

Radio Technology & Compatibility Group

Investigation into the intermodulation
response characteristics
of
a range of current maritime transceivers

Project No. 487

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1.0 Introduction

- 1.1 This work was commissioned by the Radiocommunication Agency to investigate problems with maritime communications caused by intermodulation occurring in the front end of currently available maritime receivers. It is envisaged that due to increasing demands for services in bands adjacent to the VHF maritime band, this problem is likely to worsen in the future.
- 1.2 The project sets out to compare the intermodulation performance of a new maritime transceiver employing additional RF filtering (receiver 'A') with a range of six conventional designs covering an age span of at least twenty years (receivers 'B' to 'G'), as well as assessing the effect of modifications to test arrangements.

2.0 Methodology

2.1 Comparison of performance

- 2.1.1 For the purpose of comparison all seven receivers were tested in accordance with the specified requirements of ETS 300 162 under ambient conditions for the following parameters:

Tests:

- a. Maximum Usable Sensitivity (MUS).
- b. Spurious responses (Image frequency only - to expedite tests).
- c. Blocking ($\pm 10\text{MHz}$ and $\pm 1\text{MHz}$ - to expedite tests).
- d. Intermodulation response at $+50\text{kHz}$ / $+100\text{kHz}$ offsets.
- e. Intermodulation response with random test frequencies of 153.025MHz and 154.9125MHz .

- 2.1.2 In order to more completely assess intermodulation response performance the random test frequencies of 153.025MHz and 154.9125MHz were chosen as they are representative of out of band emissions having the potential for causing interference on channel 16 (test e).
 - 2.1.3 Tests b, c, d and e were then repeated, but with the wanted signal set to a level of $+6\text{dB}\mu\text{V}$ emf at the receiver input instead of the level corresponding to the MUS. The new value of SINAD was noted and then degraded to 14dB by the unwanted signals.
 - 2.1.4 Tests a, b, c, d and e were then repeated with a 10dB attenuator at the receiver input (simulating an internal receiver attenuator).
 - 2.1.5 Tests b, c, d and e were then repeated with both the wanted level of $+6\text{dB}\mu\text{V}$ *and* the 10dB attenuator (again noting the new SINAD value and degrading to 14dB with the unwanted signals present).
-

2.1.6 Finally in order to assess the annoyance factor, the mute control on each of the seven receivers was set to just close on ambient noise, and a series of measurements made, with incremented levels of the two out of band intermodulation test frequencies required to just lift the mute. (test f).

2.2 Additional measurements made on receiver 'A' only

2.2.1 Intermodulation response is the most significant parameter being assessed by this project. It was therefore decided to repeat the measurement of this particular parameter on receiver 'A' at +55°C and -15°C (although not a requirement of ETS 300 162), in order to assess the effects of temperature extremes on the additional RF filtering.

2.2.2 In order to provide an indication of the effectiveness of the additional RF filtering, intermodulation response was measured by incrementing f_1 in 10MHz steps from 80.4MHz to 330.4MHz, and recalculating f_2 to satisfy the relationship $2f_1 - f_2 = 156.800\text{MHz}$ (channel 16).

2.2.3 The DSC performance was then assessed for MUS and intermodulation response on channel 70 (156.525MHz). As no DSC signal generator was available, it was necessary to generate a DSC distress message on the arbitrary waveform generator and phase modulate an RF signal generator with the AFSK output, in accordance with the specified requirements contained in publication ITU-R M.493-9 for VHF equipment. The criteria for determining MUS and intermodulation response was taken as the threshold of satisfactory DSC decoding by the receiver. This was defined as the threshold signal level giving 100% successful decoding of a DSC message, with a sample size of ten messages.

3.0 Results

3.1 Results for the comparison of receiver performance tests a, b, c, d, e and f, are recorded at Annex A.

3.2 Results for the additional measurements on transceiver 'A' only are recorded at Annex B.

4.0 Observations

4.1 It is apparent from the test results that receiver 'A' with its additional RF filtering has an improved ability to discriminate against signals that would otherwise result in an intermodulation response. This increased immunity was retained (to within 1dB) at extremes of temperature (+55°C to -15°C).

4.2 Although these tests were not undertaken for Type Approval purposes, it was observed that none of the receivers measured, met the requirements of ETS 300 162 for Blocking performance (although the results were generally within the measurement uncertainty of the limit for this parameter).

5.0 Recommendations

- 5.1 Consideration should be given to improving the ETS 300 162 intermodulation response limit for new equipment, in light of the enhanced performance available by using additional integral RF filtering and in view of spectrum congestion in adjacent bands and in light of the possibility of providing front end receiver attenuation to existing designs.
 - 5.2 In particular, consideration should also be given to specifying absolute intermodulation response limits of (say) 75dB μ V emf for the unwanted signals (with the wanted signal at both the MUS level and at the +6dB μ V specification limit). In the case of out of band unwanted signals the limit may be increased to +78dB μ V emf. This should ensure enhanced protection to maritime services.
 - 5.3 Similarly, in the case of DSC, consideration should be given to improving the absolute limit to (say) +73dB μ V emf for in band unwanted frequencies, and +75dB μ V for out of band unwanted frequencies (both for MUS level and the specification limit of 0dB μ V emf).
 - 5.4 In the future, it might be advisable to undertake a broader investigation into the results achievable with additional RF filtering, possibly using data gleaned from Type Approval test reports, with a view to the possibility of a further tightening of the intermodulation response limits.
 - 5.5 The measurement results for third order intermods (Annex B - table 2) shows that the improvements in intermodulation response on receiver 'A' is maintained to within 1dB over the frequency range of approximately 4MHz to 504MHz (for f_2 frequencies).
 - 5.6 This improvement could be capitalised on by extending the range of ETS 300 162 to include out of band measurements at f_2 frequencies of 44MHz, 144MHz, 244MHz and 344MHz (highlighted in table 2), where $2f_1 - f_2 =$ Maritime channel.
-

Table 1 - Measurement results for comparison of receiver performance

TEST PARAMETERS Out of band test frequencies = 154.9125MHz (unmodulated) 153.025MHz (modulated)		MEASUREMENT RESULTS (with receiver set to channel 16 - 156.800MHz)														ETS 300 162 Specification Limit	
		Receiver 'G'		Receiver 'F'		Receiver 'E'		Receiver 'D'		Receiver 'C'		Receiver 'B'		Receiver 'A'			
		levels		levels		levels		levels		levels		levels		levels			
		dB	dBµV emf	dB	dBµV emf	dB	dBµV emf	dB	dBµV emf	dB	dBµV emf	dB	dBµV emf	dB	dBµV emf		
		rel.	abs.	rel.	abs.	rel.	abs.	rel.	abs.	rel.	abs.	rel.	abs.				
Tests in accordance with ETS 300 162	a) Maximum Usable Sensitivity	-	-8.0	-	-4.3	-	+0.3	-	-2.2	-	-4.0	-	+0.1	-	-4.4	+6dBµV emf	
	b) Spurious response (image frequency)	73.0	65.0	70.4	66.1	77.8	78.1	86.6	84.4	75.5	71.5	75.7	75.8	86.3	81.9	70dB	
	c) Blocking	+10MHz	-	84.4	-	85.0	-	92.5	-	89.3	-	91.2	-	89.4	-	88.0	90dBµV emf
		+1MHz	-	84.4	-	82.8	-	89.7	-	88.8	-	89.7	-	88.3	-	88.0	
		-1MHz	-	85.1	-	78.8	-	89.7	-	89.2	-	88.7	-	89.4	-	88.0	
		-10MHz	-	85.1	-	90.0	-	92.8	-	92.8	-	91.7	-	94.7	-	88.8	
d) Intermodulation response	76.5	68.5	70.1	65.8	45.3	45.6	68.4	66.2	69.1	65.1	64.9	65.0	79.1	74.7	68dB		
e) Intermod response (out of band test freq's)	77.6	69.6	70.6	66.3	71.0	71.3	72.7	70.5	87.8	83.8	65.9	66.0	83.8	79.4	NA		
Tests to ETS 300 162 but with the wanted signal set to +6dBµV emf (SINAD degraded to 14dB).	SINAD for +6dBµV emf input	-	36.5	-	33.5	-	28.5	-	30.5	-	26.5	-	29.0	-	31.5	NA	
	Spurious response (image frequency)	80.0	86.0	75.9	81.9	83.5	89.5	92.6	98.6	79.5	85.5	80.8	86.8	92.1	98.1	NA	
	Blocking	+10MHz	-	103.1	-	98.8	-	102.2	-	101.7	-	104.2	-	100.9	-	103.1	NA
		+1MHz	-	101.3	-	96.3	-	98.7	-	98.2	-	97.8	-	97.1	-	103.1	NA
		-1MHz	-	101.6	-	92.3	-	100.3	-	101.7	-	100.1	-	97.7	-	103.1	NA
		-10MHz	-	103.9	-	102.9	-	102.8	-	104.5	-	104.9	-	104.3	-	103.7	NA
Intermodulation response	67.0	73.0	65.4	71.4	52.5	68.5	70.5	76.5	64.4	70.4	62.7	68.7	74.2	80.2	NA		
Intermod response (out of band test freq's)	69.9	75.9	65.3	71.3	68.2	74.2	68.8	74.6	82.8	88.8	64.4	70.4	78.8	84.8	NA		
Tests to ETS 300 162 but with 10dB attenuator at Rx input simulating internal attenuator. SINAD degraded to 14dB.	Maximum Usable Sensitivity	-	+2.0	-	+5.7	-	+10.2	-	+7.8	-	+6.7	-	+10.6	-	+5.6	NA	
	Spurious response (image frequency)	72.8	74.8	69.8	75.5	77.7	87.9	87.9	95.7	75.8	82.5	74.9	85.5	86.4	92.0	NA	
	Blocking	+10MHz	-	94.2	-	94.8	-	103.2	-	100.1	-	102.7	-	100.0	-	98.0	NA
		+1MHz	-	94.1	-	91.2	-	101.4	-	98.7	-	100.1	-	99.2	-	98.0	NA
		-1MHz	-	94.6	-	88.1	-	101.4	-	100.1	-	98.5	-	100.0	-	98.0	NA
		-10MHz	-	96.1	-	98.0	-	103.8	-	102.9	-	102.7	-	104.3	-	98.9	NA
Intermodulation response	73.9	75.9	69.5	75.2	46.3	56.5	69.4	77.2	67.4	74.1	64.6	75.2	79.1	84.7	NA		
Intermod response (out of band test freq's)	76.9	78.9	70.3	76.0	70.9	81.1	72.8	80.6	84.3	91.0	65.9	76.5	81.9	87.5	NA		
Tests to ETS 300 162 but with the wanted signal set to +6dBµV and a 10dB attenuator at Rx input. SINAD degraded to 14dB.	SINAD for +6dBµV emf input	-	27.0	-	20.0	-	9.0	-	17.0	-	20.0	-	7.0	-	21.5	NA	
	Spurious response (image frequency)	77.3	83.3	71.3	77.3	Tests not possible as SINAD already below 14dB		84.0	90.0	76.5	82.5	Tests not possible as SINAD already below 14dB		87.1	93.1	NA	
	Blocking	+10MHz	-	101.6	-		96.2		-	97.0	-		98.7		-	100.0	NA
		+1MHz	-	101.5	-		91.9		-	95.0	-		98.7		-	100.0	NA
		-1MHz	-	101.5	-		89.0		-	95.0	-		97.3		-	100.0	NA
		-10MHz	-	102.2	-		100.5		-	97.7	-		101.4		-	100.8	NA
	Intermodulation response	72.8	78.8	70.3	76.3			65.0	71.0	68.5	74.5			79.1	85.1	NA	
	Intermod response (out of band test freq's)	75.9	81.9	70.4	76.4		72.7	78.7	84.0	90.0		82.0	88.0	NA			

Note: **rel.** = unwanted signal level minus wanted signal level at Rx input. **abs.** = emf at Rx input. (at 10dB attenuator input where applicable)

Table 2 - Mute opening levels (Test f)

Mute set to just close on ambient receiver noise

Combinations of out of band test signal levels required to just open mute (dBµV emf)							
153.025MHz signal level	154.9125MHz signal level						
	Receiver 'A'	Receiver 'B'	Receiver 'C'	Receiver 'D'	Receiver 'E'	Receiver 'F'	Receiver 'G'
90.0	77.0	71.7	84.2	57.3	65.6	#	62.7
80.0	84.2	73.9	89.5	63.8	69.3	57.4	65.8
70.0	89.3	78.5	94.3	69.3	74.1	62.0	70.0
60.0	93.6	84.1	95.0	74.0	79.1	67.3	75.3
50.0	97.9	89.0	#	79.0	84.3	72.3	80.4
40.0	102.0	96.5	#	84.0	90.3	77.0	86.8
30.0	103.1	#	#	87.6	99.4	82.5	92.0
20.0	103.2	#	#	91.8	123.0	87.0	99.2
10.0	103.2	#	#	94.0	#	90.0	123.0

= mute already open at higher levels with only one signal applied

Additional measurements on receiver 'A'

Table 1 - Intermodulation response at temperature extremes (Test g)

Temperature	IM response rejection
+55°C	77.8dB
-15°C	78.4dB

Table 2 - Third order intermods ($2f_1-f_2$) falling on channel 16 (156.800MHz).

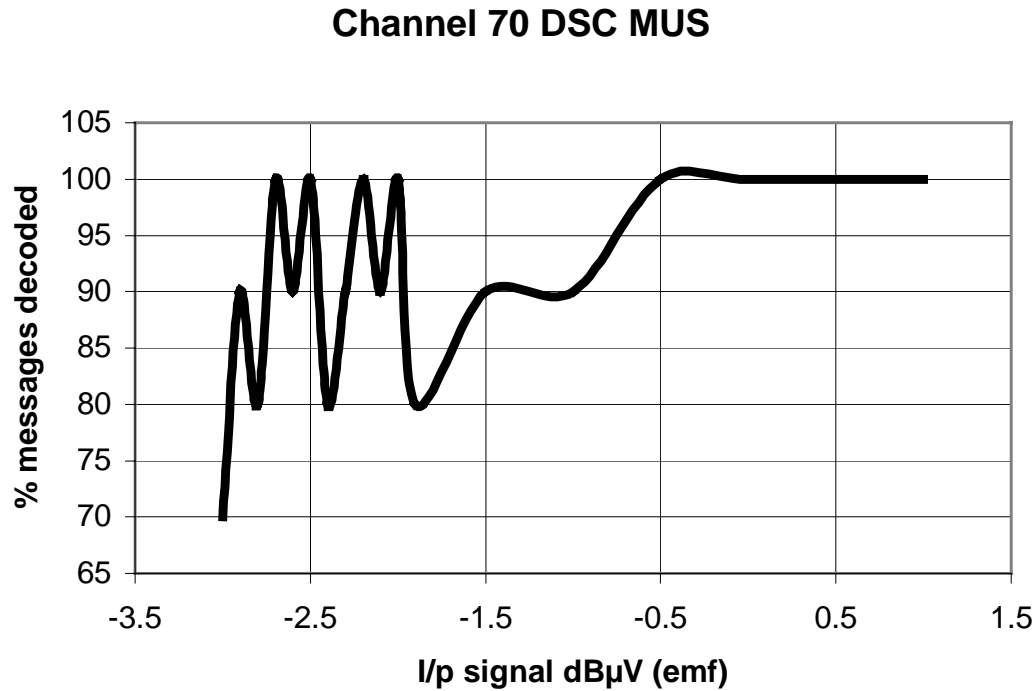
Wanted signal = MUS = -4.6dB μ V emf for 20dB SINAD.

(Test h)

Intermodulating frequencies (f_2 modulated 400Hz ± 3 kHz deviation)		unwanted signal level at Rx input required to degrade SINAD to 14dB (dB μ V emf)	Intermod response UW-W (dB)
f_1 (MHz)	f_2 (MHz)		
80.4	4.0	81.0	85.6
90.4	24.0	79.0	83.6
100.4	44.0	79.5	84.1
110.4	64.0	79.5	84.1
120.4	84.0	79.5	84.1
130.4	104.0	79.5	84.1
140.4	124.0	79.5	84.1
150.4	144.0	79.5	84.1
160.4	164.0	80.0	84.6
170.4	184.0	79.5	84.1
180.4	204.0	80.0	84.6
190.4	224.0	80.5	85.1
200.4	244.0	80.5	85.1
210.4	264.0	82.0	86.6
220.4	284.0	82.5	87.1
230.4	304.0	84.0	88.6
240.4	324.0	84.0	89.6
250.4	344.0	86.0	90.6
260.4	364.0	88.0	92.6
270.4	384.0	88.0	92.6
280.4	404.0	88.0	92.6
290.4	424.0	86.0	90.6
300.4	444.0	85.0	89.6
310.4	464.0	84.5	89.1
320.4	484.0	82.5	87.1
330.4	504.0	82.5	87.1

Graph 1 - DSC MUS

ANNEX B (cont')



Rx I/p on channel 70 (dBµV emf)	% messages decoded
-3.0	70
-2.9	90
-2.8	80
-2.7	100
-2.6	90
-2.5	100
-2.4	80
-2.3	90
-2.2	100
-2.1	90
-2.0	100
-1.9	80
-1.5	90
-1.0	90
-0.5	100
0.0	100
1.0	100

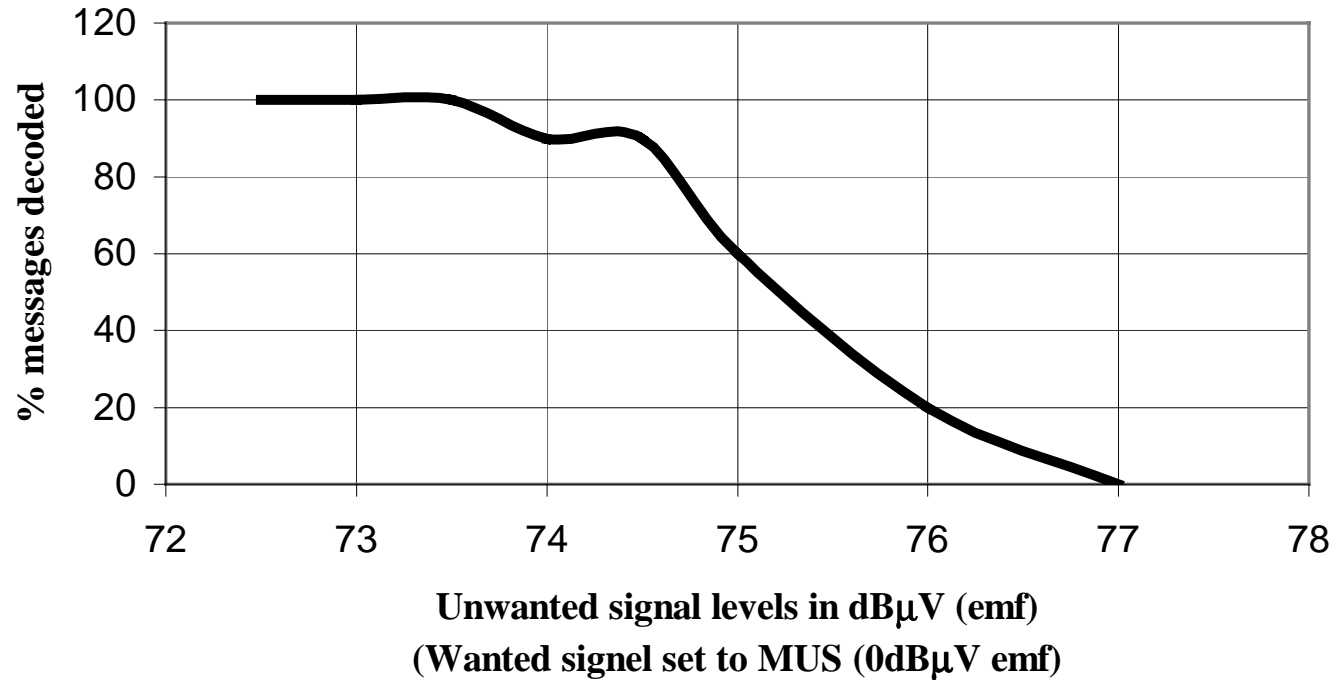
Important note: There was no DSC signal generator available for this test.

In order to measure the channel 70 MUS, it was necessary to generate a DSC distress message on the arbitrary waveform generator and phase modulate an RF signal generator with the AFSK output, in accordance with the specified requirements contained in publication ITU-R M.493-9 for VHF equipment. In the absence of a bit error rate test facility, the criteria for determining MUS was taken as the threshold of satisfactory DSC decoding by receiver 'A'. This was defined as the lowest signal level giving 100% successful decoding of a DSC message, with a sample size of ten messages.

Graph 2 - DSC intermodulation response using 50/100kHz offsets

ANNEX B (cont')

Channel 70 DSC intermodulation response



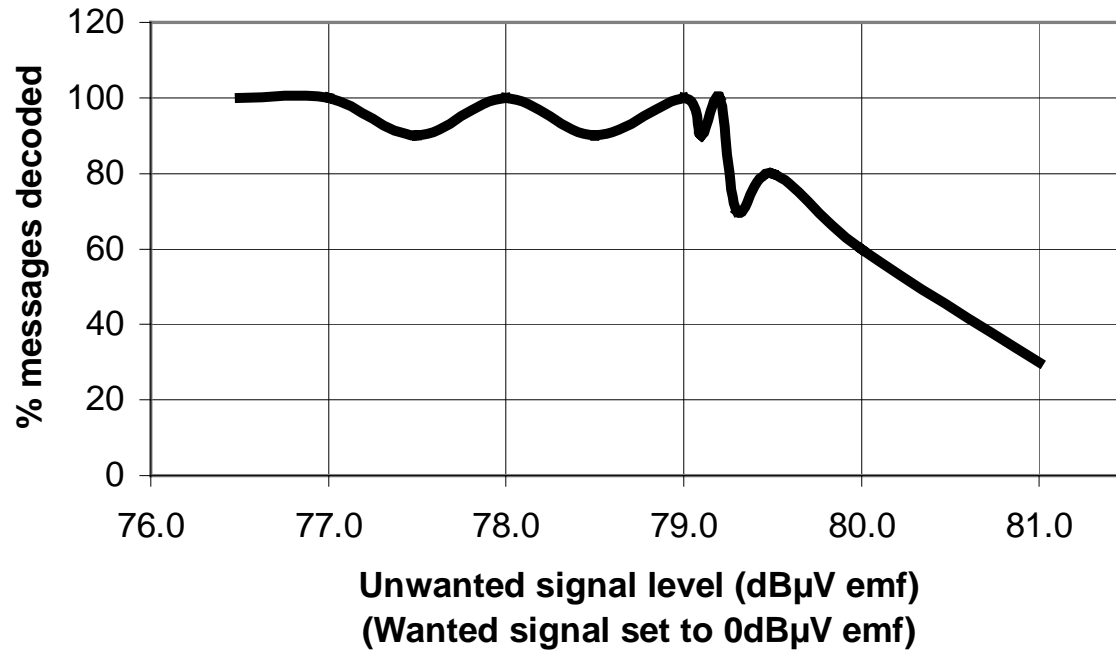
Unwanted signals (dBµV emf)	% messages decoded
77.0	0
76.0	20
75.0	60
74.5	90
74.0	90
73.5	100
73.0	100
72.5	100

Important note: There was no DSC signal generator available for this test.

The wanted signal was provided in the same way as for the the MUS test. The criteria for determining the intermodulation response was taken as the threshold of satisfactory DSC decoding. This was defined as the highest level of unwanted signal allowing 100% successful decoding of a DSC message, with a sample size of ten messages.

Graph 3 - DSC intermod response with out of band test frequencies 154.9125 & 153.300 MHz

Channel 70 DSC intermodulation response



Unwanted signal level (dBµV emf)	% messages decoded
81.0	30
80.0	60
79.5	80
79.3	70
79.2	100
79.1	90
79.0	100
78.5	90
78.0	100
77.5	90
77.0	100
76.5	100

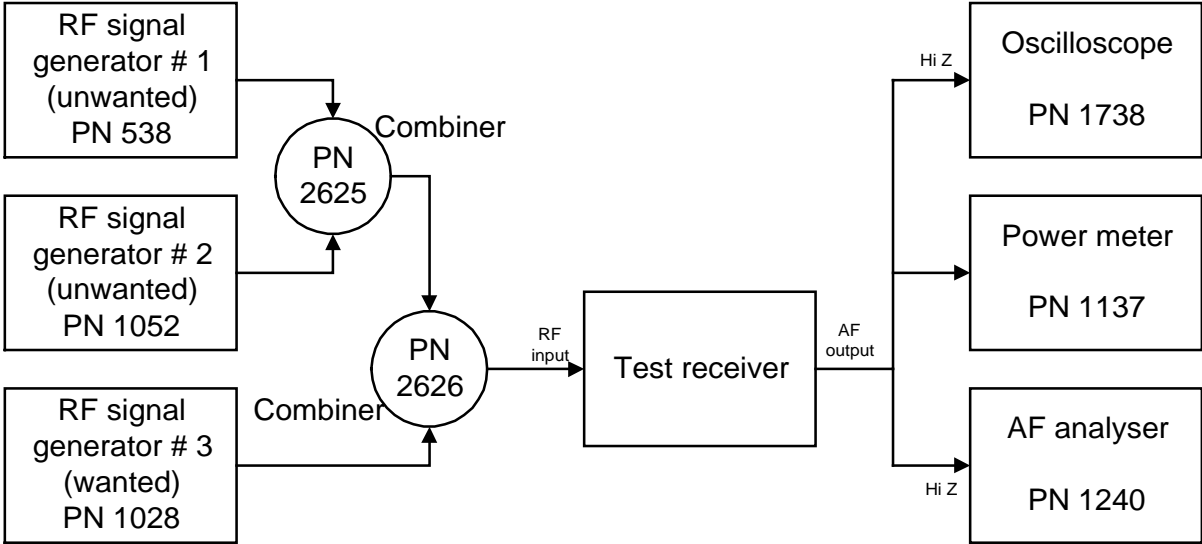
Important note: There was no DSC signal generator available for this test.

The wanted signal was provided in the same way as for the the MUS test. The criteria for determining the intermodulation response was taken as the threshold of satisfactory DSC decoding. This was defined as the highest level of unwanted signal allowing 100% successful decoding of a DSC message, with a sample size of ten messages.

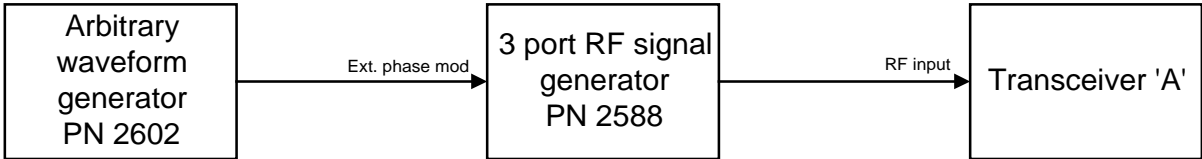
List of test equipment used

Equipment	Model	Plant No.
Marconi RF signal generator	2019A	1028
Marconi RF signal generator	2017	538
Marconi RF signal generator	2017	1052
Marconi 3 port RF signal generator	2026	2588
Farnell AF power meter	2085	1137
HP AF analyser	8903B	1240
Suhner resistive combiner	4901.01.A	2625
Suhner resistive combiner	4901.01.A	2626
Farnell DC power supply	AP60/50	1150
Gould oscilloscope	OS3350	1609
HP precision attenuator (10dB)	8491B-010	914
HP spectrum analyser	8591A	1826
Philips digital multimeter	2521	1529
HP Arbitrary waveform generator	33120A	2602

Test setup for ETS 300 162 measurements



Test setup for DSC assessment



ANNEX E

Measurement Uncertainty

- 1.0 Measurement uncertainties for the listed tests carried out in accordance with ETS 300 162 have been estimated using methods based on ETR 028 and are as follows:

$$\text{MUS} = +2.6\text{dB} / -3.0\text{dB}$$

$$\text{Blocking} = +2.3 / -2.8\text{dB}$$

$$\text{Spurious response (image)} = +2.3\text{dB} / -2.8\text{dB}$$

$$\text{Intermodulation Response} = +2.5\text{dB} / -2.8\text{dB}$$

The reported uncertainty is based upon a standard uncertainty multiplied by a coverage factor $k = 1.96$ which provides a confidence level of 95%.

- 2.0 Due mainly to the time factor involved in deriving a suitable test setup for the DSC measurements, it was not possible to provide an estimation of measurement uncertainty for DSC results in time for the compilation of this report. However, the main contributory factor is likely to be the level uncertainty for the three port RF signal generator which is specified at $\pm 1\text{dB}$.

Radio Technology & Compatibility Group

**SIMULATION OF DIGITAL SELECTIVE
CALLING (DSC) SIGNAL USING HP
FASS**

RA2/SPE

Project No. 487 – Annex 1

May 1999

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1.0 Background

RTCG was asked, by RA2/SPE, to carry out a series of intermodulation response measurements on a number of maritime radiotelephone receivers, six current and one new generation, in accordance with the test procedure detailed in ETS 300 162.

The intermodulation tests were to be repeated on Digital Selective Calling (DSC) channel 70 (156.525MHz).

As no DSC signal generator was available, it was necessary for RTCG to develop a DSC signal in accordance with ITU-R Recommendation M.493-9 [1]. Two methods were put forward:

Generate a DSC distress message using an Arbitrary Waveform Generator (AWG) and use it's output to phase modulate an RF signal generator.

Simulate a DSC signal using RTCG's Frequency Agile Signal Simulator (FASS).

This report describes how the DSC signal was generated using RTCG's FASS system.

The main body of work carried out under this project is covered by RTCG project report 487 [2].

2.0 DSC system

Within the maritime-mobile service, DSC equipment is used for calling ships and coast stations and includes calls for distress and safety purposes.

A DSC 'distress call' provides for alerting, self-identification, ship's position including time, nature of distress and contains both the distress call and the distress message, as defined in the Radio Regulations.

The system is synchronous and uses characters composed from a ten bit error-detecting code as listed in table 1, ITU-R Recommendation M.493-9 [1].

VHF channels utilise frequency modulation with a pre-emphasis of 6dB/octave (phase modulation) and a modulation index of 2.0. The frequency shifts between 1300Hz and 2100Hz (sub carrier = 1700Hz) at a baud rate of 1200Bd.

A full description of DSC equipment technical characteristics can be found in ITU-R recommendation M.493-9 [1].

3.0 Method

3.1 Signal generation

3.1.1 Program structure

FASS waveforms are created by manipulating arrays of data in the working wave. This data can be created in either the time-domain or the frequency-domain. All waveform timing and ensuing calculations are based on a specified sample clock rate. The default clock rate for Waveform Generation Language (WGL) calculations is 2^{27} Hz, which results in a time resolution of 7.45ns per waveform element.

The number of elements used for the working wave (or array) is usually referred to as its context.

Each WGL program is forged from a number of sub-routines, which carry out sets of related functions. The main program structure for this simulation is given below:

- ♣ Initialise system:
 - ◆ Reset FASS
 - ◆ Set internal clock
 - ◆ Set RF carrier/attenuation/domain/angular movement

- ♣ Generate data stream:
 - ◆ Set context lengths
 - ◆ Get distress message from disk

- ♣ Generate AF tones & modulation:
 - ◆ Integrate and scale phase for correct angular movement
 - ◆ Take sine response to produce AF tones
 - ◆ Set pre-emphasis level
 - ◆ Set deviation level

- ♣ Initialise sequencers:
 - ◆ Activate FM (frequency) memory and download data
 - ◆ Set scan routine
 - ◆ Set address rate divider
 - ◆ Activate FASS

The complete WGL program listing for this simulation can be found in appendix 1.

3.1.2 Data stream

A DSC distress message, 720 bits long, was constructed in accordance with ITU-R recommendation M.493-9 [1]. Mathcad software converted the resulting ASCII file into vector format enabling the FASS to read in the data directly from disk.

In order to achieve the correct baud rate, it was necessary to slow down the rate at which the FASS accesses the FM memory. The internal clock rate of the FASS is 2^{27} Hz. However, the FM memory accesses data at $\frac{1}{4}$ this rate (2^{25} Hz).

The memory divisor was calculated from the following formula:

$$\begin{aligned} \text{Memory_divisor} &= (\text{Low_ctx} * \text{Clock_rate}) / (\text{Hgh_ctx} * \text{Baud_rate}) \\ &= (720 * 2^{25}) / (65536 * 1200) = 307.2 \approx \mathbf{307} \end{aligned}$$

This value was used to derive the time resolution of each waveform element:

$$\text{Element_time} = \text{Memory_divisor} / \text{Clock_rate} = 307 / 2^{25} = 9.149 \mu\text{s}$$

The original block of data (of array length Low_ctx) is stretched over a defined number of elements (of array length Hgh_ctx) to ensure accurate timing.

The distress message used for this simulation can be found in appendix II.

♥ *This value must be an integer.*

3.1.3 AF tones

The DSC distress message was converted into two discrete AF tones (1300Hz = 1, 2100Hz = 0) in the following manner.

The periodic time of each AF tone is given below:

$$\text{Period}_{1300} = 1300^{-1} = 769.231 \mu\text{s}$$

$$\text{Period}_{2100} = 2100^{-1} = 476.190 \mu\text{s}$$

These values were used to derive the number of waveform elements required by one cycle of each AF tone:

$$\begin{aligned} \text{Elements}_{1300} &= \text{Period}_{1300} / \text{Element_time} = 769.231 * 10^{-6} / 9.149 * 10^{-6} = 84.078 \\ &\approx \mathbf{84} \end{aligned}$$

$$\begin{aligned} \text{Elements}_{2100} &= \text{Period}_{2100} / \text{Element_time} = 476.190 * 10^{-6} / 9.149 * 10^{-6} = 52.048 \\ &\approx \mathbf{52} \end{aligned}$$

Hence, the 1300Hz tone shifts through 360° every 84 elements and the 2100Hz tone shifts through 360° every 52 elements.

In order to give the correct angular movement, the data stream was appropriately scaled, integrated to give a continuous phase change characteristic and multiplied by the correct phase change coefficient:

$$\text{Scale_factor} = 2100/1300 = \mathbf{1.6154}$$

$$\text{Phase_change}_{1300} = 360/\text{Elements}_{1300} = 360/84 = \mathbf{4.2857}$$

$$\text{Phase_change}_{2100} = 360/\text{Elements}_{2100} = 360/52 = 6.9231$$

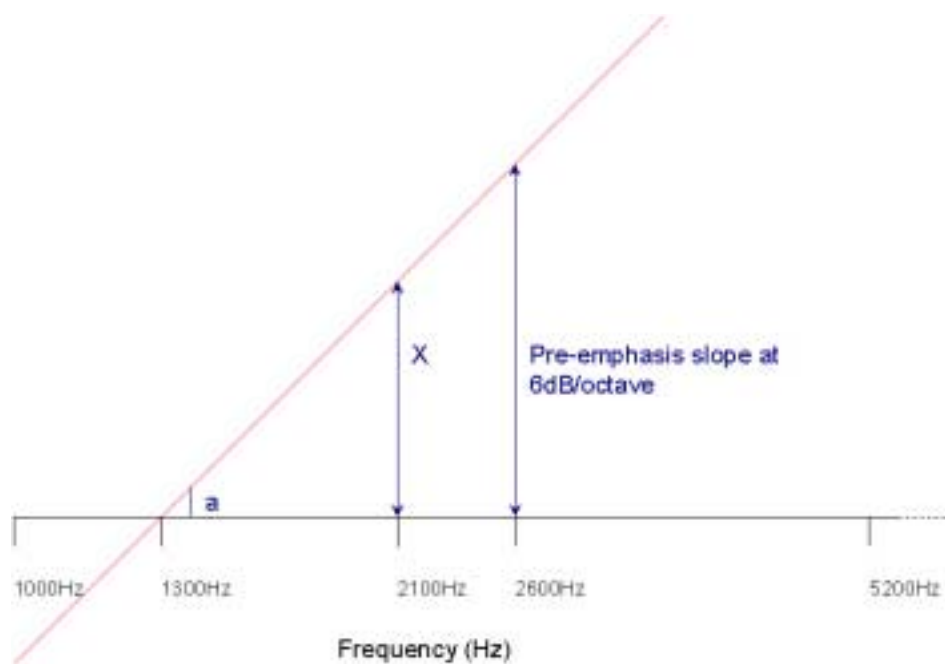
or

$$\begin{aligned} \text{Phase_change}_{2100} &= \text{Phase_change}_{1300} * \text{Scale_factor} = 4.2857 * 1.6154 \\ &= 6.9231 \end{aligned}$$

♥ *These values must be integers.*

3.1.4 Pre-emphasis

As the modulating waveform consisted of two discrete AF tones, pre-emphasis was easily applied in the time-domain.



To determine length 'X':

Linearise frequency values:

$$\text{Log}_{10}(1300) = 3.114$$

$$\text{Log}_{10}(2100) = 3.322$$

$$\text{Log}_{10}(2600) = 3.415$$

Calculate new axis lengths:

$$1300\text{Hz to }2600\text{Hz} = 3.415 - 3.114 = 0.301$$

$$1300\text{Hz to }2100\text{Hz} = 3.322 - 3.114 = 0.208$$

Calculate 'X_{dB}' using basic trigonometry:

$$a = \text{Tan}^{-1}(6/0.301) = 87.13^\circ$$

$$X_{dB} = 0.208 * \text{Tan}(87.13) = 4.15\text{dB}$$

$$\therefore X = 10^{(4.15/20)} \approx 1.6$$

Hence, the 2100Hz tone required further amplitude scaling, by 1.6, in order to achieve phase modulation.

3.1.5 Modulation

The peak frequency deviation was calculated as follows:

$$\begin{aligned} \text{Frequency_deviation} &= \text{Modulation_index} * \text{Modulating_frequency} = 2 * 2100 \\ &= 4200\text{Hz} \end{aligned}$$

♣ *Assumption: The modulation index is referenced against the highest modulating frequency.*

3.2 DSC signal verification

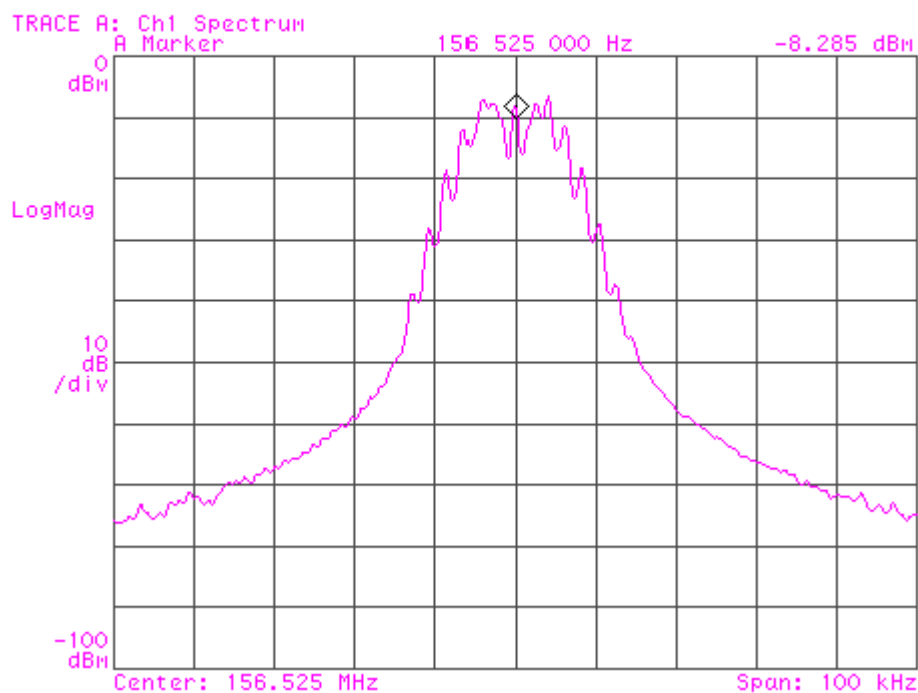
A vector signal analyser was used to demodulate the resulting DSC signal simulation and verify that the modulation scheme had been implemented correctly.

The following plots show RF spectrum and phase demodulated output:

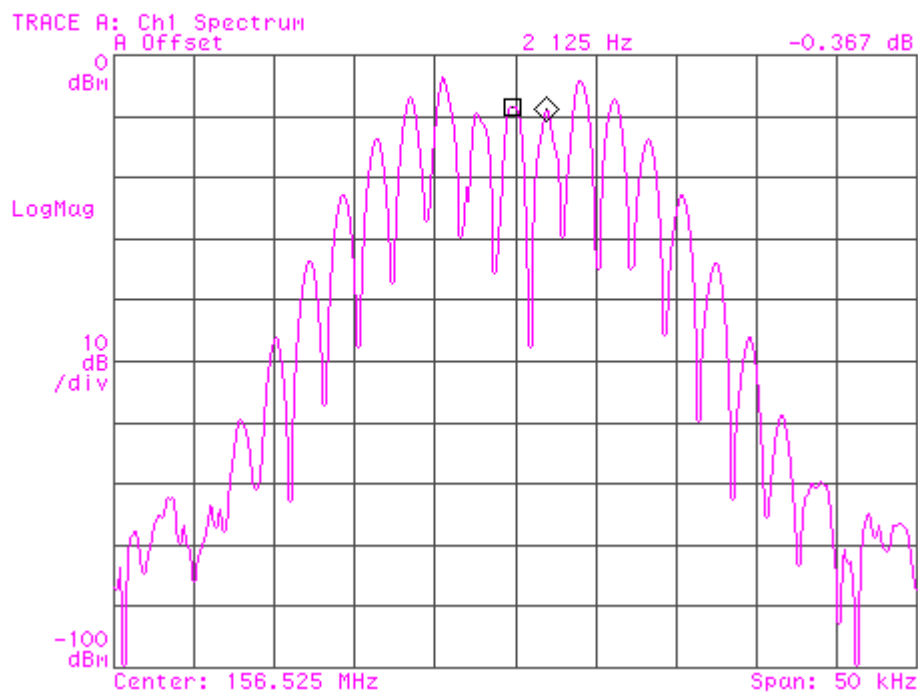
The first RF spectrum plot has been averaged over 10 traces. The second RF spectrum plot has captured a '0' data bit being sent.

The phase demodulated output plot has a constant amplitude envelope, proving that pre-emphasis has been accurately applied. The time-markers encompass periods of 762μs and 480μs, resulting in frequencies of 1312Hz and 2083Hz respectively. The slight deviation from the required values is due to the display resolution of the analyser.

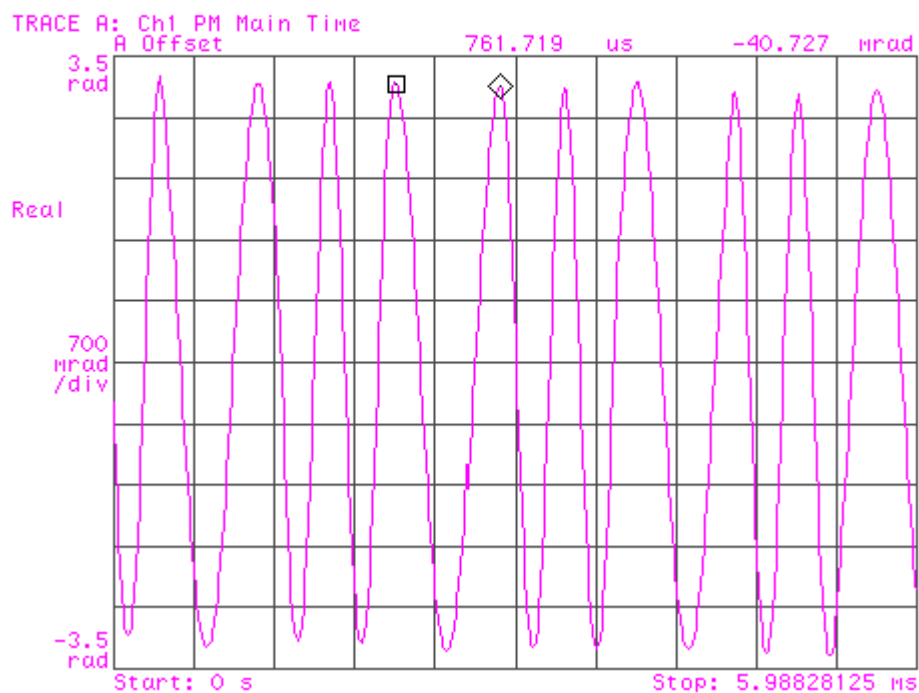
Date: 05-26-99 Time: 12:12 AM



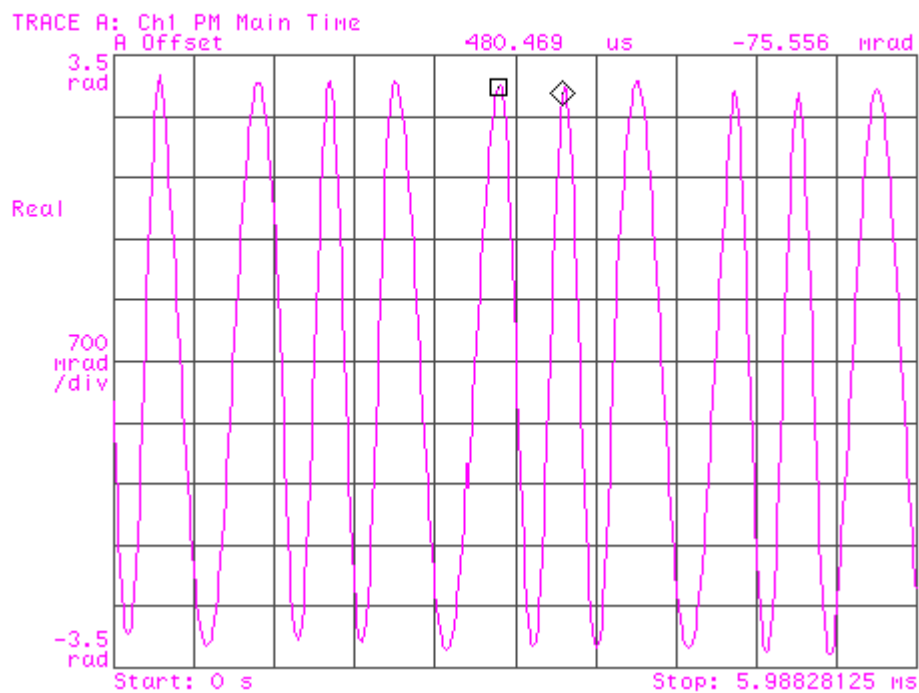
Date: 05-26-99 Time: 12:11 AM



Date: 05-26-99 Time: 12:26 AM



Date: 05-26-99 Time: 12:26 AM



4.0 Conclusions

The AWG/RF signal generator method of generating the DSC signal was completed before the FASS based version and was, therefore, used for the purpose of the test.

The integrity of the FASS based DSC signal simulation was further verified by applying the signal to a suitable receiver, which successfully decoded the distress message. When the message was purposely corrupted, the signal was not decoded.

The WGL program was set-up to loop continuously. This, could be modified to send burst messages of any desired/random message-space duration by altering the sequencing procedure. Transmission on multiple frequencies is possible, in the case of MF/HF transmissions. It would also be possible to alter the distress message, or send a number of different messages, without significantly affecting the program structure. Hence, the FASS based method of generating DSC signals ultimately offers greater flexibility over other generation methods.

In simulations where waveform timing is of utmost importance an external clock should be employed to enhance accuracy.

5.0 References

1. International Telecommunications Union (1997) *Recommendation ITU-R M.493-9 Digital Selective-Calling system for use in the Maritime Mobile Service*, Geneva, International Telecommunications Union Radiocommunications Bureau.
2. Radio Technology & Compatibility Group (1999) *Investigation into the intermodulation response characteristics of a range of current maritime transceivers*, UK, Radiocommunications Agency

Appendix I

WGL program listing

```

DEFINE DSC                                     {Digital Selective Calling signal simulation}
INIT_SYS
LOAD_DAT
AF_LEVELS
INIT_SEQ
END {DSC}

DEFINE INIT_SYS
SYSRESET                                     {Reset FASS to default state}
TDOMAIN                                     {Set domain to time}
DEG                                         {Set angular movement to degrees}
"10" $ ATTENUATE                            {Set output attenuator (10dB)}
2 25 POW CLOCK                              {Set internal clock (33.5544MHz)}
"0;65536;156.525E6" $ LDFREQ                {Set carrier frequency (156.525MHz)}
END {INIT_SYS}

DEFINE LOAD_DAT
720 STORE LOW_CTX                           {Store low context variable}
65536 STORE HGH_CTX                         {Store high context variable}
1 BIT_STREAM                               {Generate DSC data stream}
STORE A                                     {Store data}
DISP                                       {Display data}
END {LOAD_DAT}

DEFINE AF_LEVELS
NEG 1+ STORE B 1.6154* A+                  {Scale data (AF tones)}
SUM 4.2857*                                {Integrate and scale phase for correct angular movement}
SIN                                         {Take sine response to give AF tones (1300Hz & 2100Hz)}
STORE C                                    {Store data}
B? 1.6* A+                                 {Set pre-emphasis factor}
C*                                         {Scale data (apply pre-emphasis factor)}
STORE C                                    {Store data}
4.2E3*                                     {Scale data (pk frequency deviation)}
DISP                                       {Display data}
END {AF_LEVELS}

DEFINE INIT_SEQ
FM_MEM                                     {Activate FM memory}
"FMWAVE;1" $ DOWNLOAD                       {Download data}
"0;-1" $ SEQBEG                            {Begin sequence}
"1;AUTO;YES" $ LPACK                       {Define loop packet}
"FMWAVE;1;AUTO;OFF" $ PACKET              {Define regular packet}
SEQEND                                     {End sequence}
"307" $ MEMCLOCK                           {Set address rate divider}
GO                                         {Activate sequencers}
END {INIT_SEQ}

DEFINE BIT_STREAM
STORE AMP_FAC                              {Store amplitude multiplication factor variable}
HGH_CTX CTX                               {Set context to HGH_CTX points}
0 LOAD                                     {Clear working wave}
LOW_CTX CTX                               {Set context to LOW_CTX points}
"A:\Data.txt" $ GET                        {Get distress message from disk}

```

HGH_CTX CTX
LOW_CTX EXPAND2
END {BIT_STREAM}

{Set context to HGH_CTX points
{Stretch data (HGH_CTX / LOW_CTX (points per bit))

