Test report for F.C.C type acceptance of PAE transceiver 5525-D8 MODE 2

Part 87 Aeronautical Services

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Revision History

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AFFIDAVIT

The technical data in this report has been accumulated through tests that were performed by me or by engineers under my direction. To the best of my knowledge all the data submitted is true and correct.

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PRINCIPAL ENGINEER

CONTENTS

1. INTRODUCTION

This report covers the additional tests performed on the PAE 5525-D8 Digital Multimode Transceiver (Mod state M).
This equipment, which covers the VHF aeronautical band of 118 MHz to 136.975 MHz with 25 kHz channel spacing, provides communications employing AM MSK and D8PSK modulation modes. The differential eight phase shift keying modulation provides a 31.5 kb data link.

2. HISTORY

The original PAE5525-D8 only allowed the MSK (13k0A2D) modulation mode for data, but by minor improvements to the circuitry and an upgrade to the software, the equipment is now compatible with both modes and offers improved communications speed whilst continuing to meet ICAO Annex 10 and SARP's requirements.
The existing 5525-D8 is now approved for use in 16 countries throughout the world and further approvals are actively being sought. With the incorporation of the SARP's requirements for VDL in ICAO Annex 10, Park Air is now seeking to amend these approvals to include the 14K0G1DE emission (Mode 2 D8PSK).

3. RELATED DOCUMENTS

[1] '5525D8 FCC Test report C8L5525-D8

[2] CETECOM ICT Services test report 2-0031-A/98 (5525-D8 German type approval report)

4. EXISTING APPROVALS

(Approved for AM MSK operation)

COUNTRY	APPROVAL NUMBER / REFERENCE
America	C8L5525-D8
Austria	GZ 103 694-ZB/98
Belgium	WDM/98-1442
China	99-14-006
Denmark	Notified (ICAO/ITU requirements only)
Finland	F198240001
Germany	D800606K
Hong Kong	RF 299072
Iceland	IS-3144-00
Italy	DGPGF/4/2/144-02/334468
Latvia	LGS-3-1
Malaysia	Granted
Norway	97/10100-621.1
Singapore	PMREQ-VHLM-F-0994-98
Sweden	Ue970142
Switzerland	98.0715.F.P

5. TEST EQUIPMENT

Description	Type	Serial \ Prod Number
Environmental Chamber	Montford Instruments	DEV 202
Spectrum Analyser	Hewlett-Packard HP8560A	DEV 163
Network Analyser	Hewlett-Packard HP4195A	DEV 137
Vector Signal Analyser	Hewlett-Packard HP89410A / HP89430A	DEV 212/213
AC Analyser	Voltech AC Power Analyser PM 1200	DEV 196
Modulation Analyser	Hewlett-Packard HP8901B	DEV 226
Frequency Counter	Racal Instruments 9915	DEV 13
Oscilloscope	Tektronix TDS 220	DEV 222
Forward / Reverse Power Meter	Rohde & Schwarz NAP	DEV 182 / 183
r.m.s. Volts / Distortion meter	NF Electronic Instruments	PROD 152
Multi-Meter	Fluke 75	DEV 141
RF Signal Generator	Hewlett-Packard HP8644A	DEV 206
RF Signal Generator	Marconi 2030	DEV 185
Vector RF Signal Generator	Marconi 2050	DEV 211
D8PSK Test Radio	Radio consists of only the following:- DSP Board 68-5525D810 PSU Board 68-5525D813	 s/no.0121 s/no.A005
Audio Signal Generator	Gould Advance J3B	DEV 45
Function Generator	Wavetek Model 180	DEV 36
VSWR Test Jig	Adjustable load on slider	none
Adjustable Transformer (Variac)	Regavolt	none
Forward Power Time Domain Test Jig	Forward Power Test Jig (in-house build)	PDS - 04
Power RF Attenuator	Tenuline 8323	PROD 394

6. EQUIPMENT CONFIGURATION

Module Title	Hardware		
	Part Number	Type	Serial Number
VDR 5525-D8 Digital Multimode Transceiver consisting of:-			
Power Amplifier	68-5525D815	I	0230
Receive RF	68-5525D812	J	0230
Power Amplifier Control	68-5525D811	C	0237
PSU Regulators	68-5525D813	C	0234
Power Supply	68-5525D814	B	0206
DSP Board	68-5525D816	A	0361

Equipment configuration cont...

Firmware	
Part Number	Type
DSP Board contains:-	
5525-D8 BOOT S0248 V0021 20/8/98.1434	Boot Code
5525-D8 FLASH S0267 V0026 15/10/98.1214	Flash Code
5525-D8 FILL_MODE10 S0257 V0013 15/10/98.1215	Mode AM MSK
5525-D8 FILL_MODE2 S0242 V0031 15/10/98.1213	Mode 2 Code

7. TESTS

7.1 Transmitter

7.1.1 Transmitter Carrier Power Output

SPEC: 25W carrier in DSBAM AM-MSK mode
average power random data in D8PSK mode

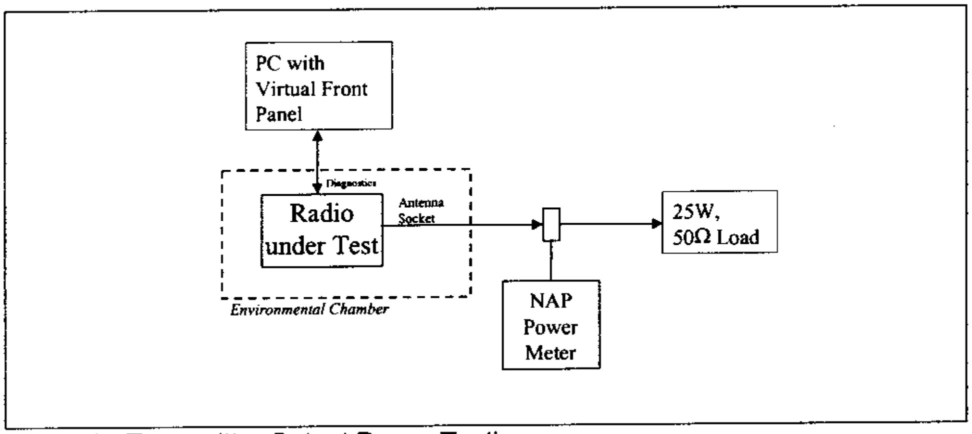

Figure 1 - Transmitter Output Power Testing

Carrier Power Variation
SPEC: -0.5 dB / +1.0 dB over frequency and temperature range

METHOD: Place the radio in the environmental chamber with the temperature initially set to -20°C and leave for 20 minutes.

The transmitter is set to AM mode with no modulation and the transmitter power set to be 25 W. The carrier power is measured for each of the frequencies given in the table below. The transmitter is then set to D8PSK with random data and the average power is measured for each of the same frequencies.

This process is repeated across the temperature range

	Power at -20°C		**Power at +25°C**		**Power at +55°C**	
Test Frequency	**AM**	**D8PSK**	**AM**	**D8PSK**	**AM**	**D8PSK**
118 MHz	43.9	43.8	43.8	43.7	44.0	43.9
126 MHz	43.9	43.8	43.8	43.7	44.0	44.0
136.975	43.8	43.7	43.7	43.6	43.9	43.9

All levels in dBm

7.1.2 Adjacent channel power (see ICAO Annex 10 / SARP's)

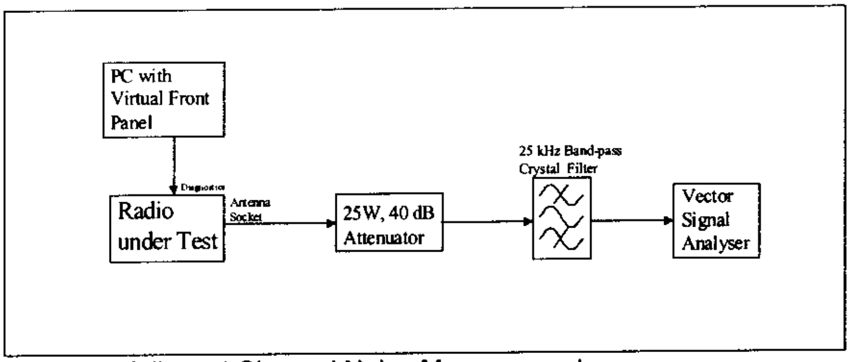

Figure 2 - Adjacent Channel Noise Measurement

SPEC: 1st adjacent channel ≤ 0 dBm over 25 kHz bandwidth
≤ -20 dBm over 16 kHz bandwidth
2nd adjacent channel ≤ -25 dBm over 25 kHz bandwidth
Others reducing at 5 dB/octave to -52 dBm

METHOD: Connect the radio to the test equipment as shown in figure 2.

Set the radio to transmit a carrier with a frequency that is 25 kHz below the crystal filter's centre frequency. Set the radio to D8PSK mode with scrambling enabled. Set the vector signal analyser to trigger on IF power level at the crystal filter frequency and enable band power measurement. Command the radio to transmit a sequence of 10,000 ASCII character '1's. Measure the average transmitted power in a 16 kHz bandwidth, then using the combined loss of the cables, attenuator and filter, calculate the power at the radio's antenna port. Repeat this measurement with a 25 kHz bandwidth. Set the radio's carrier frequency to exactly 25 kHz above the crystal filter's centre frequency and repeat the two band power measurements. Retune the radio to each of the frequencies, in turn, given in the table below and measure the 25 kHz band power and record.

RESULTS:

Radio Carrier Frequency	**Channel**	**Specified 16 kHz Band Power Level**	**Measured 16 kHz Band Power Level**
Filter frequency - 25 kHz	Lower 1st adjacent	≤ -20 dBm	-27 dBm
Filter frequency + 25 kHz	Upper 1st adjacent		-22 dBm
Radio Carrier Frequency	**Channel**	**Specified 25 kHz Band Power Level**	**Measured 25 kHz Band Power Level**
Filter frequency - 25 kHz	Lower 1st adjacent	≤ 0 dBm	-23 dBm
Filter frequency + 25 kHz	Upper 1st adjacent		-18 dBm
Filter frequency - 50 kHz	Lower 2nd adjacent	≤ -25 dBm	-32 dBm
Filter frequency + 50 kHz	Upper 2nd adjacent		-31 dBm
Filter frequency - 100 kHz	Lower 4th adjacent	≤ -30 dBm	-35 dBm
Filter frequency + 100 kHz	Upper 4th adjacent		-38 dBm
Filter frequency - 200 kHz	Lower 8th adjacent	≤ -35 dBm	-38 dBm
Filter frequency + 200 kHz	Upper 8th adjacent		-37 dBm
Filter frequency - 400 kHz	Lower 16th adjacent	≤ -40 dBm	-49 dBm

Radio Carrier Frequency	Channel	Specified 16 kHz Band Power Level	Measured 16 kHz Band Power Level
Filter frequency + 400 kHz	Upper 16th adjacent		-49 dBm
Filter frequency - 800 kHz	Lower 32nd adjacent	≤ -45 dBm	-50 dBm
Filter frequency + 800 kHz	Upper 32nd adjacent		-52 dBm
Filter frequency - 1.6 MHz	Lower 64th adjacent	≤ -50 dBm	-52 dBm
Filter frequency + 1.6 MHz	Upper 64th adjacent		-52 dBm
Filter frequency - 3.2 MHz	Lower 128th adjacent	≤ -52 dBm	-56 dBm
Filter frequency + 3.2 MHz	Upper 128th adjacent		-56 dBm

7.1.3 Occupied Bandwidth

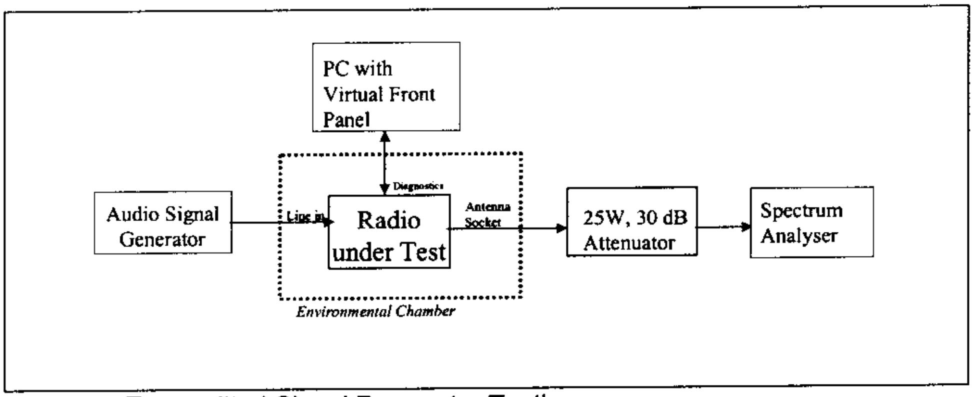

Figure 3 - Transmitted Signal Parameter Testing

SPEC: > 99% energy within ±12 kHz

METHOD: Set the radio to transmit 127.475 MHz AM. Set the spectrum analyser to a centre frequency of 127.475 MHz and span of 25kHz. Set the audio signal generator's level such that 90% modulation depth is produced. Slowly tune the audio signal generator's frequency from 10Hz to 10kHz whilst repeatedly executing the power bandwidth measurement on the spectrum analyser. Record the largest measured 99% power bandwidth and record the modulating frequency for which it occurred.

RESULTS:

Maximum 99% Power Bandwidth	**7.79 kHz**
Modulating Frequency	**3.79 kHz**

7.1.4 Differential Group Delay

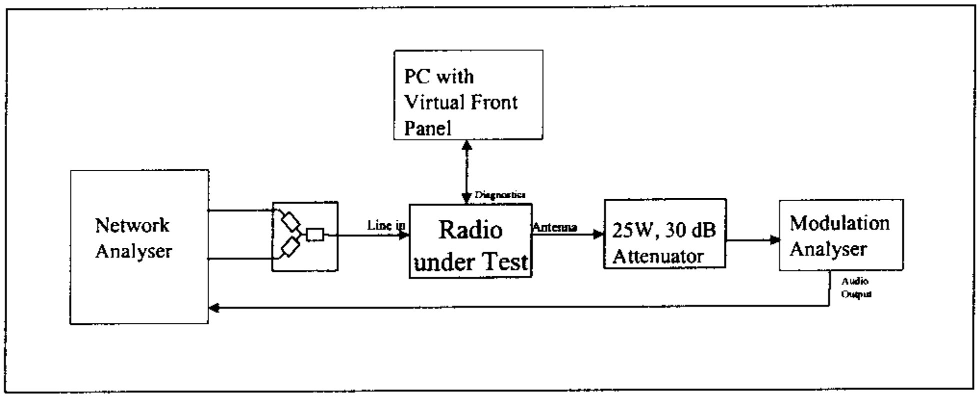

Figure 4 - Group Delay Measurement

SPEC: < 60 µs from 1.2 kHz to 2.4 kHz

METHOD: Set the radio to enable AM transmission with a carrier frequency of 118 MHz. Then set the network analyser to measure group delay for frequencies between 1.2 kHz and 2.4 kHz. Record the maximum and minimum group delays within the 1.2 kHz to 2.4 kHz range and ensure that the overall range of group delay is within 60 µs.

Repeat this test for carrier frequencies of 127.475 MHz and 136.975 MHz.

Carrier Frequency	Maximum Group Delay	Minimum Group Delay	Differential Group Delay
118 MHz	1.75704 ms	1.73158 ms	25.5 µs
127.475 MHz	1.75789 ms	1.73162 ms	26.27 µs
136.975 MHz	1.75430 ms	1.73021 ms	24.09 µs

7.1.5 Modulation Characteristics

Definition
SPEC: Differentially encoded 8 phase shift keying using raised cosine filtering with α=0.6. Refer to SARPS for full definition and phase mapping.

Formatting
SPEC: The transmitter shall compute the FEC, interleave, prepend the training sequence, carry out bit scrambling, and finally encode and modulate the RF signal. Refer to SARPS for full definition.

Modulation Rate
SPEC: 10,500 symbols/second ± 0.005%

R.M.S. Phase Error
SPEC: < 3 degrees at symbol centres

D8PSK transmission at 118 MHz with a scramble vector of 0x4D4B.

Set the vector signal analyser to 8PSK vector mode with a symbol capture length of 10.

Set the radio to repeatedly transmit a block of 100 ASCII '1' characters. The vector signal analyser should then be repeatedly capturing the initial 10 symbols shown by an identical vector diagram for each transmission. Set the analyser to phase error measurement and record the 10 phase errors of each symbol centre. Using the table below, record the square of each error, then sum the squared errors. Finally take the square root to yield the r.m.s. phase error.
Repeat this test at the frequencies shown in the tables below.

At 118 MHz Carrier Frequency

	At 25°C	
Symbol	**Phase Error**	**Phase Error^2**
0	-0.21°	0.044
1	-1.01°	1.02
2	-1.18°	1.392
3	-0.5°	0.25
4	-0.39°	0.152
5	-0.53°	0.281
6	0.81°	0.656
7	2.5°	6.25
8	0.99°	0.980
9	-0.28°	0.078
Mean Square		1.11
Root Mean Square		**1.05°**

At 127.475 MHz Carrier Frequency

	At 25°C	
Symbol	**Phase Error**	**Phase Error^2**
0	-0.16°	0.026
1	-0.33°	0.109
2	-0.44°	0.194
3	0.027°	0.001
4	-0.24°	0.058
5	-0.47°	0.221
6	0.42°	0.176
7	0.83°	0.689
8	0.14°	0.020
9	-0.36°	0.13
Mean Square		0.16
Root Mean Square		**0.4°**

At 136.975 MHz Carrier Frequency

	At 25°C	
Symbol	**Phase Error**	**Phase Error^2**
0	0.23°	0.053
1	0.28°	0.078
2	0.03°	0.001
3	-0.09°	0.008
4	-0.42°	0.176
5	-0.67°	0.449
6	-0. 36°	0.13
7	0.29°	0.084
8	0.005°	0
9	-0.71°	0.504
Mean Square		0.148
Root Mean Square		**0.38°**

Summary:

	r.m.s. Phase Error at carrier frequency:		
Temperature	**118 MHz**	**127.475 MHz**	**136.975 MHz**
25 °C	1.05°	0.40°	0.38°

7.1.6 Harmonic Outputs

SPEC: <-80 dBc

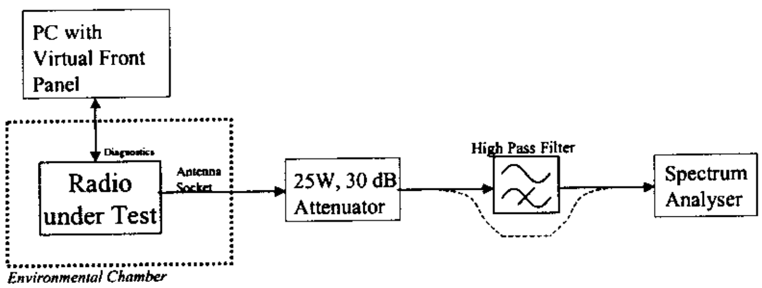

Figure 5 - Harmonic Testing

118 MHz Carrier	Fundamental	2nd Harmonic	3rd Harmonic	4th Harmonic	5th Harmonic	6th Harmonic	7th Harmonic
Power	+13 dBm	-75.5 dBm	-81.2 dBm	-128 dBm	-113 dBm	<-135 dBm	<-135 dBm
Filter Loss		<0.1 dB	<0.1 dB	<0.1 dB	<0.1 dB	<0.1 dB	<0.1 dB
Corrected		-75.5 dBm	-81.2 dBm	-128 dBm	-113 dBm	<-135 dBm	<-135 dBm
Rejection		**88.5 dBc**	**94.2 dBc**	**141 dBc**	**146 dBc**	**>148 dBc**	**>148 dBc**

127.475 MHz Carrier	Fundamental	2nd Harmonic	3rd Harmonic	4th Harmonic	5th Harmonic	6th Harmonic	7th Harmonic
Power	+13.2 dBm	-89.7 dBm	-82.3 dBm	-129 dBm	-120 dBm	<-135 dBm	<-135 dBm
Filter Loss		<0.1 dB	<0.1 dB	<0.1 dB	<0.1 dB	<0.1 dB	<0.1 dB
Corrected		-89.7 dBm	-82.3 dBm	-129 dBm	-120 dBm	<-135 dBm	<-135 dBm
Rejection		**102.9 dBc**	**95.5 dBc**	**142.2 dBc**	**133.2 dBc**	**>148.2dBc**	**>148.2dBc**

136.975 MHz Carrier	Fundamental	2nd Harmonic	3rd Harmonic	4th Harmonic	5th Harmonic	6th Harmonic	7th Harmonic
Power	+13 dBm	-94.3 dBm	86.8 dBm	<-135 dBm	-115 dBm	<-135 dBm	<-135 dBm
Filter Loss		<0.1 dB	<0.1 dB	<0.1 dB	<0.1 dB	<0.1 dB	<0.1 dB
Corrected		-94.3 dBm	86.8 dBm	<-135 dBm	-115 dBm	<-135 dBm	<-135 dBm
Rejection		**107.3 dBc**	**99.8 dBc**	**> 148 dBc**	**128 dBc**	**> 148 dBc**	**> 148 dBc**

7.2 Receiver

7.2.1 Antenna Radiation

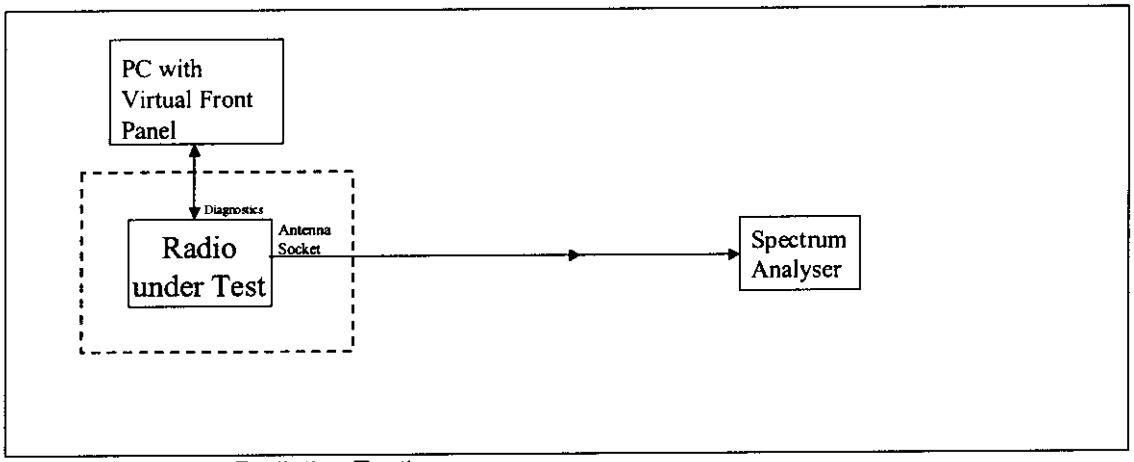

Figure 6 - Antenna Radiation Testing

SPEC: < -70dBm

	Antenna radiation
118 MHz	-72 dBm
127.475 MHz	-72.9 dBm
136.975 MHz	-73.9 dBm

7.2.2 Differential Group Delay

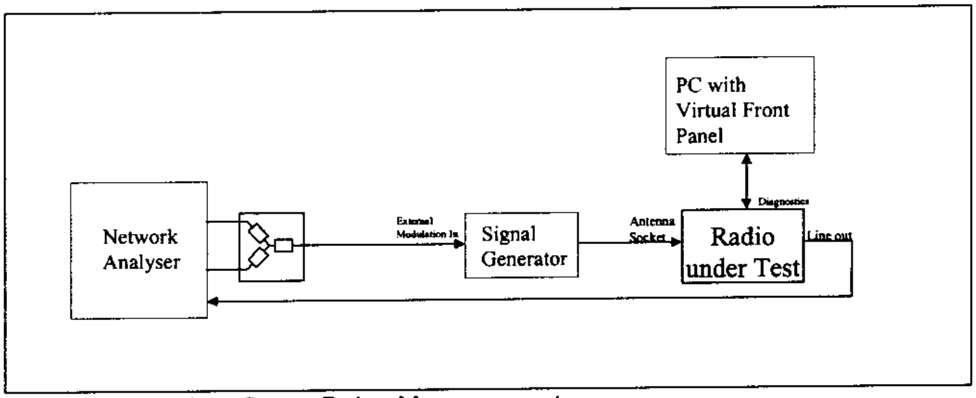

Figure 7 - Receiver Group Delay Measurement

SPEC: <60us from 1.2kHz to 2.4 kHz

METHOD: Set the signal generator to produce a carrier of 118 MHz at a power level of -50 dBm that is externally AM modulated. Connect the driving port of the network analyser to the AM modulating input on the signal generator. Connect the 'line out' output of the radio to the receive port of the network analyser. Measure the group delay across the frequency range of 1.2 kHz to 2.4 kHz.

Repeat this test at carrier frequencies of 127.475 MHz and 136.975 MHz.

RESULTS:

	Max Group Delay	Min. Group Delay	Deviation
118 MHz	4.0752 ms	4.048 ms	27.2 μs
127.475 MHz	4.0745 ms	4.048 ms	26.75 μs
136.975 MHz	4.0759 ms	4.048 ms	27.8 μs

7.2.3 Receiver RF Characteristics

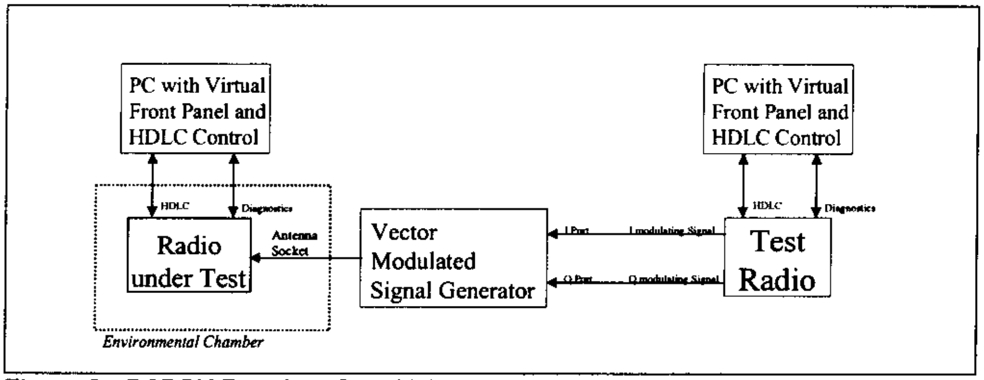

Figure 8 - D8PSK Receiver Sensitivity

SPEC: BER of $1*10^3$ for –100 dBm.

Sensitivity

METHOD: The 'test radio' shown in figure 8 is a VDR which has been modified such that the I and Q modulating signals from the digital signal processor board have been made available externally.

Set the signal generator to provide a carrier frequency of 118 MHz with external I/Q modulation enabled. Set the test radio to D8PSK mode with a 0x0000 scramble vector and disable the control application routine. Set the radio under test to enable D8PSK reception at 118 MHz with a scramble vector of 0x0000. Follow the procedure for measurement of bit error rate using the in-built routine in the radio under test. Repeatedly measure bit error rate (allowing at least 20 seconds for the bit errors to average to a stable value) whilst varying the signal generator carrier level. Record the minimum level at which a bit error rate of better than $1x10^{-3}$ results. Repeat this measurement at all the frequencies given in the table below.

The test radio, unfortunately, does not provide sufficiently large I/Q signal amplitudes to fully drive the vector inputs of the signal generator. This results in a lower than indicated output power from the signal generator. Therefore, once all measurements have been taken, connect the output of the signal generator to a spectrum analyser. Set the signal generator to each of the frequencies in the table below and measure the output power in a 25 kHz bandwidth at that frequency. Record the difference between the RF power indicated by the signal generator and that measured by the spectrum analyser. Apply this difference to all the previously recorded minimum levels.

Repeat these measurements at each of the temperatures given in the table below. Allow 20 minutes of stabilisation time before commencement.

Test Frequency	**Rx Level for BER = $1x10^3$ at -20°C**	**Rx Level for BER = $1x10^3$ at 0°C**	**Rx Level for BER = $1x10^3$ at +25°C**	**Rx Level for BER = $1x10^3$ at +40°C**	**Rx Level for BER = $1x10^3$ at +55°C**
118 MHz	-106.1 dBm	-105.7 dBm	-105.3 dBm	-105.1 dBm	-104.4 dBm
120 MHz	-106.1 dBm	-105.8 dBm	-105.4 dBm	-105.1 dBm	-104.5 dBm
122 MHz	-106.0 dBm	-105.5 dBm	-105.4 dBm	-105.0 dBm	-104.3 dBm
124 MHz	-106.0 dBm	-105.6 dBm	-105.2 dBm	-105.0 dBm	-104.3 dBm
126 MHz	-106.0 dBm	-105.3 dBm	-105.5 dBm	-105.1 dBm	-104.3 dBm
128 MHz	-105.7 dBm	-105.4 dBm	-105.1 dBm	-104.7 dBm	-104.1 dBm
130 MHz	-105.0 dBm	-105.5 dBm	-105.2 dBm	-104.6 dBm	-104.0 dBm
132 MHz	-105.6 dBm	-105.3 dBm	-105.1 dBm	-104.6 dBm	-104.0 dBm
134 MHz	-105.6 dBm	-105.4 dBm	-105.1 dBm	-104.7 dBm	-104.1 dBm
136 MHz	-105.3 dBm	-105.2 dBm	-105.1 dBm	-104.6 dBm	-104.1 dBm
136.975 MHz	-104.9 dBm	-104.8 dBm	-104.7 dBm	-104.2 dBm	-103.7 dBm

7.2.4 IF Characteristics

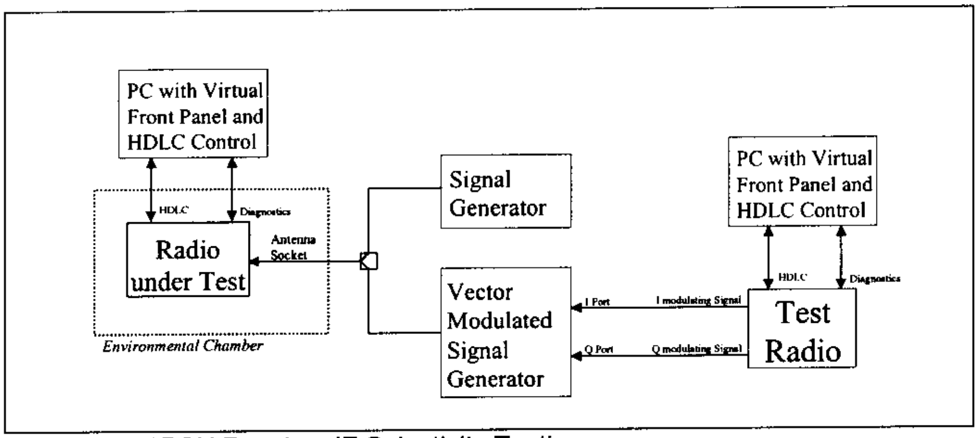

Figure 9 - D8PSK Receiver IF Selectivity Testing

Automatic Gain Control

SPEC: Range –103dBm to +10dBm

METHOD: Connect the radio to the test equipment as shown in figure 9. Set the radio to mode 2 with a carrier of 127.475 MHz carrier. Set the signal generator to a carrier frequency of 127.475 MHz and enable I/Q digital phase modulation.

Perform a bit error rate test with the carrier RF level of the signal generator set to those given in the table below. Record each bit error rate. Use the correction figures derived in the test of paragraph 5.4.3.1 to convert the RF level indicated by the signal generator into average signal power. Record these in the table below.

RESULTS:

Carrier Level	Correction from 7.2.3	Average Power	Measured Bit Error Rate
-110 dBm	-4.0 dB	-114 dBm	No signal
-105 dBm	-4.0 dB	-109 dBm	0.033
-100 dBm	-4.0 dB	-104 dBm	0.00035
-95 dBm	-4.0 dB	-99 dBm	$< 1x10^{-5}$
-80 dBm	-4.0 dB	-84 dBm	$< 1x10^{-5}$
-65 dBm	-4.0 dB	-69 dBm	$< 1x10^{-5}$
-50 dBm	-4.0 dB	-54 dBm	$< 1x10^{-5}$
-35 dBm	-4.0 dB	-39 dBm	$< 1x10^{-5}$
-20 dBm	-4.0 dB	-24 dBm	$< 1x10^{-5}$
-5 dBm	-4.0 dB	-9 dBm	$< 1x10^{-5}$
+10 dBm	-4.0 dB	+6 dBm	$< 1x10^{-5}$