

1.16 Quadrature Modulation

1.16.1 Test Case

1.16.1.1 Purpose

This test verifies requirements related to the Quadrature Modulation of the transmitter. This is a test of requirements allocated to both software and the equipment.

1.16.1.2 Setup/Initial Conditions

A Vector Analyzer shall serve as the primary test equipment. The Vector Analyzer shall be configured with the following settings:

INSTRUMENT MODE	Demodulation	demod type	[digital]
	Demodulation Setup	demod format	[8PSK]
		symbol rate	[10.5 kHz]
		result length	[32 symbols]
		meas filter	[off]
		ref filter	[raised cosine]
		alpha	[0.6]
			[IF section (0-10 MHz)]
	Receiver		
DISPLAY	[2 grids]		
Trace A	MEASUREMENT DATA	[IQ measured time]	
	DATA FORMAT	[polar(IQ) constellation]	
Trace B	MEASUREMENT DATA	[symbol table/error summary]	
FREQUENCY	Center	[25 kHz]	
	Span	[18 kHz]	
RES BW / WINDOW	Window	[flat top]	
RANGE	[Channel 1]		
	Channel 1 Range	Adjust Manually As Required	
TIME	Result Length	[28 symbols]	
	Points / Symbol	[1]	
SOURCE	[off]		
INPUT	Channel 1	[on]	
	Channel 1 Input Z	[1MOhm]	
	Channel 1 Coupling	[AC]	
AVERAGE	[on]		
	Num Averages	[100]	
	Average Type	[rms expo]	
	Fast Avg	[off]	
TRIGGER	Trigger Type	[external]	
	Ext Level	[~ 1 V] or as required	
	Ext Slope	[-]	
	Channel 1 Delay	2.77 milliseconds	

SWEEP [continuous]
AUTO SCALE Scale Trace A As Required

A VHF Data Link Transmitter shall serve as the host unit under test for verifying these Product Specification and SRS requirements.

The equipment shall be configured in the test setup shown in Figure 3.3.2.4-1. Unless otherwise directed, the transmitter “enable” function must be active (TTL low). The initial condition for the transmitter shall be the Operational Mode. To enter Operational Mode, apply power to the transmitter. Following completion of power-on tests (less than 1 second), the transmitter will enter Operational Mode. Unless otherwise directed, allow the UUT to warm up for 15 minutes before taking data.

1.16.1.3 Definition of Inputs

This test shall verify that the relationship between the quadrature components (I and Q) in the transmitted signal is less than or equal to ± 0.5 degrees from quadrature as generated by the software and less than or equal to ± 3.0 degrees overall. This test and analysis shall also verify that the quadrature components (I and Q) are equal in amplitude within ± 0.05 dB as generated by the software and ± 1.0 dB overall. Finally, this test shall verify that the carrier component of the transmitted RF signal is at least -20 dB relative to the peak RF amplitude of the modulated signal.

To properly perform these measurements, it is required that the transmitter be transmitting continuous identical 36 byte messages. The Vector Analyzer is synchronized to the 1 Hz GPS Time Sync Discrete and obtains an average of 100 measurements. To ensure measurement of worse case performance, the overall transmitter tests are performed at both ends of the frequency band and at the center. The tests are also performed at min and max input dc voltages for the worst case frequency. The specific inputs for this test case are provided in Table 4.16.1.3-1.

The application data message that must be used for this procedure is a 36 byte message that contains data specifically designed to generate 3 full constellations of 32 symbols each. One full constellation of 32 symbols is to be included in the vector analyzer analysis. The 36 byte data stream is composed of 9 four-byte long words with the following decimal values:

1	2685284880
2	2969892997
3	3000796806
4	1509796135
5	3047428815
6	1119185864
7	1052543747
8	1379521713
9	2050814573

The 2.77 millisecond vector analyzer trigger delay shown in the configuration setup starts the

display at the very start of the first repetition of the three full constellations generated by this data message.

Table 4.16.1.3-1 Quadrature Modulation Test Case Inputs		
Step	Input	Description
A	DC input voltages at nominal: 5 Vdc +15 Vdc -12 Vdc +28 Vdc	
B	Send a Tune Command with Frequency set to 112.000 MHz and Time Slot FFh (all slots).	
C	Send a 36 Byte Application Data Message, continuously in all time slots	Causes transmitter to transmit continuously.
D	Send a 36 Byte Application Data Message, continuously in all time slots	Causes transmitter to transmit continuously.
E	Send a Tune Command with Frequency set to 115.000 MHz and Time Slot FFh (all slots).	
F	Send a 36 Byte Application Data Message, continuously in all time slots	Causes transmitter to transmit continuously.
G	Send a Tune Command with Frequency set to 117.950 MHz and Time Slot FFh (all slots).	
H	Send a 36 Byte Application Data Message, continuously in all time slots	Causes transmitter to transmit continuously.
I	DC input voltages at minimum: 5 Vdc +14.25Vdc -11.4 Vdc +26.6 Vdc	
J	Send a 36 Byte Application Data Message, continuously in all time slots	Causes transmitter to transmit continuously.
K	DC input voltages at maximum: 5.5 Vdc +15.75Vdc -12.6 Vdc +29.4 Vdc	
L	Send a 36 Byte Application Data Message, continuously in all time slots	Causes transmitter to transmit continuously.

1.16.1.4 Major Steps

Verify the Quadrature Modulation requirements for both the software and the overall transmitter equipment by performing the following steps.

- A Configure the Vector Analyzer as described in the Setup/Initial Conditions.
2. Set the power supply voltages to nominal as shown in Table 4.16.1.3-1, Step A.
3. Set the transmitter to operate at 112.000 MHz and all slots as shown in Table 4.16.1.3-1, Step B.
- D. To measure the vector characteristics of the software generated signal, connect the Vector Analyzer to the output of the D/A converter at pin 1 of the inter-board connector between the DSP A200197-01 CCA and the Upconverter A200195-01 CCA.
5. Cause the transmitter to transmit maximum messages in all time slots by applying the input shown in Table 4.16.1.3-1, Step C.
6. Using the Vector Analyzer, measure the rms phase error and compare to the expected output shown in Table 4.16.1.5-1, Step A.
7. Due to measurement and instrumentation errors, the Vector Analyzer cannot be used to accurately measure the amplitude difference between the I and Q components at the D/A output port for comparison with the expected output (≤ 0.05 dB) shown in Table 4.16.1.5-1, Step A. The value derived in post processing analysis section 4.16.1.6 is entered instead.
8. Cease transmissions and connect the Vector Analyzer to the attenuated RF output of the transmitter so as to measure the vector characteristics of the overall transmitter.
9. Cause the transmitter to transmit maximum messages in all time slots by applying the input shown in Table 4.16.1.3-1, Step D.
10. Using the Vector Analyzer, measure the rms phase error and compare to the expected output shown in Table 4.16.1.5-1, Step B.
11. Using the Vector Analyzer, measure the amplitude difference between the I and Q components and compare to the expected output shown in Table 4.16.1.5-1, Step B.
12. Using the Vector Analyzer, measure the carrier component level relative to the RF peak and compare to the expected output shown in Table 4.16.1.5-1, Step B.
13. Set the transmitter to operate at 115.000 MHz and all slots as shown in Table 4.16.1.3-1, Step E.
14. Cause the transmitter to transmit maximum messages in all time slots by applying the input shown in Table 4.16.1.3-1, Step F.

15. Using the Vector Analyzer, measure the rms phase error and compare to the expected output shown in Table 4.16.1.5-1, Step B.
16. Using the Vector Analyzer, measure the amplitude difference between the I and Q components and compare to the expected output shown in Table 4.16.1.5-1, Step B.
17. Using the Vector Analyzer, measure the carrier component level relative to the RF peak and compare to the expected output shown in Table 4.16.1.5-1, Step B.
18. Set the transmitter to operate at 117.950 MHz and all slots as shown in Table 4.16.1.3-1, Step G.
19. Cause the transmitter to transmit maximum messages in all time slots by applying the input shown in Table 4.16.1.3-1, Step H.
20. Using the Vector Analyzer, measure the rms phase error and compare to the expected output shown in Table 4.16.1.5-1, Step B.
21. Using the Vector Analyzer, measure the amplitude difference between the I and Q components and compare to the expected output shown in Table 4.16.1.5-1, Step B.
22. Using the Vector Analyzer, measure the carrier component level relative to the RF peak and compare to the expected output shown in Table 4.16.1.5-1, Step B.
23. Note at which frequency the worst case phase error measurement was obtained.
24. Return to the worst case frequency of operation.
25. Set the power supply voltages to minimum as shown in Table 4.16.1.3-1, Step I.
26. Cause the transmitter to transmit maximum messages in all time slots by applying the input shown in Table 4.16.1.3-1, Step J.
27. Using the Vector Analyzer, measure the rms phase error and compare to the expected output shown in Table 4.16.1.5-1, Step B.
- AB. Using the Vector Analyzer, measure the amplitude difference between the I and Q components and compare to the expected output shown in Table 4.16.1.5-1, Step B.
- AC. Using the Vector Analyzer, measure the carrier component level relative to the RF peak and compare to the expected output shown in Table 4.16.1.5-1, Step B.
- AD. Set the power supply voltages to maximum as shown in Table 4.16.1.3-1, Step K.
- AE. Cause the transmitter to transmit maximum messages in all time slots by applying the

input shown in Table 4.16.1.3-1, Step L.

- AF. Using the Vector Analyzer, measure the rms phase error and compare to the expected output shown in Table 4.16.1.5-1, Step B.
- AG. Using the Vector Analyzer, measure the amplitude difference between the I and Q components and compare to the expected output shown in Table 4.16.1.5-1, Step B.
- AH. Using the Vector Analyzer, measure the carrier component level relative to the RF peak and compare to the expected output shown in Table 4.16.1.5-1, Step B.

1.16.1.5 Expected Outputs

Table 4.16.1.5-1 Quadrature Modulation Test Case Outputs		
Step	Expected Results	Comment
A	RMS Phase Error Less than or equal to .5 Degrees I/Q Amplitude Difference Less than or equal to .05 dB (EVM less than or equal to 0.288%)	Measured at output of D/A Converter
B	RMS Phase Error Less than or equal to 3.0 Degrees I/Q Amplitude Difference Less than or equal to 1.0 dB (EVM less than or equal to 5.75%) Carrier Component Less than or equal to -20 dB	Measured at RF output of transmitter.

1.16.1.6 Post Processing/Analysis

For a given D8PSK I/Q amplitude imbalance X (in dB), the variable Y is defined as

$$Y = 10 \exp (X / 20) ,$$

which is equivalent to

$$Y = I / Q .$$

It is useful to define another variable R, which is the absolute value of the ratio of (I - Q) to the average of I and Q.

$$R = \text{ABS} [(I - Q) / ((I + Q) / 2)]$$

$$R = \text{ABS} [2 (Y - 1) / (Y + 1)]$$

$$R = \text{ABS} [2 (10 \exp (X / 20) - 1) / (10 \exp (X / 20) + 1)]$$

The vector analyzer EVM (error vector magnitude) parameter readout is based on a reference constellation that is normalized for best fit to the collected data. An error vector extends from each reference constellation point to each corresponding measured constellation point. All the error vectors are RSS'd to derive the EVM. Based on this "best fit" scenario, the nominal EVM is half the ratio R just calculated. For the requirements analyzed in this section, the following test limits are calculated as shown:

Specified Amplitude Imbalance	0.05 dB	1.0 dB
R	0.005756	0.115
EVM test limit (rms)	0.288%	5.75%

These are the test limits shown in the test procedure.

The following values are generated by DSP software for the D8PSK constellation points:

Position	I (In-Phase)	Q (Quadrature-Phase)
0	31	0
1	22	22
2	0	31
3	-22	22
4	-31	0
5	-22	-22
6	0	-31
7	22	-22

The tabular derivation of this constellation in software may be verified by referring to file D8INIT.C. The tables used for defining the constellation are as follows:

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_dphase_tab_g
_Cos_Tab_g
_Sin_Tab_g

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By inspection it is seen that the I and Q component magnitudes are exactly 0 or 31 for on-axis points, and that the I and Q component magnitudes are identical (22) for all other constellation points. Thus the I and Q amplitude difference is 0.0%.

Measurement and instrumentation errors make it unlikely that the 0.05 dB maximum permissible I/Q imbalance at the D/A output can be measured. Therefore the analysis result (0.0% rms) is entered in the test results box with the notation "Derived Value."

Even though the "22,22" constellation points have an amplitude of 31.1127 and not exactly 31.000, this is not indicative of I and Q component imbalance. The effect of this relatively insignificant adjacent point amplitude imbalance is ultimately measured in this test procedure when phase error and EVM are measured for the UUT RF output signal.

1.16.1.7 Pass/Fail Criteria

The Criteria for successfully passing these test cases are the output results indicated in Table 4.16.1.5-1.

1.16.2 Test Procedure

1.16.2.1 Quadrature Modulation

Test Procedure Steps

P e r f. ()	Results	P a s ()	F a i l ()
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- Record the version of Lab Software used to control the UUT host computer. Without applying supply voltage to the transmitter, adjust power supply voltages to the nominal values shown in Table 4.16.1.3-1 Step A. Configure the UUT and vector analyzer as described in 4.16.1.2. With the UUT cover removed, connect a X1 probe from the analyzer IF Channel 1 input port to the D/A output signal on A200197-01 connector U23 pin 1 with the probe ground connected to digital ground U23 pin 34. Apply power to the UUT. Set the transmitter to operate at 112.000 MHz and all slots as shown in Table 4.16.1.3-1, Step B. Cause the transmitter to transmit maximum messages in all time slots by applying the input shown in Table 4.16.1.3-1, Step C.

√	Ver 1.0	N / A	N / A
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Lab SW
Version

- Using the Vector Analyzer, measure the rms phase error for comparison with the expected output (≤ 0.5 degrees rms) shown in Table 4.16.1.5-1, Step A.

√	.24	√	
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(≤ 0.5 Degrees
rms)

- Due to measurement and instrumentation errors, the Vector Analyzer cannot be used to accurately measure the amplitude difference between the I and Q components at the D/A output port for comparison with the expected output (≤ 0.05 dB) shown in Table 4.16.1.5-1, Step A. This equivalent EVM value must be less than or equal to 0.288% rms. The value derived in post processing analysis section 4.16.1.6 (0.0%) is entered instead, and the note "Derived Value" has been added.

√	0.0 % rms "Derived Value"	√	
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Test Procedure Steps

P er f. ()	Results	P as s ()	F ai l ()
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($\leq 0.288\%$ rms)

- Cease transmissions, remove the probe from connector U23, and install the cover on the transmitter. Connect an RF cable from the RF attenuator output port to the input port of the Vector Analyzer RF section for measurement of the vector characteristics of the overall transmitter. Use the INSTRUMENT MODE vector analyzer button to change the receiver to [RF (2 - 1800 MHz)]. Use the FREQUENCY button to set the center frequency to 112 MHz. Use the INPUT button to change the channel 1 impedance to 50 Ohms. Cause the transmitter to transmit maximum messages in all time slots by applying the input shown in Table 4.16.1.3-1, Step D.

(N/A)	N / A	N / A
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- Using the Vector Analyzer, measure the rms phase error for comparison with the expected output (≤ 3.0 degrees rms) shown in Table 4.16.1.5-1, Step B.

√	2.3	√	
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(≤ 3.0 degrees rms)

- Using the Vector Analyzer, measure the amplitude difference between the I and Q components for comparison with the expected output (≤ 1.0 dB) shown in Table 4.16.1.5-1, Step B. This measurement is made by reading the EVM (error vector magnitude), which must be less than or equal to 5.76% rms.

√	5.27	√	
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($\leq 5.75\%$ rms)

- Using the Vector Analyzer, measure the carrier component level relative to the RF peak and compare to the expected output (≤ -20 dB) shown in Table 4.16.1.5-1, Step B. This measurement is made by reading the IQ Offset, which must be less than or equal to -20 dB.

√	-52.0	√	
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(≤ -20.0 dB)

Test Procedure Steps

P er f. ()	Results	P as s ()	F ai l ()
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8. Set the transmitter to operate at 115.000 MHz and all slots as shown in Table 4.16.1.3-1, Step E. Cause the transmitter to transmit maximum messages in all time slots by applying the input shown in Table 4.16.1.3-1, Step F.

√	(N/A)	N / A	N / A
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9. Change the Vector Analyzer center frequency to 115.000 MHz. Using the Vector Analyzer, measure the rms phase error for comparison with the expected output (≤ 3.0 degrees rms) shown in Table 4.16.1.5-1, Step B.

√	2.7	√	
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(≤ 3.0 degrees rms)

10. Using the Vector Analyzer, measure the amplitude difference between the I and Q components for comparison with the expected output (≤ 1.0 dB) shown in Table 4.16.1.5-1, Step B. This measurement is made by reading the EVM (error vector magnitude), which must be less than or equal to 5.76% rms.

√	5.60	√	
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(≤ 5.75 % rms)

11. Using the Vector Analyzer, measure the carrier component level relative to the RF peak and compare to the expected output (≤ -20 dB) shown in Table 4.16.1.5-1, Step B. This measurement is made by reading the IQ Offset, which must be less than or equal to -20 dB.

√	-49.0	√	
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(≤ -20.0 dB)

12. Set the transmitter to operate at 117.950 MHz and all slots as shown in Table 4.16.1.3-1, Step G. Cause the transmitter to transmit maximum messages in all time slots by applying the input shown in Table 4.16.1.3-1, Step H.

√	(N/A)	N / A	N / A
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13. Change the Vector Analyzer center frequency to 117.950 MHz. Using the Vector Analyzer, measure the rms phase error for comparison with the expected output (≤ 3.0 degrees rms) shown in Table 4.16.1.5-1, Step B.

√	2.7	√	
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Test Procedure Steps

P er f. ()	Results	P as s ()	F ai l ()
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(≤ 3.0 degrees rms)

14. Using the Vector Analyzer, measure the amplitude difference between the I and Q components for comparison with the expected output (≤ 1.0 dB) shown in Table 4.16.1.5-1, Step B. This measurement is made by reading the EVM (error vector magnitude), which must be less than or equal to 5.76% rms.

√	5.6	√	
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(≤ 5.75 % rms)

15. Using the Vector Analyzer, measure the carrier component level relative to the RF peak and compare to the expected output (≤ -20 dB) shown in Table 4.16.1.5-1, Step B. This measurement is made by reading the IQ Offset, which must be less than or equal to -20 dB.

√	-48.0	√	
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(≤ -20.0 dB)

16. Note and record the frequency at which the worst-case phase error measurement was obtained, then set the transmitter to operate at the noted frequency and in all slots as shown in Table 4.16.1.3-1, Step B, E, or G. Set the power supply voltages to minimum as shown in Table 4.16.1.3-1, Step I. Cause the transmitter to transmit maximum messages in all time slots by applying the input shown in Table 4.16.1.3-1, Step J.

√	117.95	√	
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(Reference Frequency)

17. Change the Vector Analyzer center frequency to that recorded in the previous step. Using the Vector Analyzer, measure the rms phase error for comparison with the expected output (≤ 3.0 degrees rms) shown in Table 4.16.1.5-1, Step B.

√	2.9	√	
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(≤ 3.0 degrees rms)

18. Using the Vector Analyzer, measure the amplitude difference between the I and Q components for comparison with the expected output (≤ 1.0 dB) shown in Table 4.16.1.5-1, Step B. This measurement is made by reading the EVM (error vector magnitude), which must be less than or equal to 5.76% rms.

√	5.6	√	
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Test Procedure Steps

P er f. ()	Results	P as ()	F ai l ()
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(≤ 5.75 % rms)

19. Using the Vector Analyzer, measure the carrier component level relative to the RF peak and compare to the expected output (≤ -20 dB) shown in Table 4.16.1.5-1, Step B. This measurement is made by reading the IQ Offset, which must be less than or equal to -20 dB.

√	-49	√	
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(≤ -20.0 dB)

20. Set the power supply voltages to maximum as shown in Table 4.16.1.3-1, Step K. Cause the transmitter to transmit maximum messages in all time slots by applying the input shown in Table 4.16.1.3-1, Step L.

√	(N/A)	N / A	N / A
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21. Using the Vector Analyzer, measure the rms phase error for comparison with the expected output (≤ 3.0 degrees rms) shown in Table 4.16.1.5-1, Step B.

√	2.9	√	
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(≤ 3.0 degrees rms)

22. Using the Vector Analyzer, measure the amplitude difference between the I and Q components for comparison with the expected output (≤ 1.0 dB) shown in Table 4.16.1.5-1, Step B. This measurement is made by reading the EVM (error vector magnitude), which must be less than or equal to 5.76% rms.

√	5.5	√	
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(≤ 5.75 % rms)

23. Using the Vector Analyzer, measure the carrier component level relative to the RF peak and compare to the expected output (≤ -20 dB) shown in Table 4.16.1.5-1, Step B. This measurement is made by reading the IQ Offset, which must be less than or equal to -20 dB.

√	-48	√	
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(≤ -20.0 dB)

Examination of the post processing analysis in section 4.16.1.6 provides analytical proof that the requirement in step 3 is met. The result is entered as 0.0 % with the notation "Derived Value."

0.0.1 Results Summary

Passed

Performed by _Dave Dautel_____ Date _12-14-98_____