

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 high probability of collision. 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:

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

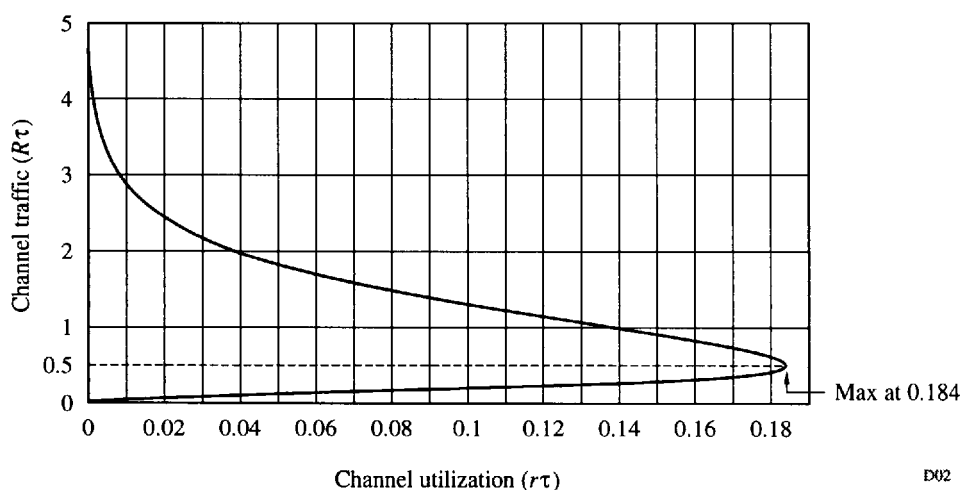
and hence:

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

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:

$$\frac{0.1 \times 3600}{8.2 + 6.4} \approx 24 \text{ calls (and 24 acknowledgements) per hour}$$

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:

$$\frac{0.1 \times 3600}{6.4 + 6.4} \approx 28 \text{ calls (and 28 acknowledgements) per hour}$$

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

$$\text{Therefore traffic loading} = \frac{(2 \times 5 \times 7.2) + (2 \times 8.6)}{3600} = 0.0248 \text{ E}$$

2.2.3 If the total allowable traffic = 0.1 E, safety and urgency traffic may occupy $0.1 - 0.0248 = 0.0752 \text{ E}$.

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 $4 \times 7.2/3600 = 0.0080$. 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 $8.6/3600 = 0.0024$, 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:

$$\frac{0.1 \times 3600}{0.533 + 0.533} = 337.7 \text{ calls (and 337.7 acknowledgements) per hour}$$

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.