RECOMMENDATION ITU-R M.822-1

CALLING-CHANNEL LOADING FOR DIGITAL SELECTIVE-CALLING (DSC) FOR THE MARITIME MOBILE SERVICE

(Question ITU-R 9/8)

(1992-1994)

The ITU Radiocommunication Assembly,

considering

a) that the Radio Regulations contain designated and dedicated channels for the digital selective-calling in the maritime mobile service bands (MF, HF and VHF);

b) that Question ITU-R 9/8 requests studies of the information necessary for the operation of future maritime communication systems in conjunction with the digital selective call;

c) that the ITU-R studied the subject of calling-channel loading and developed a methodology on how to determine acceptable calling-channel loading and on how to decide how many calling channels would be required in each of the bands,

recommends

1. that the maximum traffic offered to any calling channel used for digital selective calling should not exceed 0.1 E on an MF or HF channel or 0.15 E on a VHF channel;

2. that, as a consequence of § 1, where a DSC channel is used for distress and safety calling the probability of a distress call attempt being mutilated will be less than 0.1%, assuming that two distress call attempts are transmitted per hour;

3. that, as a consequence of § 1 and 2 and based on the calculations given in Annex 1, the maximum number of routine DSC calls which can be supported is:

– 24 calls/h on an MF or HF non-distress and safety coast station transmit channel;

– 28 calls/h on an MF or HF non-distress and safety ship station transmit channel;

– 500 calls/h on the single DSC VHF channel (channel 70);

4. that, as a consequence of § 2 and based on the calculations given in Annex 1, the maximum number of urgency and safety DSC calls which can be supported on the dedicated MF and HF distress and safety channels is 20 calls/h;

5. that the implications of using conventional scanning receivers in terms of the probability of calls lost due to scanning be based on the calculations given in Annex 2.

ANNEX 1

Channel loading calculations

1. General ALOHA traffic theory

1.1 The characteristics of DSC on common calling channels may be compared to a classical ALOHA channel which is a form of demand-assignment time-division multiple access suited to channels with random access where there is a high peak-to-average calling density. The number of calls originating per unit time then follows a Poisson distribution.

1.2 According to classical ALOHA calculations, if R is the average number of DSC calls plus re-transmissions per unit time and τ is the call duration, the probability that a given call will have to be re-transmitted (due to call collisions) is given by:

$$1 - e^{-2R\tau}$$

1.3 $R\tau$, the channel traffic is therefore equivalent to the total traffic loading (including repetitions) in erlang.

1.4 It should be noted that the factor of 2 in the equation in § 1.2 is due to the fact that, with purely random calling, there is a time period of duration 2τ in which no other call must originate if a collision is to be avoided, i.e. $\pm\tau$ from the start of transmission of any particular call. Any call originating during this period will overlap another call to a greater or lesser extent and thus collide.

1.5 If r is the average number of calls offered to the channel (excluding retransmissions), it follows that:

$$R = r + R\ (1 - e^{-2R\tau})$$

and hence:

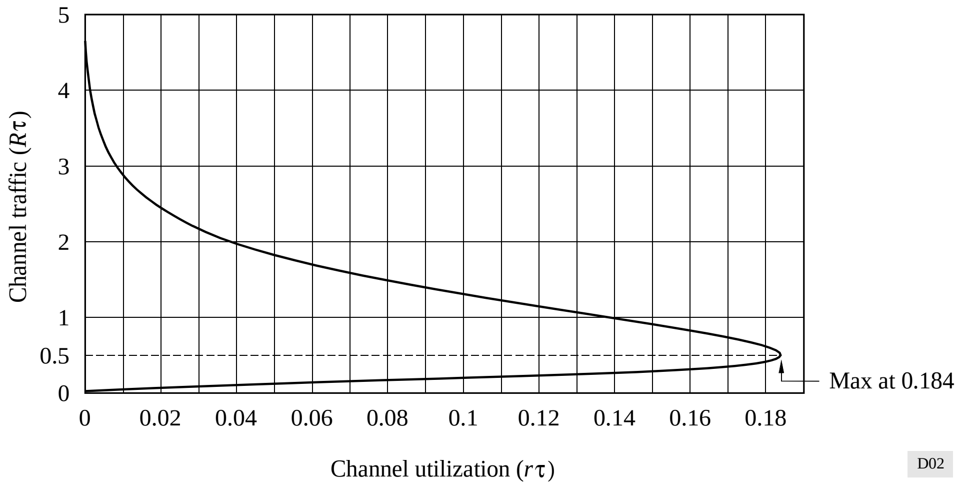
$$r\tau = R\ \tau e^{-2R\tau}$$

where $r\tau$ is the channel utilization, i.e. the amount of time that the channel is occupied by the offered DSC calls (excluding the time occupied by retransmissions). This value is also equivalent to the offered traffic in erlang.

1.6 If the channel utilization ($r\tau$) is plotted against the channel traffic ($R\tau$) the graph in Fig. 1 is obtained. If, in the above equation, the differential of $r\tau$ with respect to $R\tau$ is equated to zero, it will be found, as illustrated on the graph, that $r\tau$ reaches a maximum value of 1/2e = 0.184 when $R\tau$ = 0.5. This value of $r\tau$ is therefore the maximum capacity of the channel since at higher values of $R\tau$ the channel becomes unstable and its utilization reduces due to an increasing number of repetitions.

FIGURE 1

Channel utilization versus channel traffic



1.7 It can be seen that the relationship between the channel utilization ($r\tau$) and the channel traffic ($R\tau$) is substantially linear up to around $r\tau$ = 0.1 E and produces an acceptable margin to cope with peak concentrations of traffic. At this value $R\tau$ = 0.13 E and the probability of a re-transmission being required due to call collisions, from § 1.2, is therefore:

$$1 - e^{-2 \times 0.13} = 0.229$$

2. MF/HF DSC calling

2.1 MF/HF routine calling

2.1.1 Routine (non-distress and safety) DSC calling at MF/HF uses paired frequencies in which the coast station transmit channel will contain DSC calls to ships which have a duration of 8.2 s (including a 200-bit dot pattern) and acknowledgements from coast stations to ships which have a duration of 6.4 s (having a 20-bit dot pattern). Although the ALOHA channel calculations given in § 1 assume that the call duration τ is a constant, the calculations are still considered to be valid for slight variation in the length of DSC calls bearing in mind that the 0.1 E figure (§ 1.7) is a conservative figure compared to the maximum channel utilization of 0.184 E.

2.1.2 The ship station transmit channel will contain DSC calls to coast stations which have a duration of 6.4 s (including a 20-bit dot pattern) and acknowledgements from ships to coast stations which also have a duration of 6.4 s (20-bit dot pattern).

2.1.3 For the coast station transmit channel of a paired frequency the total number of DSC calls and acknowledgements allowable within the 0.1 E limit per channel is therefore:

$$\frac{0.1 \times 3\,600}{8.2 + 6.4} \approx 24 \text{ calls (and 24 acknowledgements) per hour}$$

2.1.4 For the ship station transmit channel of a paired frequency the total number of DSC calls and acknowledgements allowable within the 0.1 E limit per channel is therefore:

$$\frac{0.1 \times 3\,600}{6.4 + 6.4} \approx 28 \text{ calls (and 28 acknowledgements) per hour}$$

2.1.5 It should be noted that, as a result of imperfect propagation and interfering signals, in some cases calls or acknowledgements will need to be repeated (over and above any repetitions as a consequence of call collisions) to establish each successful traffic communication. However, due to the conservative nature of the 0.1 E figure (see § 1.7, 2.1.1 and Fig. 1), the above figures for the offered calls per hour are considered to be acceptable.

2.2 MF/HF distress and safety calling

2.2.1 At MF and HF, dedicated frequencies exist for DSC distress and safety (including urgency) calling. However, the use of such channels for safety and urgency calling is allowed on condition that the total channel loading is maintained below 0.1 E (see Recommendation ITU-R M.541, Annex 1, § 4). For the purposes of the following calculations, it is assumed that this figure is intended to apply to the offered traffic.

2.2.2 Assuming that two single frequency DSC distress call attempts (each consisting of five consecutive distress calls) are transmitted on any particular DSC distress and safety channel per hour and that each call attempt results in one DSC distress call acknowledgement, the distress traffic loading can be calculated as follows:

Duration of single distress call (with 200-bit dot pattern) = 7.2 s

Duration of distress acknowledgement (with 200-bit dot pattern) = 8.6 s

$$\text{Therefore traffic loading} \quad \frac{(2 \times 5 \times 7.2) + (2 \times 8.6)}{3\,600} = 0.0248 \text{ E}$$

2.2.3 If the total allowable traffic = 0.1 E, safety and urgency traffic may occupy 0.1 – 0.0248 = 0.0752 E.

2.2.4 The duration of a safety or urgency call addressed to an individual ship (worst case, including an address and a 200-bit dot pattern) = 8.2 s. The duration of a safety or urgency call transmitted by a ship to a coast station (containing an address and a 20-bit dot pattern) = 6.4 s. The acknowledgement in each case (with a 20-bit dot pattern) also has a duration of 6.4 s.

2.2.5 Assuming that an equal number of safety or urgency calls are transmitted to ships and coast stations, the total number of such calls allowed per hour (where each call results in one acknowledgement) is therefore given by:

$$\frac{0.0752 \times 3600}{[(8.2 + 6.4) + (6.4 + 6.4)]/2} = 19.8$$

2.2.6 In practice, the majority of safety or urgency calls transmitted by coast stations will be addressed to all ships (for which the duration of the DSC call is 7.2 s) and no DSC acknowledgement will result. Hence it may be assumed that, on average, *20 safety or urgency calls per hour* may be transmitted on MF/HF distress and safety frequencies.

2.2.7 The probability of a complete distress call attempt being mutilated by collisions with other distress calls or with safety or urgency calls may be calculated as follows:

– the probability of a single distress call being mutilated (from § 1.7):

$$1 - e^{-2 \times 0.13} = 0.229$$

– but the five calls within a distress call attempt cannot interfere with each other and therefore the traffic loading due to calls capable of mutilating a distress call may be reduced by 4 × 7.2/3 600 = 0.0080. Furthermore, a distress acknowledgement to a distress call attempt will not interfere since it follows the distress call attempt and therefore an additional channel loading of 8.6/3 600 = 0.0024, i.e. a total of 0.0104, may be subtracted;

– therefore, the probability of a single distress call being mutilated:

$$1 - e^{-2 \times (0.13 - 0.0104)} = 0.2127$$

– therefore, the probability of all five calls within the call attempt being mutilated:

$$(0.2127)^5 = 0.0004 \ (= 0.04\%)$$

3. VHF DSC calling

3.1 VHF routine calling

3.1.1 All DSC calling at VHF (i.e. routine and distress and safety calling) uses a single frequency channel (channel 70) for all calls and acknowledgements. Individual station calls and acknowledgements (including urgency and safety calls) have a duration of 0.533 s.

3.1.2 If the calling is random the channel capacity for 0.1 E of offered traffic is:

$$\frac{0.1 \times 3\,600}{0.533 + 0.533} = 337.7 \text{ calls (and 337.7 acknowledgements) per hour}$$

3.1.3 However, all VHF DSC routine calling requires listening to the channel and transmitting only after detection of the absence of another call or the cessation of another call (see Recommendation ITU-R M.541, § 3.6) and therefore it may be assumed that truly random calling will only apply to stations which are out of range of the station transmitting an existing DSC call and to distress and safety calls. Examples of such "unheard call" cases are those of two ships, both within range of a particular coast station but out of range of each other, and two coast stations, both within range of a particular ship but out of range of each other.

3.1.4 The above "listen before transmission" calls may be compared to a slotted ALOHA system where transmissions are only permitted to start at the beginning of a time slot which have the same duration as the call duration. In this case, since calls, if they collide, will do so completely instead of merely overlapping to a certain extent, the factor of 2 in the equation given in § 1.2 and explained in § 1.4 is reduced to a factor of 1.

3.1.5 Therefore, in this slotted ALOHA case the probability that a given call will have to be re-transmitted (due to call collisions) is given by:

$$1 - e^{-R\tau}$$

3.1.6 By carrying out similar calculations to those in § 1 it will be found that the maximum value of channel utilization ($r\tau$) is doubled to 0.368 and, in comparison with § 1.7, a channel utilization of = 0.2 E equates to a channel traffic loading ($R\tau$) of 0.26 which still results (using the formula in § 3.1.5) in a probability of a re-transmission being required due to call collisions of 0.229.

3.1.7 The equivalence of the "listen before transmission" VHF DSC calling to the slotted ALOHA situation is only strictly valid if any delay between the detection of no call and the transmission of a VHF DSC call is a minimum and constant value between different equipments. In other words, there should be no random delay built into the equipment otherwise the doubling of the channel utilization will be reduced.

3.1.8 Applying a similar calculation to that in § 3.1.2 it can be seen that the VHF DSC channel would have a capacity of 675 offered calls (and 675 acknowledgements) per hour if all calls were of the "listen before transmission" type. A more rigorous and complex mathematical analysis of the VHF situation may be conducted using calculations of "carrier sense multiple access" (CSMA) packet switching systems.

3.1.9 In practice, for the reasons stated in § 3.1.3, there will be a mix of random "unheard" calls and the "listen before transmission" calls and if a 50/50 mix is assumed, the channel should support approximately *500 calls per hour* which is equivalent to 0.15 E.

3.2 VHF distress and safety calling

3.2.1 Assuming that two VHF DSC distress call attempts (each consisting of five consecutive distress calls) are transmitted on channel 70 per hour and that each call attempt results in one DSC distress call acknowledgement, the distress traffic loading can be calculated as follows:

Duration of single distress call (with 20-bit dot pattern) = 0.45 s

Duration of distress acknowledgement (with 20-bit dot pattern) = 0.567 s

$$\text{i.e. traffic loading} \quad \frac{(2 \times 5 \times 0.45) + (2 \times 0.567)}{3\,600} = 0.001565 \text{ E}$$

3.2.2 It should be noted that VHF distress calls are transmitted without listening to the channel. The probability of a complete distress call attempt being mutilated by collisions with non-distress calls (routine, safety or urgency calls) may be calculated as follows:

– The channel traffic loading on VHF, assuming a 50/50 mix of "listen before transmission" and "unheard" calls, based on the figures for $R\tau$ given in § 1.7 and 3.1.6 will be between 0.13 and 0.26 so an average value of 0.20 may be assumed.

– Since a distress call may be transmitted at any random time, the classical ALOHA formula applies to the probability of a collision between a single distress call transmission with a non-distress call (§ 1.2), i.e.:

$$p_1 = 1 - e^{-2 \times 0.20} = 0.330$$

– However, the distress call attempt consists of five consecutive distress calls and therefore this five-call transmission, once started, will prevent the transmission of any new non-distress calls within listening range. However, since the duration of a single distress call is less than that of a non-distress call (0.45 s compared to 0.533 s) it may be assumed, in a worst case, that the second distress call will suffer the same collision probability as the first call (p_1).

– As far as the third, fourth and fifth transmissions are concerned, only the “unheard” non-distress calls may cause collisions. Assuming that these total 50% of the 500 allowable calls (from § 3.1.9), i.e. 250 calls (plus 250 acknowledgements) per hour, the offered “unheard” channel utilization ($r\tau$) can be calculated using the formula in § 3.1.2, i.e.:

$$\frac{r\tau \times 3\,600}{0.533 + 0.533} = 250, \text{ and therefore } r\tau = 0.074$$

– For this value of $r\tau$, using the formula in § 1.5, the channel traffic $R\tau$ is 0.088 and hence the probability of a collision between the third, fourth or fifth distress calls with an “unheard” non-distress call (from § 1.2) is:

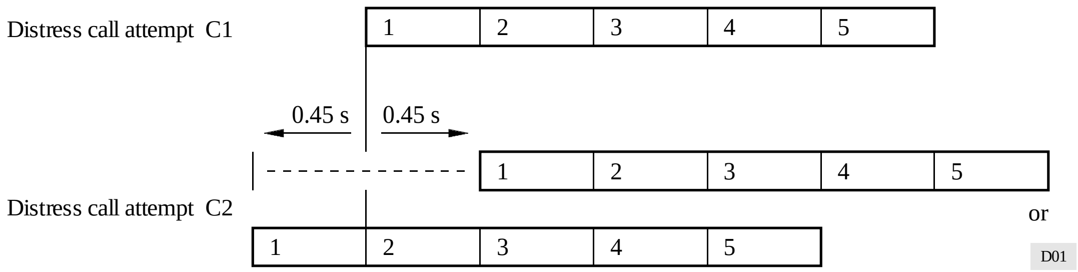
$$p_2 = 1 - e^{-2 \times 0.088} = 0.161$$

– Therefore the probability that all five distress calls within the five-call attempt collide with a non-distress call is given by:

$$p_3 = (p_1)^2 \times (p_2)^3 = (0.330)^2 \times (0.161)^3 = 0.00045$$

3.2.3 The probability of a complete distress call attempt being mutilated by a collision with another distress call attempt (assuming two distress call attempts per hour) may be calculated as follows:

– The probability that all five calls in the distress call attempt are mutilated is the probability that the second distress call attempt starts within the duration of a single call of the first call attempt. This can be illustrated as:



where | - - - - - - - - - - - - - | is the duration (0.9 s) during which the second call attempt must not start.

– Therefore the classical ALOHA formula given in § 1.2 may be used where τ is the duration of a single call (0.45 s) and R is the number of calls per second (2/3 600), hence:

$$p_4 = 1 - e^{-2 \times (2/3\,600) \times 0.45} = 0.0005$$

– But, this illustration, and the probability p_4 relates to both complete distress call attempts being mutilated and therefore the probability of a single complete distress call attempt being mutilated is half of p_4, i.e.

the probability p_5 of distress call attempt being mutilated by another distress call attempt is given by:

$$p_5 = 0.00025$$

(the probability p_5 could alternatively be calculated by using the classical ALOHA formula with $R = 1$ which results in the same figure. This approach may also be used to calculate the probabilities where there are more than two distress call attempts per hour).

3.2.4 Therefore, the probability of a complete distress call attempt being mutilated by a collision with another distress call attempt (assuming two distress call attempt transmissions per hour) or by collision with non-distress calls is given by:

$$p_3 + p_5 = 0.0007$$

ANNEX 2

Scanning loss

1. Use of scanning receivers

The use of a scanning receiver means that there is some probability that a call intended for the receiving station is lost due to the decoder being engaged on another channel, usually referred to as the scanning loss. Scanning loss is a function of the number of channels scanned by a single receiver and the loading of the DSC channels. As a general rule the use of scanning receivers is not to be encouraged as the scanning loss increases channel loading and thus has a cumulative effect. Nevertheless, it must be recognized that the use of scanning receivers may be a necessity on many ships for economic reasons but they should not normally be used at coast stations.

The calculations indicate that, for non-distress DSC reception, a single receiver should scan not more than six channels thus the number of channels that a ship station should be expected to watch is of significant economic consequence. Two cases may be considered for non-distress and safety calls:

– minimum of about 6 frequencies, i.e. one national and one international channel in three bands. This would require cooperation of the ship's personnel to select the most appropriate bands at any given time and could increase the traffic load on the international channels due to the limited watch on national channels;

– minimum of about 15 frequencies, i.e. two national and one international channel in each of the bands 4, 6, 8, 12 and 16 MHz. This would give a more automatic service to the ship's personnel but would require more than one scanning receiver.

For distress and safety calls a separate scanning receiver would be necessary which could scan up to six dedicated distress and safety frequencies in the MF and HF bands.

2. Non-distress and safety frequencies

2.1 Assumptions

Calculations were based on non-distress calls and the following assumptions:

– the scanner only halts at a calling channel if the dot pattern is recognized;

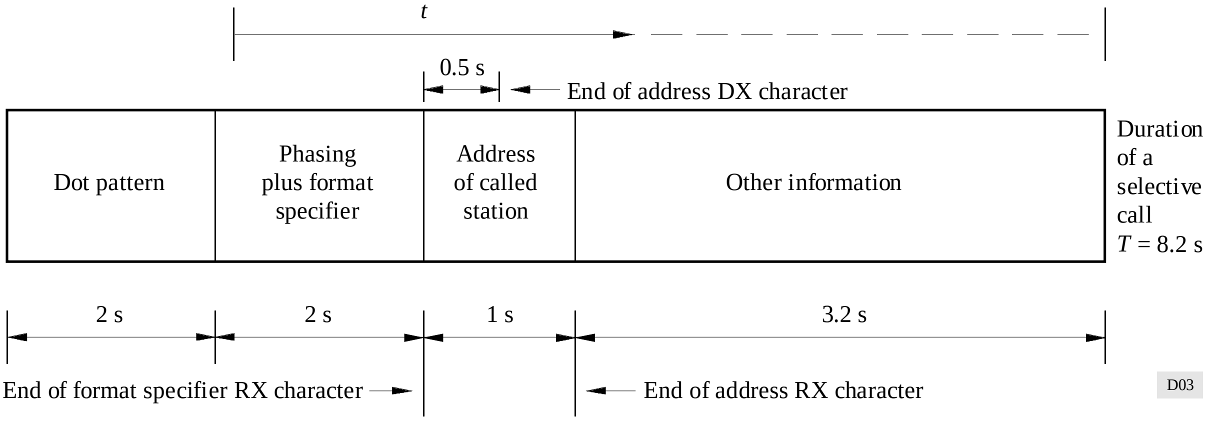
– in all other cases the scanner immediately moves on (so no time is required for recognizing another situation);

– a time t is required, on an average, to recognize that a call is destined for a different station: after that the scanner immediately moves on.

2.2 *Format of the call*

Figure 2 contains information relevant for the calculation:

FIGURE 2



Three options for t are considered:

– $t = 2.5$ s

when the signal processing of the receiver disregards the RX character positions (for scanning control) if no bit error is found in the last DX position of the address;

– $t = 3.0$ s

if the signal processing of the receiver requires both the RX and the DX position of each address character to be decoded;

– $t = 6.2$ s

if the signal processing of the receiver requires the complete message to be decoded.

2.3 *Results of the calculations*

The probability that a call for station A fails, due to scanning, is equal to the sum of two sub-probabilities:

– p_1, the probability that the scanner is busy decoding calls (on other channels) for other stations while the dot pattern is being transmitted;

– p_2, the probability that the scanner is busy decoding calls (on other channels) for station A while the dot pattern is being transmitted.

$$p_1 = 1 - e^{-(n-1)\lambda t}$$

$$p_2 = 1 - e^{-(n-1) 6.2 \lambda a}$$

in which:

n : number of channels scanned by the scanner

λ : average calling frequency: if the average load of a calling channel is 0.1 E, $\lambda T = 0.1$, so that $\lambda = 1/82$

a : percentage of calls for station A

t : see § 2.2.

For ships, a can be considered to be 0; for coast stations monitoring international HF channels it is assumed that $a = 3.5\%$ (although, as stated in § 1, scanning receivers should not normally be used at coast stations).

The results of the calculations are given in Tables 1a, 1b and 1c below for channel loading values ranging from 0.13 E (the channel traffic loading, including repetitions, for an offered traffic channel utilization of 0.1 E) to 0.05 E.

TABLE 1a

Percentage of calls lost as a result of scanning for *t* = 2.5 s

	Number of channels scanned (*n*)												
Average calling frequency λ	3	4	5	6	7	8	9	10	11	12	13	14	
λ = 1/63	8.3	12.3	16.0	19.7									Coast station $a = 3.5\%$
(0.13 E)	7.6	11.2	14.7	18.0									Ships
λ = 1/82	6.4	9.5	12.5	15.5	18.3			Impermissibly high (> 20%)					Coast station $a = 3.5\%$
(0.1 E)	5.9	8.7	11.5	14.1	16.7	19.2							Ships
λ = 1/109	4.9	7.2	9.6	11.8	14.0	16.2	18.3						Coast station $a = 3.5\%$
(0.075 E)	4.5	6.6	8.8	10.8	12.9	14.8	16.8	18.7					Ships
λ = 1/164	3.3	4.9	6.4	8.0	9.5	11.0	12.5	14.0	15.5	16.9	18.3	19.7	Coast station $a = 3.5\%$
(0.05 E)	3.0	4.5	5.9	7.3	8.7	10.1	11.5	12.8	14.1	15.4	16.7	18.0	Ships

TABLE 1b

Percentage of calls lost as a result of scanning for *t* = 3.0 s

λ \ *n*	3	4	5	6	7	8	9	10	11	12	13	14	
λ = 1/63	9.8	14.3	18.7										Coast station $a = 3.5\%$
(0.13 E)	9.1	13.3	17.3										Ships
λ = 1/82	7.6	11.2	14.7	18.0									Coast station $a = 3.5\%$
(0.1 E)	7.1	10.4	13.6	16.7	19.7			Impermissibly high (> 20%)					Ships
λ = 1/109	5.8	8.5	11.2	13.8	16.4	18.9							Coast station $a = 3.5\%$
(0.075 E)	5.4	7.9	10.4	12.9	15.2	17.5	19.8						Ships
λ = 1/164	3.9	5.7	7.6	9.4	11.2	12.9	14.7	16.4	18.0	19.7			Coast station $a = 3.5\%$
(0.05 E)	3.6	5.3	7.1	8.7	10.4	12.0	13.6	15.2	16.7	18.2	19.7		Ships

TABLE 1c

Percentage of calls lost as a result of scanning for t = 6.2 s

n / λ	3	4	5	6	7	8	9	10	11	12	13	14	
λ = 1/63	18.6												Coast station a = 3.5%
(0.13 E)	17.9												Ships
λ = 1/82	14.6												Coast station a = 3.5%
(0.1 E)	14.0						Impermissibly high (> 20%)						Ships
λ = 1/109	11.2	16.3											Coast station a = 3.5%
(0.075 E)	10.8	15.7											Ships
λ = 1/164	7.5	11.1	14.6	17.9									Coast station a = 3.5%
(0.05 E)	7.3	10.7	14.0	17.2									Ships

3. Distress and safety frequencies

3.1 Assumptions

The same assumptions as those given in § 2.1 for non-distress calls apply to distress calls but in addition, for the purposes of the calculations, it is assumed that:

– all DSC calls on the six dedicated MF/HF distress and safety channels are either distress calls, distress acknowledgements, safety calls or safety acknowledgements (in practice there may also be some distress relay calls and acknowledgements);

– all distress calls on all of the dedicated distress and safety channels are implicitly addressed to, and should be received by, all ships;

– distress calls may be transmitted either as a 5-call single-frequency call attempt or as a 6-call multi-frequency call attempt (see Recommendation ITU-R M.541, Annex 1, § 3.1.3.1 and 3.1.3.2);

– safety calls on all of the dedicated distress and safety channels are either addressed to, and should be received by, all ships or addressed to individual ships (although, in practice, some calls will be addressed to individual geographic areas);

– after a single distress call within a single-frequency 5-call distress call attempt is received the scanner resumes scanning. In the absence of the dot pattern of another call being detected during the receiver's scanning cycle (assumed to be less than 2 s), the scanner will again stop on detection of the next single call within the same distress call attempt.

3.2 Calculations

The probability p that a distress call is not received by station A, due to scanning, may be calculated as the sum of two sub-probabilities:

– p_d the probability that the scanner is busy decoding distress calls on other channels while the dot pattern is being transmitted;

– p_s the probability that the scanner is busy decoding safety calls on other channels (either for station A, including all ships calls, or for other stations) while the dot pattern is being transmitted.

For each of these two sub-probabilities the calculations assume two possible scenarios, as follows:

For p_d:

scenario *ds :* all distress call attempts are single-frequency, or

scenario *dm :* all distress calls attempts are multi-frequency.

For p_s:

scenario *sa :* all safety calls are all ships calls, or

scenario *si :* all safety calls are individual calls.

The formulae to calculate these four scenario probabilities are given below:

3.2.1 Scenario ds – all distress call attempts are single-frequency

The probability that a single distress call within a single-frequency distress call attempt (5 calls) will be lost due to scanning when only other single-frequency distress call attempts (and their associated distress acknowledgements) are considered may be calculated using the formula for p_2 (see § 2.3 except that 6.2 is replaced by the duration of a single distress call minus the dot pattern (5.2 s) and $a = 1$ (since all calls are for station A)), i.e.

$$p_{ds} = 1 - e^{-(n-1)\,5.2\,\lambda}$$

Based on two distress call attempts and two distress acknowledgements per hour per channel, the traffic loading per channel (from Annex 1, § 2.2.2) is 0.0248 E and therefore λ, the average calling frequency per single call = 0.0248/7.2 = 0.003444. p_{ds} for various values of n (the number of channels scanned) is given in Table 2.

TABLE 2

Percentage probabilities and percentage distress call scanning loss

	Number of channels scanned (n)				
Loss probability (p)	2	3	4	5	6
Loss due single-frequency distress call attempt, p_{ds} (%)	1.7752	3.5188	5.2315	6.9138	8.5663
Loss due to multi-frequency distress call attempt, p_{dm} (%)	3.4094	6.7025	9.8834	12.9558	15.9235
Average loss due to distress call attempt, p_d (%)	2.5923	5.1107	7.5575	9.9348	12.2449
Loss due to all ships safety, p_{sa} (%)	5.2863	10.2931	15.0352	19.5267	23.7807
Loss due to individual safety, p_{si} (%)	2.7072	5.3411	7.9037	10.3970	12.8227
Average loss due safety calls, p_s (%)	3.9967	7.8171	11.4695	14.9618	18.3017
1 distress call lost/distress call attempt, $p^{(1)}$ (%)	6.5890	12.9278	19.0269	24.8966	30.5466
2 distress calls lost/distress call attempt, $p^{(2)}$ (%)	0.4342	1.6713	3.6202	6.1984	9.3309
3 distress calls lost/distress call attempt, $p^{(3)}$ (%)	0.0286	0.2161	0.6888	1.5432	2.8503
4 distress calls lost/distress call attempt, $p^{(4)}$ (%)	0.0019	0.0279	0.1311	0.3842	0.8707
5 distress calls lost/distress call attempt, $p^{(5)}$ (%)	0.0001	0.0036	0.0249	0.0957	0.2660

3.2.2 Scenario dm – all distress calls attempts are multi-frequency

The probability of loss, due to scanning, of a single distress call within a multi-frequency distress call attempt (consisting of six single distress calls dispersed over up to six frequencies) uses the same formula as for the single frequency case, i.e.:

$$p_{dm} = 1 - e^{-(n-1)\,5.2\,\lambda}$$

However, for traffic loading calculations it may be assumed that each single distress call transmission results in an acknowledgement. Hence for the same number of originated distress call attempts per frequency as the single-frequency case, the traffic loading is given by:

$$\frac{(2 \times 6 \times 7.2) + (2 \times 6 \times 8.6)}{3\,600} = 0.0527 \text{ E}$$

therefore $\lambda = 0.0527 \times 2/(7.2 + 8.6) = 0.006671$. p_{dm} for various values of n is given in Table 2.

3.2.3 Scenario sa – all safety calls are all ships calls

The probability that a single distress call is lost due to scanning when all calls on the other scanned channels are all ships safety calls (which have a duration excluding the dot pattern of 5.2 s) uses the same formula as p_{ds} and p_{dm}, i.e.:

$$p_{sa} = 1 - e^{-(n-1)\,5.2\,\lambda}$$

The relevant value of traffic loading is given in Annex 1, § 2.2.3, i.e. 0.0752 E, therefore $\lambda = 0.0752/7.2 = 0.010444$. p_{sa} for various values of n is given in Table 2.

3.2.4 Scenario si – all safety calls are individual calls

The probability that a single distress call is lost due to scanning when all calls on the other scanned channels are individual safety calls is calculated using the formula $p_1 + p_2$ from § 2.3 since individual calls to other stations must also be considered. The call format of individual safety calls is the same as that for non-distress calls illustrated in § 2.2. However, for ships a can be considered to be 0 and, to simplify the options for calculations, a value of $t = 2.5$ s is assumed, hence:

$$p_{si} = 1 - e^{-(n-1)\,2.5\,\lambda}$$

As in § 3.2.3 the traffic loading = 0.0752 E but the average duration of an individual call = 6.85 s (assuming equal numbers of to-ship and from-ship calls and the same number of acknowledgements – see Annex 1, § 2.2.4), therefore $\lambda = 0.0752/6.85 = 0.010978$. p_{si} for various values of n is given in Table 2.

3.3 Results

3.3.1 The values of the probabilities described in § 3.2.1 to 3.2.4 are given as percentages in Table 2. In addition Table 2 contains the probability $p^{(1)}$ that a single distress call within a distress call attempt is not received by a particular ship due to scanning loss, which is given by:

$$p^{(1)} = p_d + p_s$$

3.3.2 In order to simplify the results, the calculation of p_d and p_s is based on the rationale that, since distress call attempts can be either single-frequency or multi-frequency, a 50/50 split is assumed between the two types of distress call attempt. Furthermore, since safety calls can be either to all ships or to individual stations a 50/50 split is also assumed between these types of safety calls. Hence the following formulas apply:

$$p_d = \frac{p_{ds} + p_{dm}}{2}$$

$$p_s = \frac{p_{sa} + p_{si}}{2}$$

3.3.3 In practice, only one distress call within a distress call attempt need be received by a particular ship, therefore the probabilities of loss of 2, 3, 4 or 5 distress calls are also contained in Table 2. The formulas for these probabilities is given by:

$$p(x) = [p^{(1)}]^x$$

where $x = 2, 3, 4$ or 5.

3.3.4 Bearing in mind that, for propagation and interference reasons, it will often be unlikely that all distress calls within a distress call attempt will be capable of being received and decoded error-free by a particular ship, an acceptable loss may be considered to be three distress calls for which the probability, from Table 2, is less than 3% assuming that six channels are scanned.

4. Conclusions

4.1 Non-distress and safety frequencies

It follows from Tables 1a, 1b and 1c above that in the case of ships' receivers scanning non-distress and safety frequencies, for an acceptable loss (<18%):

– six channels could be scanned for 0.13 E channel loading and a message holding time of 2.5 s;

– five channels could be scanned for 0.13 E channel loading and a message holding time of 3 s.

The number of channels that may be scanned varies approximately in inverse proportion to the channel loading.

It also follows from Table 1c that scanning is of limited use when the complete message has to be decoded before scanning can be resumed.

4.2 Distress and safety frequencies

From Table 2 above, the number of single distress calls within a multi-call distress call attempt which may be lost due to scanning, assuming that six channels are scanned, varies from approximately 0.25 to 30%. An acceptable loss may be considered to be three calls for which the probability of loss is 2.85%.