, after which the retransmission (RX) of the first character takes place, allowing for time-diversity reception at 280 ms time space:

3.2.1.2 emits as a preamble to messages or to the call sign, alternately the phasing signal 1 and the phasing signal 2 whereby phasing signal 1 is transmitted in the RX, and phasing signal 2 in the DX position. At least four of these signal pairs (phasing signal 1 and phasing signal 2) should be transmitted.

3.2.2 ***The staion sending in the collective B-mode (CBSS):***

3.2.2.1 emits during the breaks between two messages in the same transmission the phasing signals 1 and the phasing signals 2 in the RX and the DX position, respectively.

3.2.3 ***The station sending in the selective B-mode (SBSS):***

3.2.3.1 emits after the transmission of the required number of phasing signals (see § 3.2.1.2) the call sign of the station to be selected. This call sign is a sequence of four characters that represents the number code of the called station. This transmission takes place in the time diversity mode according to § 3.2.1.1;

3.2.3.2 emits the call sign and all further signals in a 3B/4Y ratio, i.e. inverted with respect to the signals of § 2 in the column "emitted 7-unit signal". Consequently, all signals, i.e. both traffic information signals and service are transmitted in the 3B/4Y ratio;

3.2.3.3 emits the service information signal "Idle Signal /" during the idle time between the messages consisting of traffic information signals.

3.2.4 ***The station (s) receiving in the collective or in the selective B-mode (CBRS or SBRS):***

3.2.4.1 checks both characters (DX and RX), printing an unmutilated DX or RX character, or printing an error symbol or space, if both are mutilated.

3.2.5 ***Phasing***

3.2.5.1 When no reception takes place, the system is in the "stand-by" position as laid down in § 3.1.4.1.

3.2.5.2 On receipt of the sequence phasing signal 1 – phasing signal 2, or of the sequence phasing signal 2 – phasing signal 1, in which phasing signal 2 determines the DX and phasing signal 1 determines the RX position, and at least one further phasing signal in the appropriate position, the system changes from "stand-by" to the CBRS position.

3.2.5.3 When started as CBRS the system changes to the SBRS (selectively called receiving station) position on receipt of the inverted characters representing its selective call number.

3.2.5.4 Having been changed into the CBRS or into the SBRS position the system offers continuous stop-polarity to the line output terminal until either the signal "carriage return" or "line feed" is received.

3.2.5.5 When started as SBRS, the decoder re-inverts all the following signals received to the 3Y/4B ratio, so that these signals are offered to the SBRS in the correct ratio, but they remain inverted for all other stations.

3.2.5.6 Both the CBRS and the SBRS revert to the stand-by position if, during a predetermined time, the percentage of mutilated signals received has reached a predetermined value.

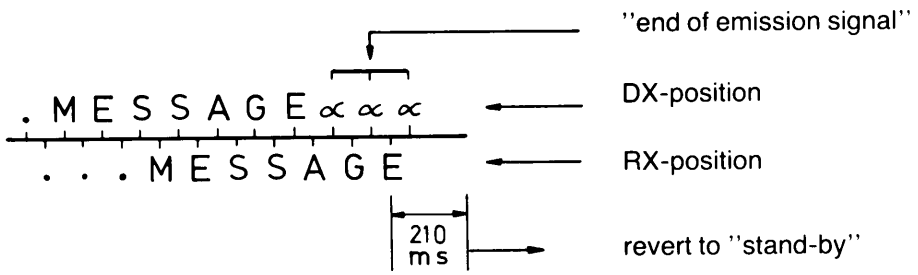
3.2.6 ***Output to line***

3.2.6.1 The signal offered to the line output terminal is a 5-unit start-stop CCITT-2-code signal at a modulation rate of 50 bauds.

3.2.7 ***End of emission***

3.2.7.1 The station sending in the B-mode (CBSS or SBSS) that wishes to terminate the emission transmits the "end of emission signal;

3.2.7.2 the "end of emission signal" consists of three consecutive "idle signals" transmitted in the DX position, after which the station terminates its emission and reverts to the "stand-by" position,



3.2.7.3 The CBRS or the SBRS reverts to the "stand-by" position not less than 210 ms after receipt of at least two consecutive "idle signals α" in the DX position.

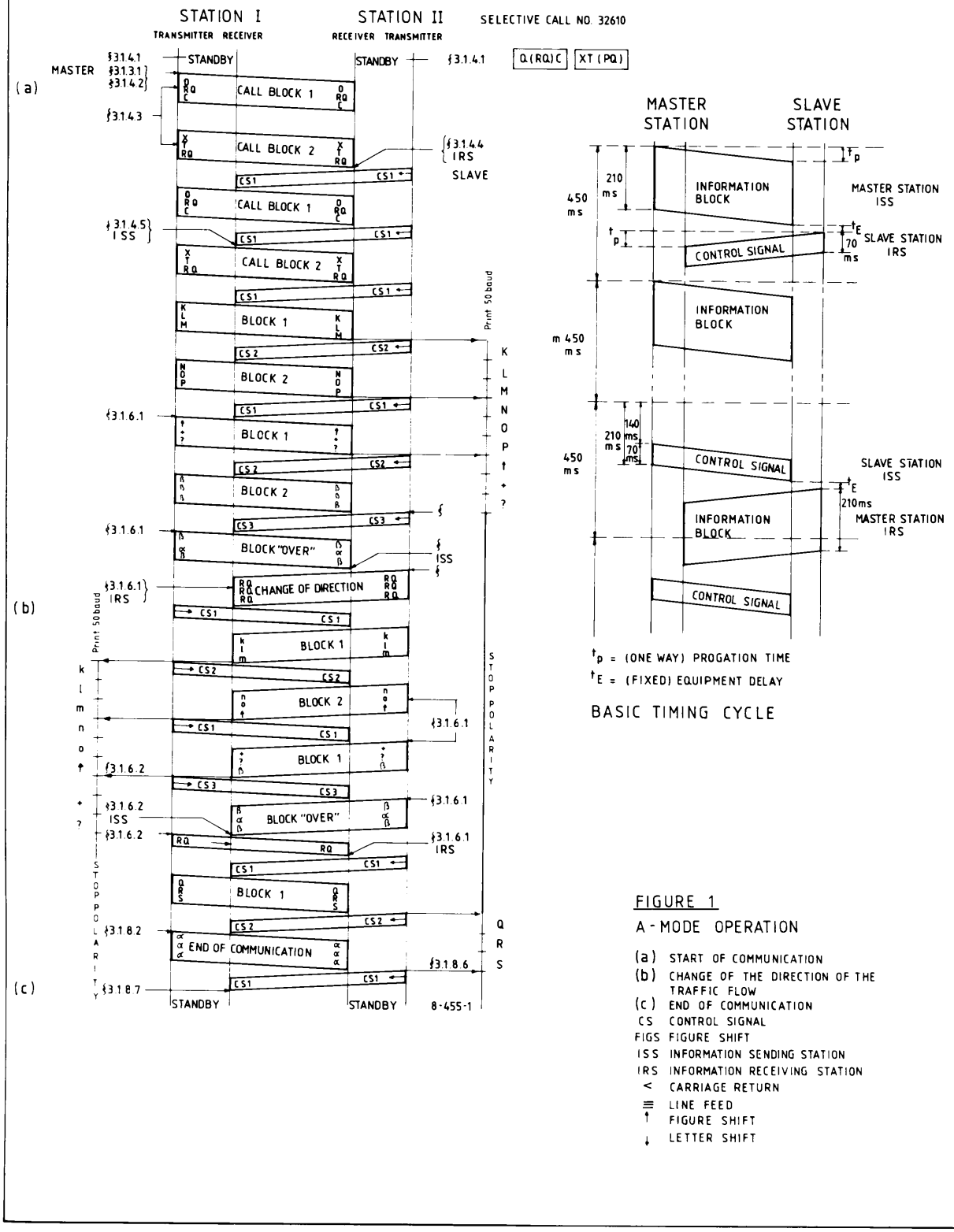


FIGURE 1

A-MODE OPERATION

(a) START OF COMMUNICATION
(b) CHANGE OF THE DIRECTION OF THE TRAFFIC FLOW
(c) END OF COMMUNICATION
CS CONTROL SIGNAL
FIGS FIGURE SHIFT
ISS INFORMATION SENDING STATION
IRS INFORMATION RECEIVING STATION
< CARRIAGE RETURN
≡ LINE FEED
↑ FIGURE SHIFT
↓ LETTER SHIFT

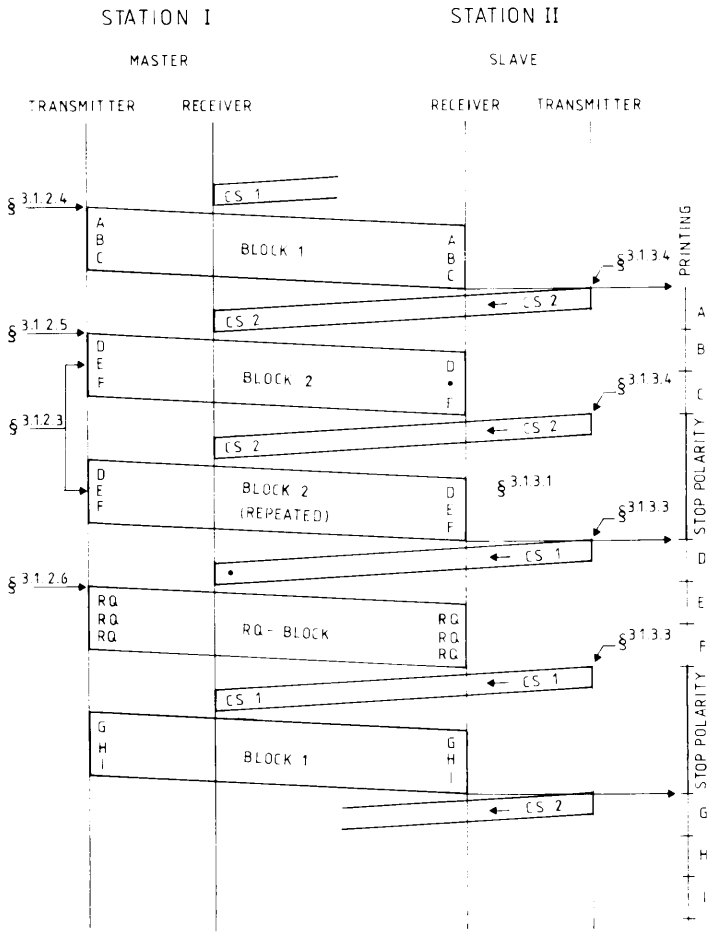


FIGURE 2

MODE A UNDER ERROR RECEIVING CONDITIONS

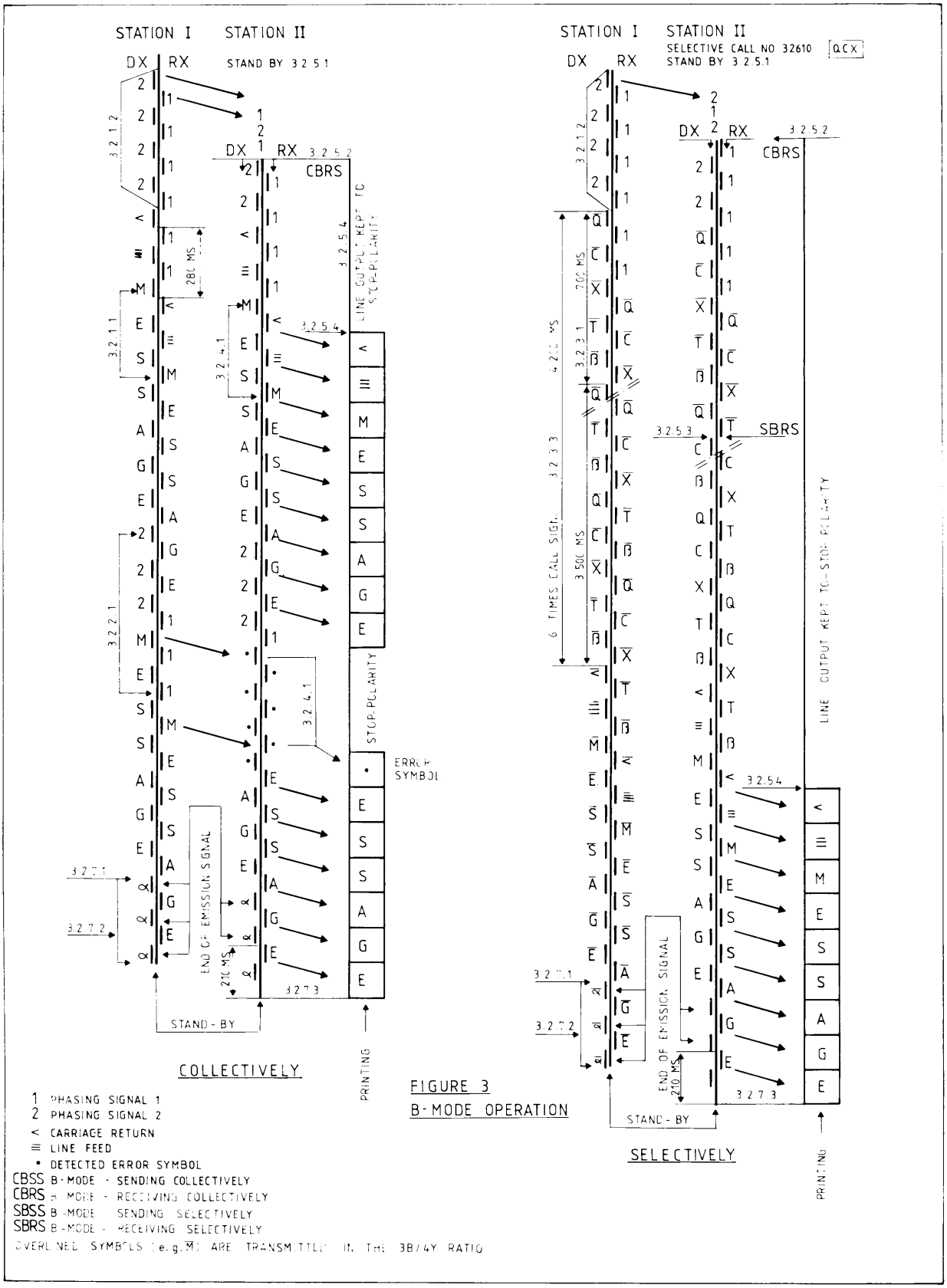


FIGURE 3
B-MODE OPERATION

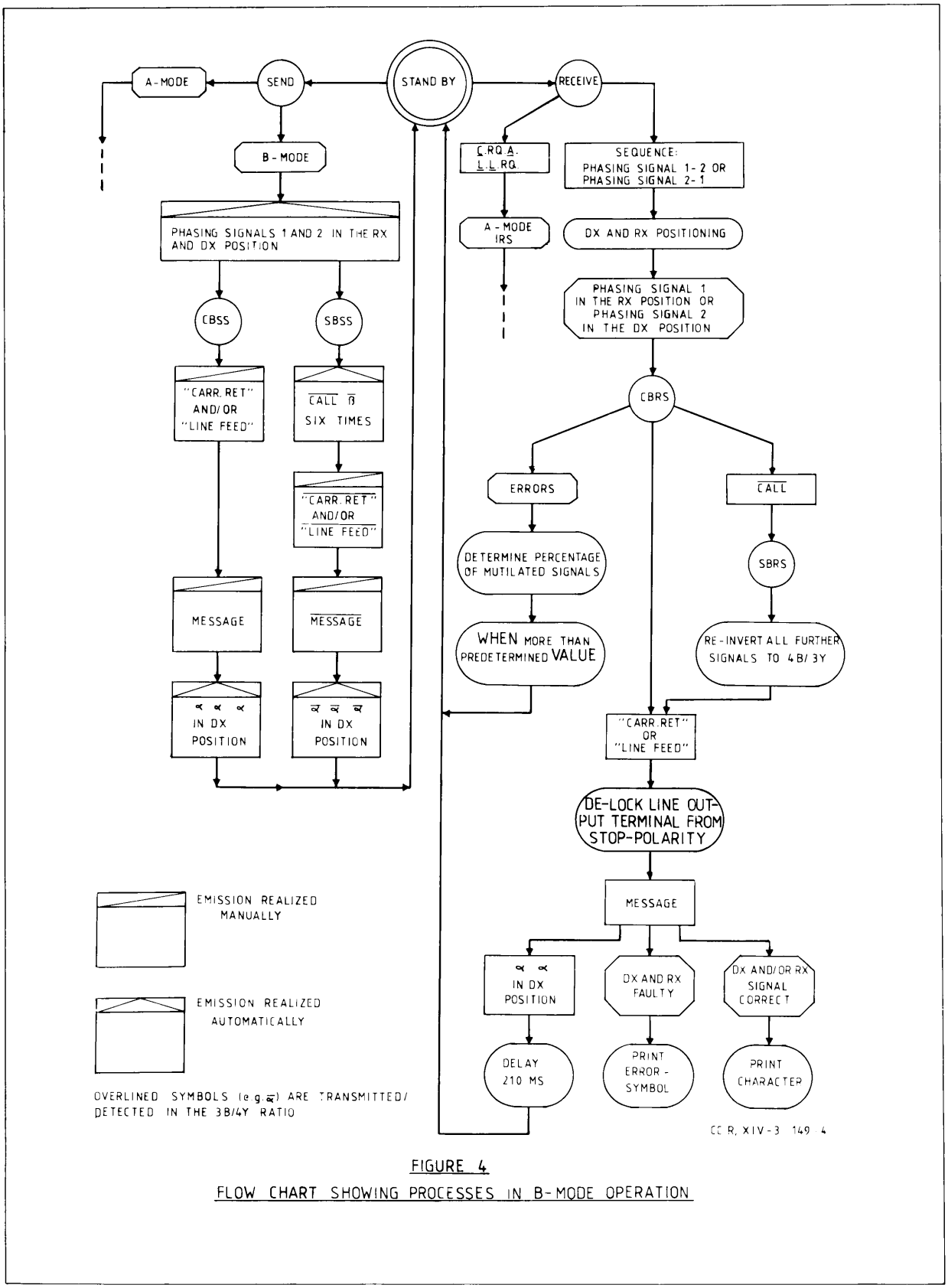


FIGURE 4

FLOW CHART SHOWING PROCESSES IN B-MODE OPERATION

REC 491

The CCIR Recommendation 491 regulates the composition of selective call signals used in equipment built to CCIR recommendation 476.

To translate a number, proceed as follows:

For a 5-digit number let the first digit determine which vertical column in Table I to use. Translate the last four digits to four alphabetic characters as indicated for each digit in the column selected in accordance with the table of conversion as given in Table I.

TABLE I

5-digit numbers											
1st digit		0	1	2	3	4	5	6	7	8	9
2nd digit	0	T	V	V	V	T	T	T	V	V	V
	1	B	X	X	X	B	B	B	X	X	X
	2	U	Q	Q	Q	U	U	U	Q	Q	Q
	3	E	K	K	K	E	E	E	K	K	K
	4	O	M	M	M	O	O	O	M	M	M
	5	I	P	P	P	I	I	I	P	P	P
	6	R	C	C	C	R	R	R	C	C	C
	7	Z	Y	Y	Y	Z	Z	Z	Y	Y	Y
	8	D	F	F	F	D	D	D	F	F	F
	9	A	S	S	S	A	A	A	S	S	S
3rd digit	0	V	T	V	V	T	V	V	T	T	V
	1	X	B	X	X	B	X	X	B	B	X
	2	Q	U	Q	Q	U	Q	Q	U	U	Q
	3	K	E	K	K	E	K	K	E	E	K
	4	M	O	M	M	O	M	M	O	O	M
	5	P	I	P	P	I	P	P	I	I	P
	6	C	R	C	C	R	C	C	R	R	C
	7	Y	Z	Y	Y	Z	Y	Y	Z	Z	Y
	8	F	D	F	F	D	F	F	D	D	F
	9	S	A	S	S	A	S	S	A	A	S
4th digit	0	V	V	T	V	V	T	V	T	V	T
	1	X	X	B	X	X	B	X	B	X	B
	2	Q	Q	U	Q	Q	U	Q	U	Q	U
	3	K	K	E	K	K	E	K	E	K	E
	4	M	M	O	M	M	O	M	O	M	O
	5	P	P	I	P	P	I	P	I	P	I
	6	C	C	R	C	C	R	C	R	C	R
	7	Y	Y	Z	Y	Y	Z	Y	Z	Y	Z
	8	F	F	D	F	F	D	F	D	F	D
	9	S	S	A	S	S	A	S	A	S	A
5th digit	0	V	V	V	T	V	V	T	V	T	T
	1	X	X	X	B	X	X	B	X	B	B
	2	Q	Q	Q	U	Q	Q	U	Q	U	U
	3	K	K	K	E	K	K	E	K	E	E
	4	M	M	M	O	M	M	O	M	O	O
	5	P	P	P	I	P	P	I	P	I	I
	6	C	C	C	R	C	C	R	C	R	R
	7	Y	Y	Y	Z	Y	Y	Z	Y	Z	Z
	8	F	F	F	D	F	F	D	F	D	D
	9	S	S	S	A	S	S	A	S	A	A

TABLE II

4-digit numbers		
1st digit	0	V
	1	X
	2	Q
	3	K
	4	M
	5	P
	6	C
	7	Y
	8	F
	9	S
2nd digit	0	V
	1	X
	2	Q
	3	K
	4	M
	5	P
	6	C
	7	Y
	8	F
	9	S
3rd digit	0	V
	1	X
	2	Q
	3	K
	4	M
	5	P
	6	C
	7	Y
	8	F
	9	S
4th digit	0	V
	1	X
	2	Q
	3	K
	4	M
	5	P
	6	C
	7	Y
	8	F
	9	S

Examples:

The 5-digit number 32610 is transmitted as: Q (RQ) C | X T (RQ)

The 4-digit number 1234 is transmitted as: X (RQ) Q | K M (RQ)

REC 492

CCIR Recommendation 492 regulates the operational procedures for use of direct-printing telegraph equipment in the Maritime mobile service:

1. ***MODE A*** (ARQ)

1.1 Methods used for setting up narrow-band direct-printing telegraph communications between a ship station and a coast station in the ARQ-mode should be on a fully automatic or semi-automatic basis, in so far that a ship station should have direct access to a coast station on a coast station receiving frequency and a coast station should have direct access to a ship station on a coast station transmitting frequency;

1.2 however, where necessary, prior contact by morse telegraphy, radiotelephony or other means is not precluded;

1.3 through connection to a remote teleprinter station over a dedicated circuit or to a subscriber of the international telex network may be achieved by manual, semi-automatic or automatic means (see Note);

1.4 when, by prior arrangement, unattended operation is required for communication from a coast station to a ship station, or between two ship stations, the receiving ship station should have a receiver tuned to the other station's transmitting frequency and a transmitter tuned or a transmitter capable of being tuned automatically to the appropriate frequency and ready to transmit on this frequency;

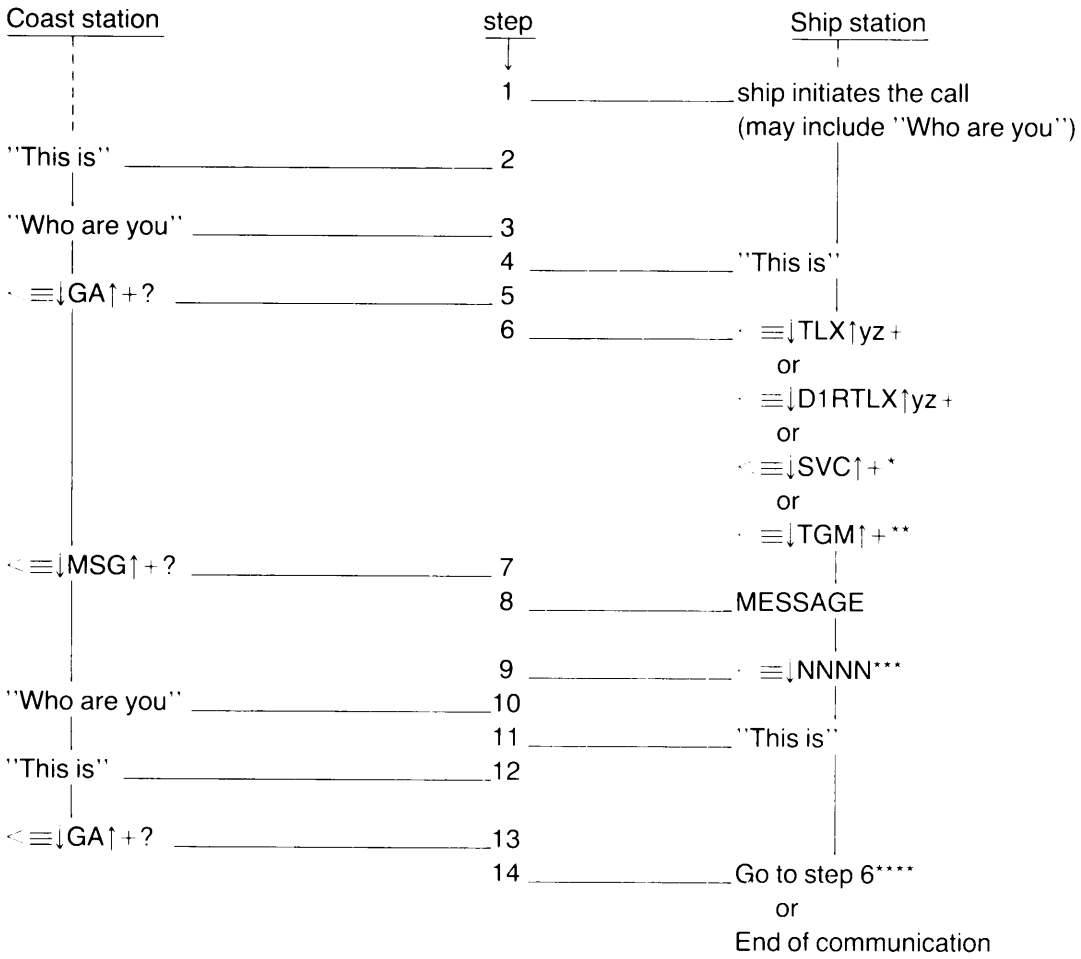
1.5 for unattended operation a ship station should be called selectively by the initiating coast or ship station as provided for by Recommendation 476-1. The ship station concerned could have available traffic stored ready for automatic transmission on demand of the calling station;

1.6 at the "over" signal, initiated by the calling station, any available traffic in the ship's traffic store could be transmitted;

1.7 at the end of message exchange, an "end of communication" signal should be transmitted, whereupon the ships' equipment should automatically revert to the "stand-by" condition;

1.8 where paired frequencies are used, as for the bands 4 MHz to 22 MHz, arrangements should be made, if required, for the coast station to indicate when the circuit is open for traffic. The format of the signal, transmitted by the coast station, i.e. the "free channel" signal should be composed of signals in the 7-unit error detecting code as listed in the § 2 of Annex I to Recommendation 476-1 (Rev 78). Three of these signals are grouped into a block, the middle signal being the "Signal Repetition" (RQ), the first and third signals of the block being any of the signals VXQKMPCYFS TBUEOIRZDA (see Recommendation 491). The signals in the block are transmitted at a modulation rate of 100 baud and the blocks are separated by pauses of 240 milliseconds. This "free channel" signal may be interrupted by a signal or signals, that would enable an operator to recognize the "free channel" condition by ear. The aurally recognizable signal, e.g. a Morse signal, may be used alone as the "free channel" signal in manual systems.

1.9 *Procedure for setting up a call in the ship-to-coast station direction*



* The characters SVC · are transmitted in sequence and preceded by at least one carriage return and a line feed, where SVC denotes that the message that follows is a service message and " · " indicates end of sequence.

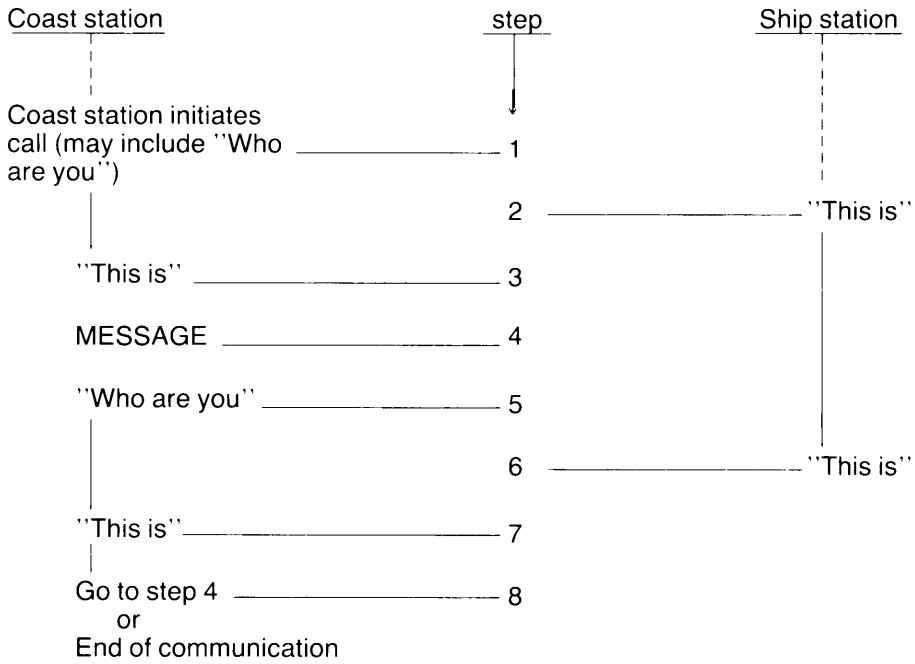
** The characters TGM · are transmitted in sequence and preceded by at least one carriage return and a line feed, where TGM denotes that the message that follows is a radiotelegram and " · " indicates end of sequence.

*** This sequence of combinations may need to be considered further by the CCITT.

**** Each separate radiotelegram shall be both preceded and followed by an exchange of answerback signals, the latter indicating the acknowledgement of receipt of that particular radiotelegram.

1.10 ***Procedure for setting up a call in the coast-to-ship station direction***

Operation in the direction coast station to ship may need to be in the store-and-forward mode owing to the fact that radio propagation conditions may not allow the setting up of a call at the intended time.



Note: Before an international automatic service can be reached, agreement has to be reached on a numbering plan, traffic routing and charging. This should be considered by both the CCITT and the CCIR.

2. ***MODE B*** (FEC)

2.1 Messages could, by prior arrangement, be sent in the B mode from a coast station or ship to a number of ships or to a single ship, preceded if desired by the selective call code of the ship(s) concerned where:

2.1.1 a receiving ship station is not permitted or not able to use its transmitter, or

2.1.2 communications are intended for more than one ship, or

2.1.3 unattended reception of the B mode is required and automatic acknowledgement is not necessary;

in such cases, the ship station receivers should be tuned to the appropriate coast or ship station transmitting frequency;

2.2 all B mode messages should start with "carriage return" and "line feed" signals;

2.3 when the ship station receives phasing signals in the B mode, its teleprinter should start automatically and should stop automatically when reception of the emission ceases.