Certification Application

For

Federal Communications Commission

CANAC Radio Transmitter

Model #: 2MOD-6322-A411 (450-460 MHz, 12.5 KHz channel spacing)

2MOD-6322-A511 (460-470 MHz, 12.5 KHz channel spacing)

May 31, 2000

Table of Contents

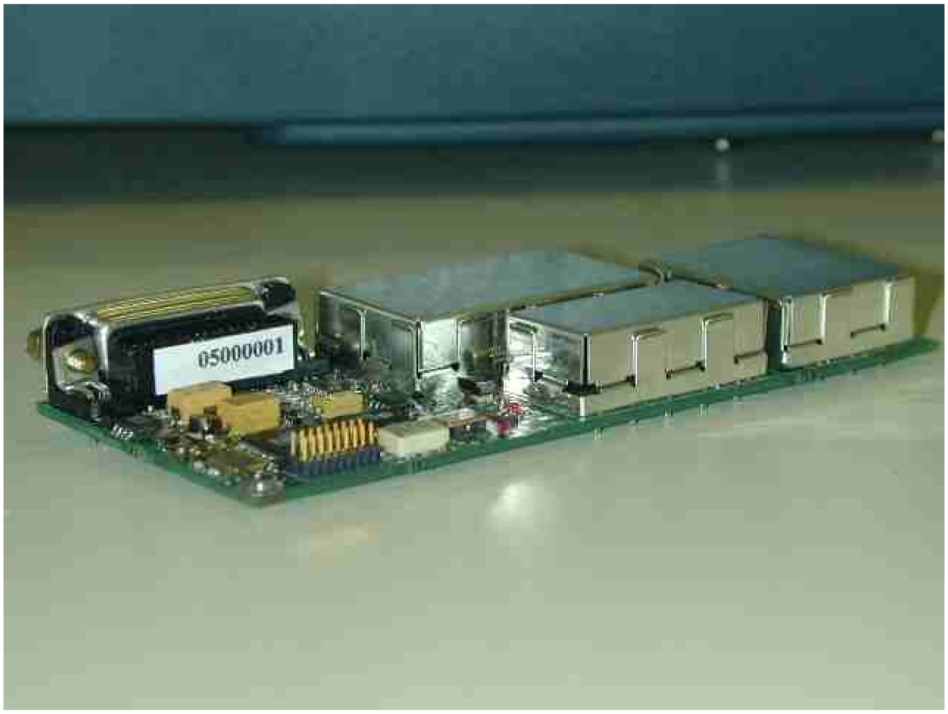
Technical Description

The present document describes each functional block of the radio. The information regarding calculations of the detailed design; PLL loop filter, impedance matching, VCO tank circuit etc. are described in the DESIGN DETAIL of the RF Radio and is available upon request. The module contains only a transmitter however the hardware is ready to install a future receiver.

1.0 Context of Operation:

The main purpose of this radio is to enable the locomotive engineer to remotely control the locomotive in the yard. The locomotive engineer is equipped with an *operator control unit* (OCU) and communicates with the locomotive directly or via a *repeater unit* (RPU) that is well located within the yard. Other purposes include any type of tele-operating system.

The overall system must support many operators on the same frequency with different time slots (TDMA) in half duplex. The frequencies used are between 450-470 MHz and 806-870 MHz. The radio transmits at 9.6 Kbaud in a 12.5 KHz or 4.8 Kbaud in a 6.25 KHz channel spacing at a maximum power of 1 Watt.



Photograph of the radio board with out the enclosure (above) and with in the enclosure (below).

2.0 General Design Overview

2.1 3FSK Partial Response Modulator

The core of the 3FSK modulator is completely digital by means of a direct digital synthesizer (DDS). The DDS requires a clock at 153.6 MHz to generate an output frequency at 63.6 MHz and an aliaising at 90 MHz (153.6 - 63.6 MHz). The selected frequency output is 90 MHz, because it is easier to perform filtering after an up-conversion process. In the present design, the DDS clock is provided by the auxiliary VCO and it is locked on the temperature compensated crystal oscillator (TCXO). This signal is converted into CMOS level by a transistor.

Compared to the 6412 series, this new generation of modulator eliminates the need to multiply the output frequency of the DDS by 8 and one phase lock loop is eliminated. In doing so, the close in phase noise is improved by a factor of 8 to 9 dB (10 log 8).

Figure 1 illustrates the process of the generation of the 3FSK signal.

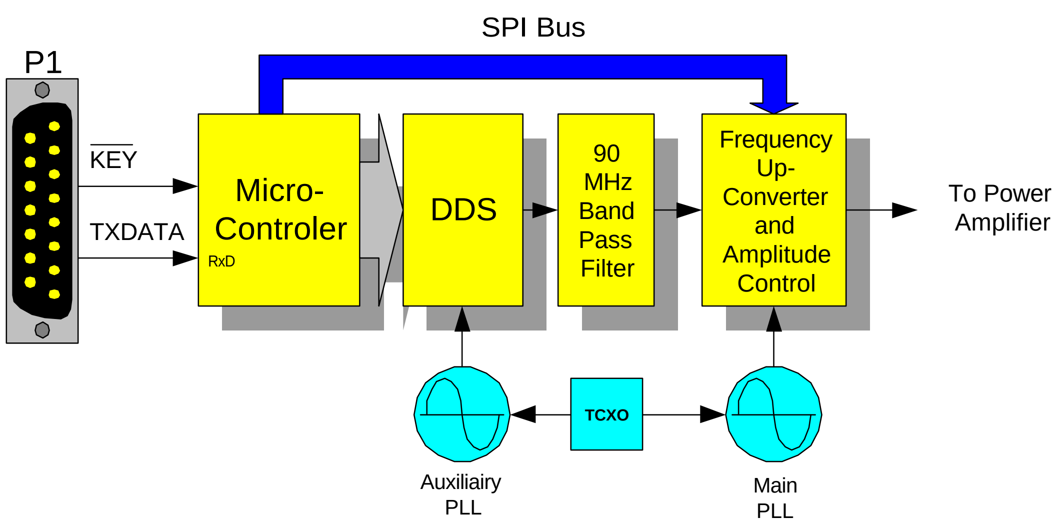


Figure 1

The micro controller (U3) receives the DATA to be transmitted by TXDATA at P1 and follows this information to the RX port of the micro controller via U4. The information is stored in RAM. The program starts a routine to initialise the transmitter with the proper sequence for the power up. After the power up, the micro controller starts the DDS to generate the FM signal. The algorithms to generate the FM signal incorporate the data filtering as follows:

1. At the beginning of each transmission, the DDS generates a preamble that consists of the center frequency F0 for a duration of five bits time plus 3 bits time. During the first five bits, the RF pulse shaping to control spurious due to turn on takes place. During that time, the power amplifier reaches the maximum power as a sine shape at each T/4, where T is the bit time, over the first five bits (see figure 9). Then the transmission starts with three bits of center frequency. These three bits are used on the receiver side for carrier detection and to prepare the clamp circuit (dc offset of the data signal).

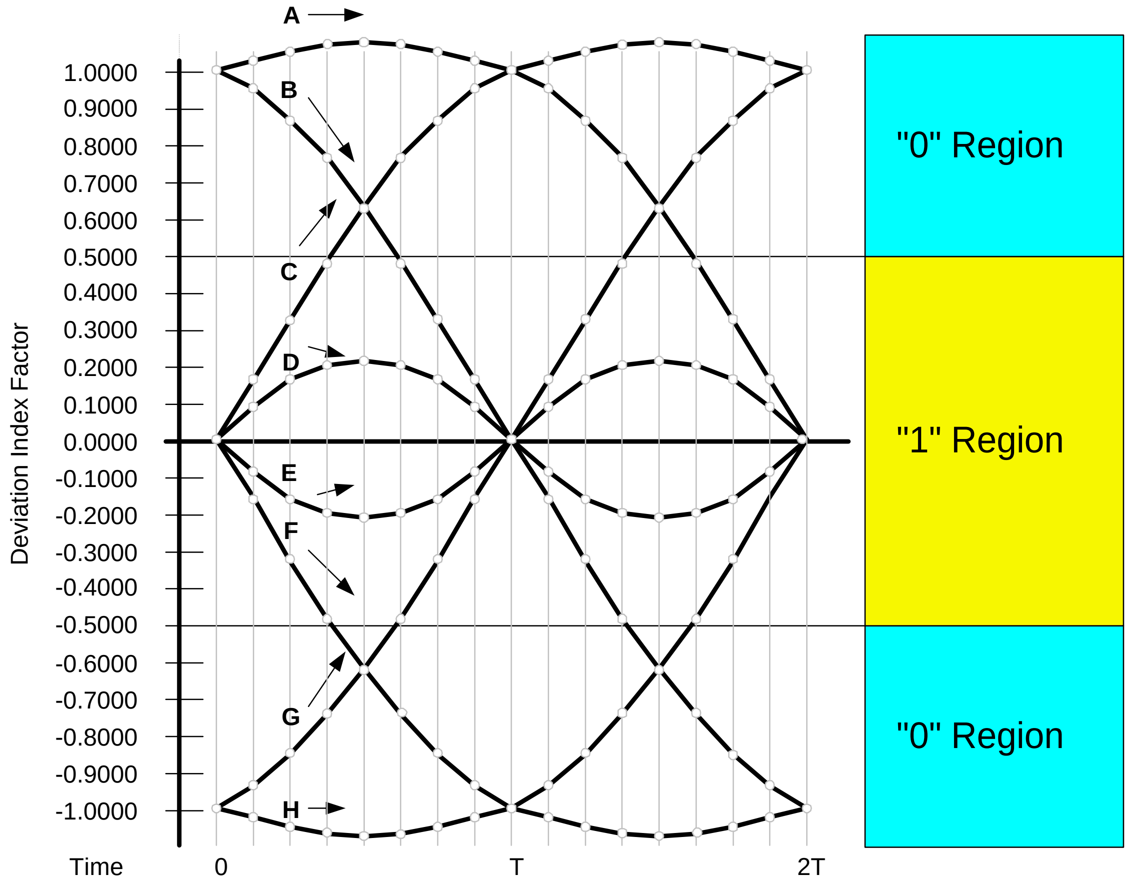
2. The carrier is then frequency modulated in relation to the DATA level and the two previous bits. For a binary level “0”, the DDS generates frequencies that correspond to trajectories H, D, F and B functions of the two previous bits (see figure 2). Intermediate frequencies are generated to reach the frequency at each T/4.

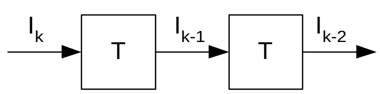
Note: A trajectory consists of a series of 4 or 8 different frequencies equally spaced for each symbol. To achieve a 3 FSK Partial Response, we need a table of 8 trajectories (32 frequencies). The trajectories are pre-calculated to perform the equivalent of DATA filtering.

3. For a binary level “1”, the DDS generates frequencies that correspond to trajectories G, C, E and A functions of the two previous bits. Intermediate frequencies are also generated to reach this value at each T/4 (Figure 2).

4. When the data is finished, the DDS generates F0 for a five bit time to perform the RF sine pulse shaping.

Note: The data needs to be precoded NRZI prior to being encoded 3 FSK Partial Response.





I_k = NRZI precoded data

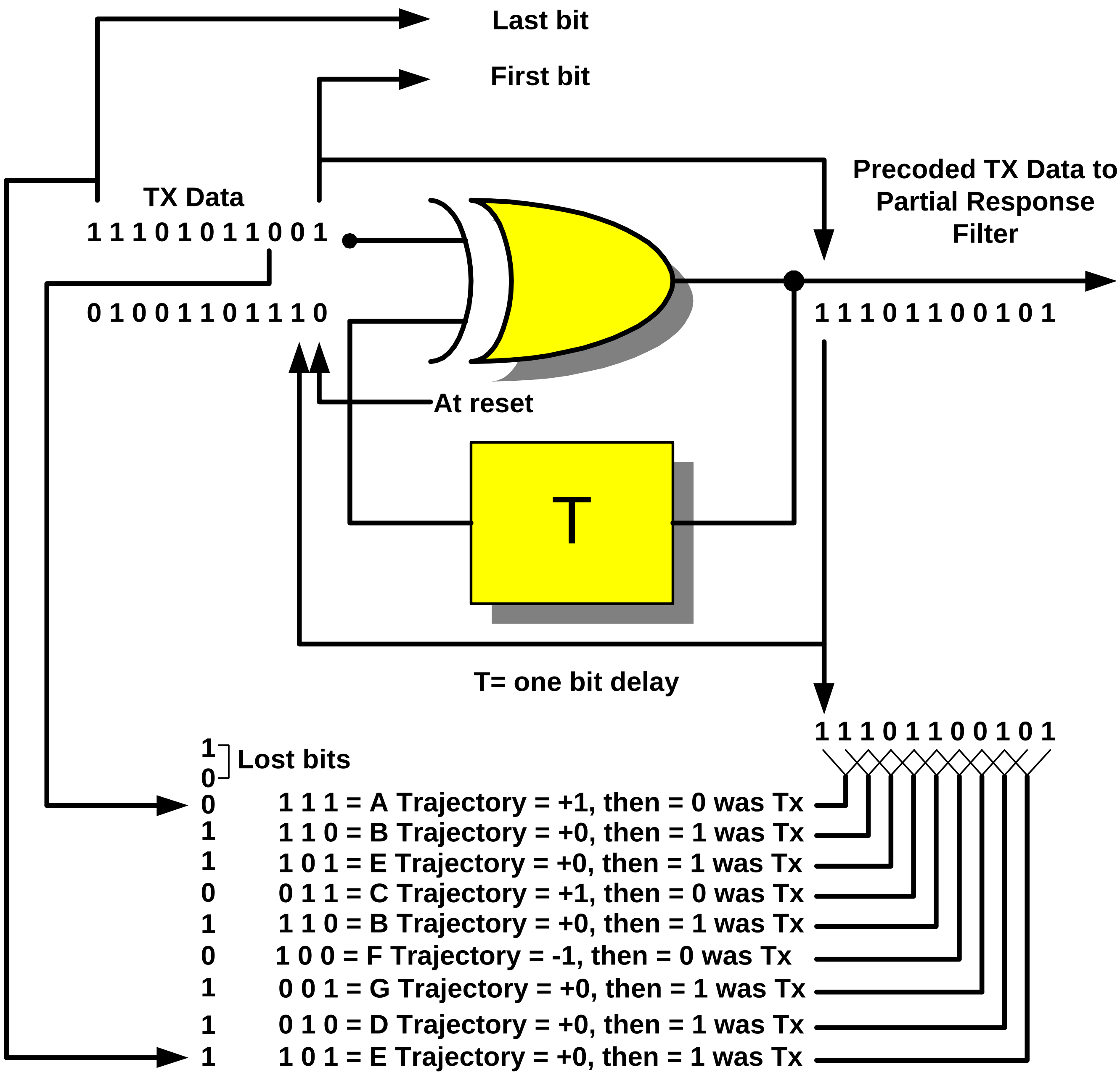
Trajectory for 3FSK, 8 samples per bits

Two previous bits I_{k-2}	I_{k-1}	New bit I_k	
0	0	0	H = (-1.0000 -1.0255,-1.0448, -1.0557,-1.0598, -1.0557,-1.0448, -1.0255)
0	0	1	G = (-1.000,-0.9539, -0.8756, -0.7684,-0.6370,-0.4869, -0.3254,-0.1599)
0	1	0	D = (0.0, +0.0884,+0.1562,+0.1995, +0.2143, +0.1995,+0.1562,+0.0884)
0	1	1	C = (0.0,+0.1599,+0.3254,+0.4869, +0.6370,+0.7684,+0.8756,+0.9539)
1	0	0	F = (0.0,-0.1599,-0.3254,-0.4869,-0.6370,-0.7684,-0.8756,-0.9539)
1	0	1	E = (0.0, -0.0884,-0.1562,-0.1995, -0.2143, -0.1995,-0.1562,-0.0884)
1	1	0	B = (1.000,+0.9539,+0.8756,+0.7684,+0.6370,+0.4869,+0.3254,+0.1599)
1	1	1	A = (1.0000,+1.0255,+1.0448,+1.0557,+1.0598,+1.0557,+1.0448,+1.0255)

Figure 2

Figure 2 shows the deviation index at each T/8 in order to obtain a perfect Partial Response baseband signal with limited RF bandwidth.

Encoding / Decoding Example



Decoding rule: If received +1 or -1 then 0 was transmitted
If received is 0 then 1 was transmitted

Figure 3

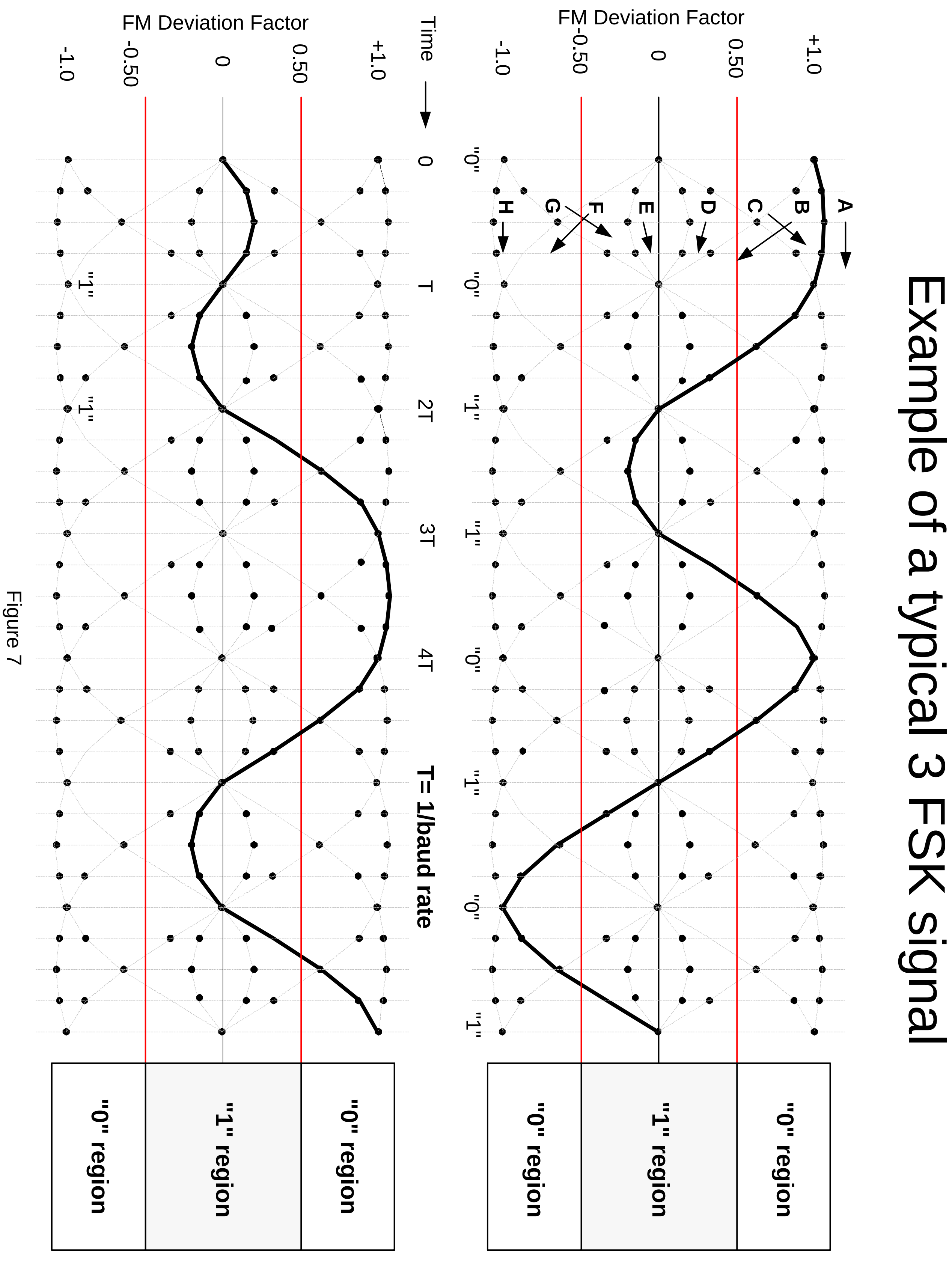

Example of a typical 3 FSK signal
FM Deviation Factor
+1.0
0.50
0
-0.50
-1.0
A
B
C
D
E
F
G
H
"0"
"0"
"1"
"1"
"0"
"1"
"0"
"1"
"0" region
"1" region
"0" region
Time
0
T
2T
3T
4T
T= 1/baud rate
FM Deviation Factor
+1.0
0.50
0
-0.50
-1.0
"1"
"1"
"0" region
"1" region
"0" region
Figure 7

Figure 4

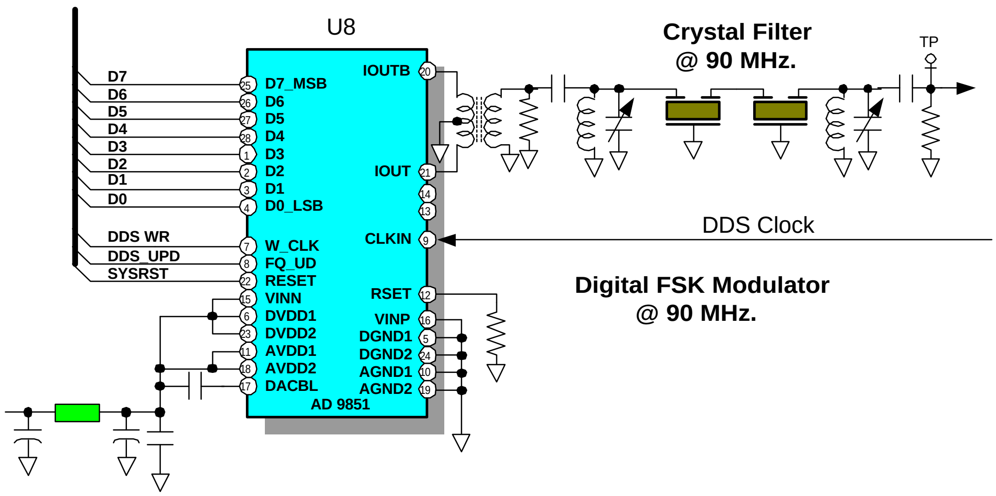


Figure 5

Implementation of the direct digital modulator

The transmit IF signal is generated by a single IC which combines the digital and analog D/A converter. One of the aliaising frequency is filtered. This technique allows to synthesise an output frequency higher than the Nyquist minimum sampling rate.

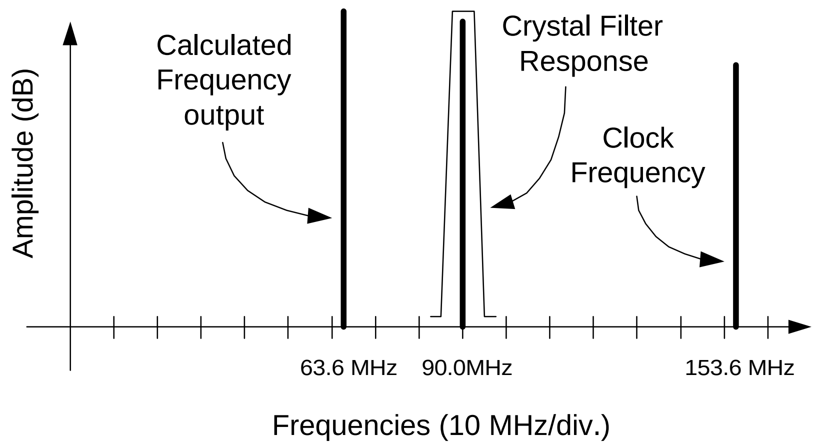


Figure 6

Frequency representation at the output of the DDS

2.2 Up-Converter

The frequency up-converter SA900 integrated circuit was designed by Phillips. In the present application, SA900 is configured for digital mode (DUAL TX). By using the DUAL path in this IC, the output amplifier can be controlled by an attenuator with steps of 0.7 dB.

The output frequency of the DDS is directly injected in the internal VCO of SA900.

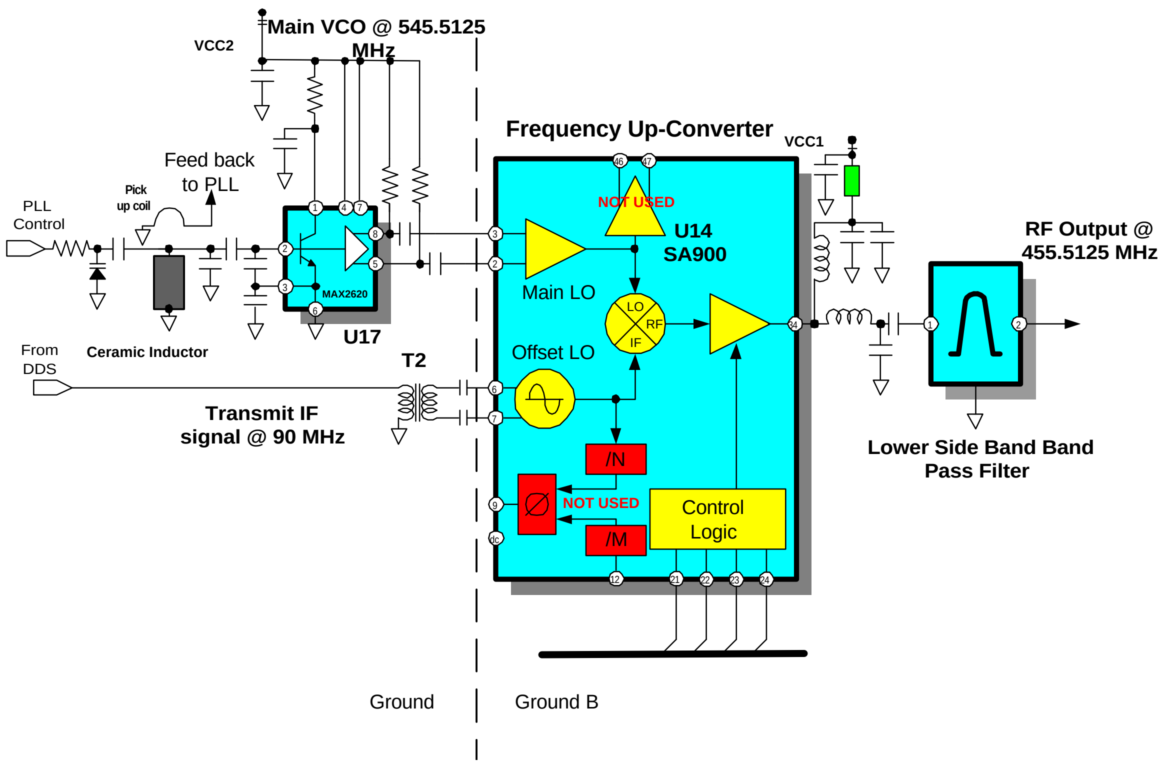


Figure 7

Up-conversion process example

Three functions inside the SA900 are intentionally not used:

1 The phase lock loop is no longer required because the DDS can generate the transmit IF at the proper frequency. There is no need to multiple by 8.

2 The QPSK modulator is still not required in this version because this is a DDS IF modulator.

3 The Main VCO feedback to the PLL is coupled by a pick up coil close to the tank circuit instead using the internal buffer of the SA900. This way of coupling increases the isolation between the main VCO and the RF output frequency. This technique overcomes the problem caused by the leakage mixing product that leaks through the LO port of the mixer, which is then amplified by the LO buffer. The problem created by this leaking produces a second frequency signal at the input of the PLL and disturbs the pre-scalor and phase comparator during the beginning of the transmission.

2.4 RF Pulse Shaping-

The gain control function in SA900 provides a precise attenuation over 64 steps (5bits). The range is 40 dB, but this range is reduced because the power amplifier that follows is not linear near saturation. The linear range is reduced to 38.4 dB. To design a digitally controlled RF pulse shaping, a section of a sin function is used as a template over 90 degrees using 20 bits time with 4 samples per bit. This represents 20 steps of 4.5 degrees.

1-At t =0, the attenuation is maximum; (1-sin 0^{o}) 32.6dB =32.6dB
2-At t =T, the attenuation is = (1-sin 4.5^{o}) 32.6dB =30.0dB
3-At t =2T, the attenuation is = (1-sin 9.0^{o}) 32.6dB =27.5dB
■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■
19- At t =20T, the attenuation is = (1-sin 85.5^{o}) 32.6dB =0.1dB

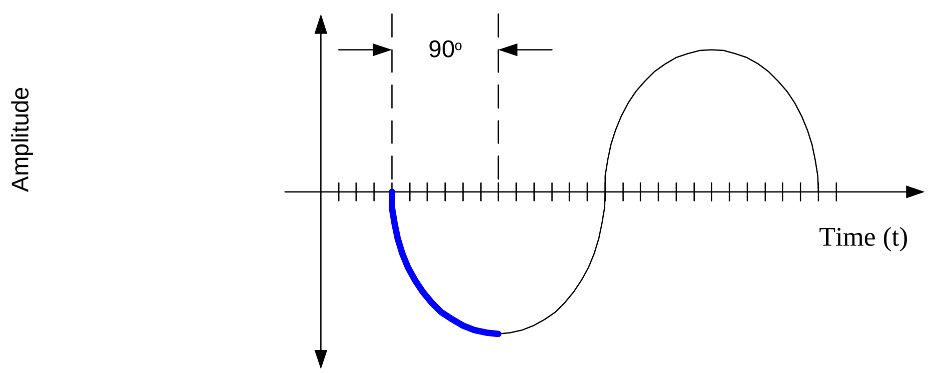


Figure 8

Step	Measured	Step	Measured	Step	Measured	Step	Measured
0	0	**16**	**7.70**	32	19.10	48	29.10
1	0.10	17	8.40	**33**	**19.80**	49	29.80
2	0.20	**18**	**9.10**	34	20.50	**50**	**30.50**
3	**0.34**	19	9.80	35	21.20	51	30.30
4	0.57	**20**	**10.5**	36	21.90	52	31.00
5	0.88	**21**	**11.20**	**37**	**22.60**	53	31.70
6	1.25	22	11.90	38	23.30	54	32.40
7	1.70	**23**	**12.60**	39	24.00	**55**	**33.10**
8	2.24	24	13.30	**40**	**24.70**	56	33.80
9	2.90	**25**	**14.00**	41	25.40	57	34.50
10	3.50	26	14.70	42	26.10	58	35.20
11	4.20	27	15.60	**43**	**26.80**	**59**	**35.90**
12	**4.90**	**28**	**16.30**	44	27.50	60	36.60
13	5.60	29	17.00	45	28.80	61	31.40
14	**6.30**	**30**	**17.70**	46	27.70	62	32.00
15	7.00	31	18.40	**47**	**28.40**	**63**	**38.40**

The measurements in this table were taken at each step directly at the output of the radio with the command that controls each step of the attenuator of SA900. The bold number represents the actual value in the program to match the sin curve.

Figure 9 shows the RF envelope of the transmitted signal. It shows the effect of the pulse shaping at the beginning and end of the transmission. The pulse shaping reduces the harmonic content of repetitive ON/OFF of the RF signal.

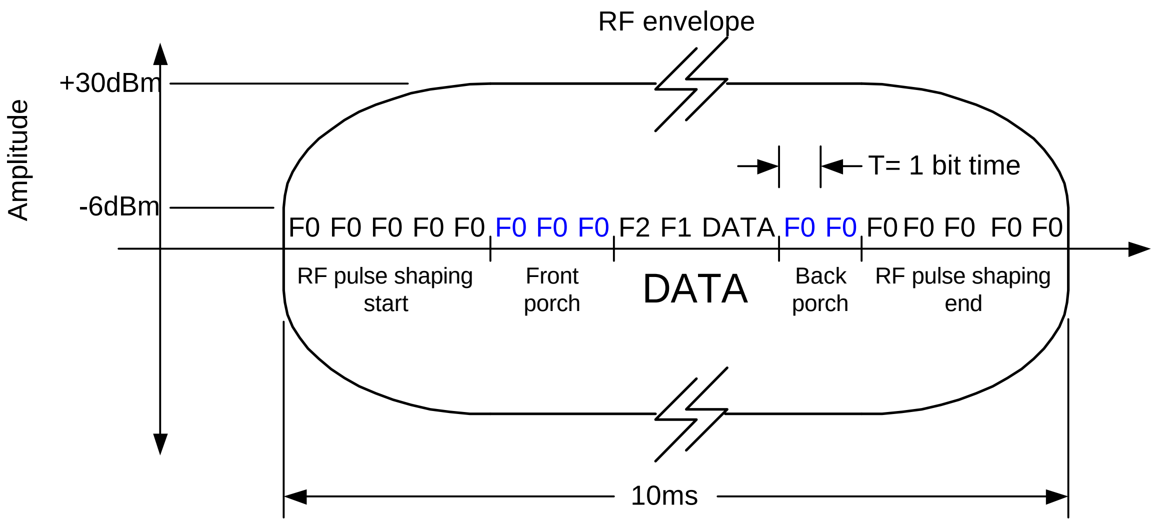


Figure 9

2.3 Power Amplifier and RX/TX Switch

The Power amplifier is a class A/B that can deliver up to 1.5 Watt with four 10 dB steps of output level control. The four steps of power control are provided with the GainA* and GainB signals. The amplifier is enabled with the TXEN signal before the RF pulse shaping is activated in SA900. The layout provides two types of configuration to allow optimum matching in the 450 MHz and 850 MHz band.

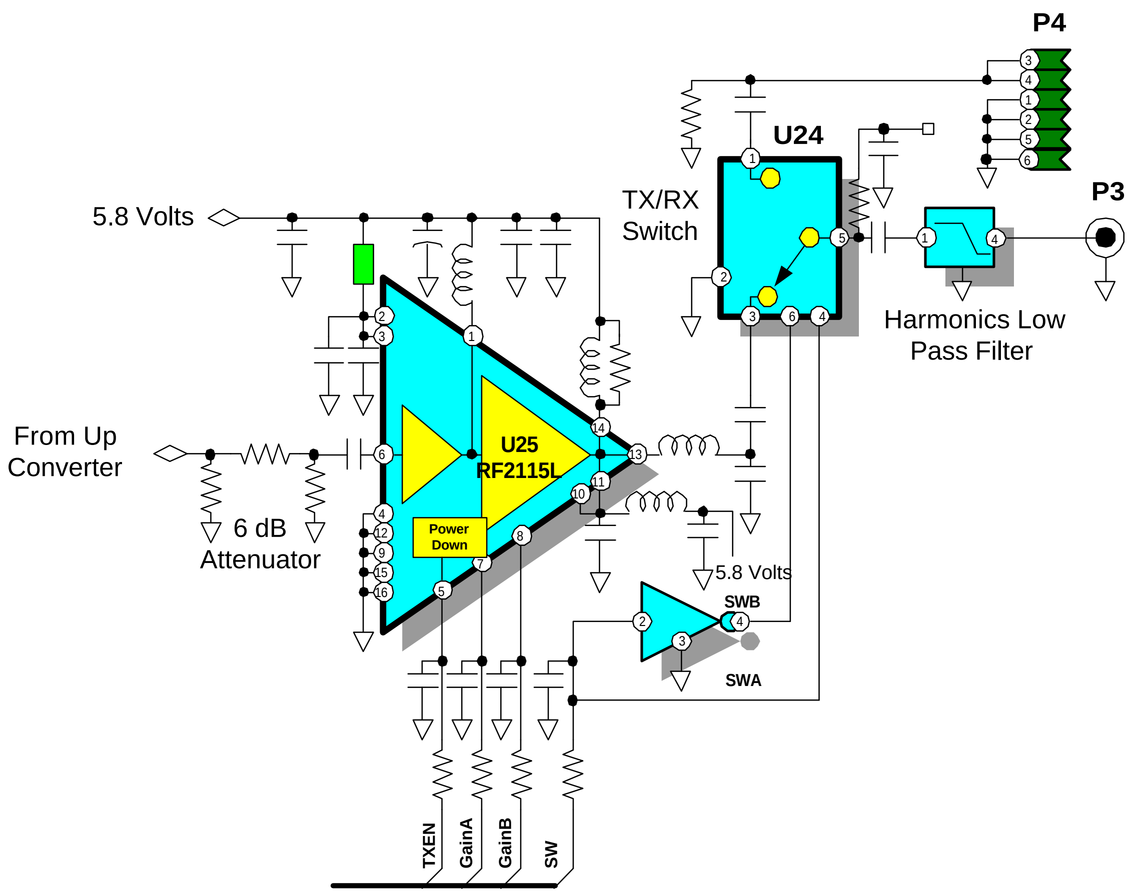


Figure 10

Implementation of the power amplifier and the TX/RX switch

* The gainA signal is also used during the received time as another function. This signal is used to select between two signals: the RX analog signal or the Data out from the micro-controller (figure 12). The Data out signal provides information from U9 analog to digital converter.

2.4 Synthesizer

There are two synthesizers in this transmitter. The auxiliary synthesizer generates the fixed frequency to clock the DDS at 153.6 MHz. The choice of the DDS clock frequency is based on the need a multiple frequency of 400 KHz. By choosing to lock the auxiliary VCO on a 400 KHz reference frequency (12.8 MHz divide by 32), this 400 KHz signal can be routed out of the PLL IC through pin 18 of U13 and serve as a synchronisation signal for the two switching DC/DC converter on board.

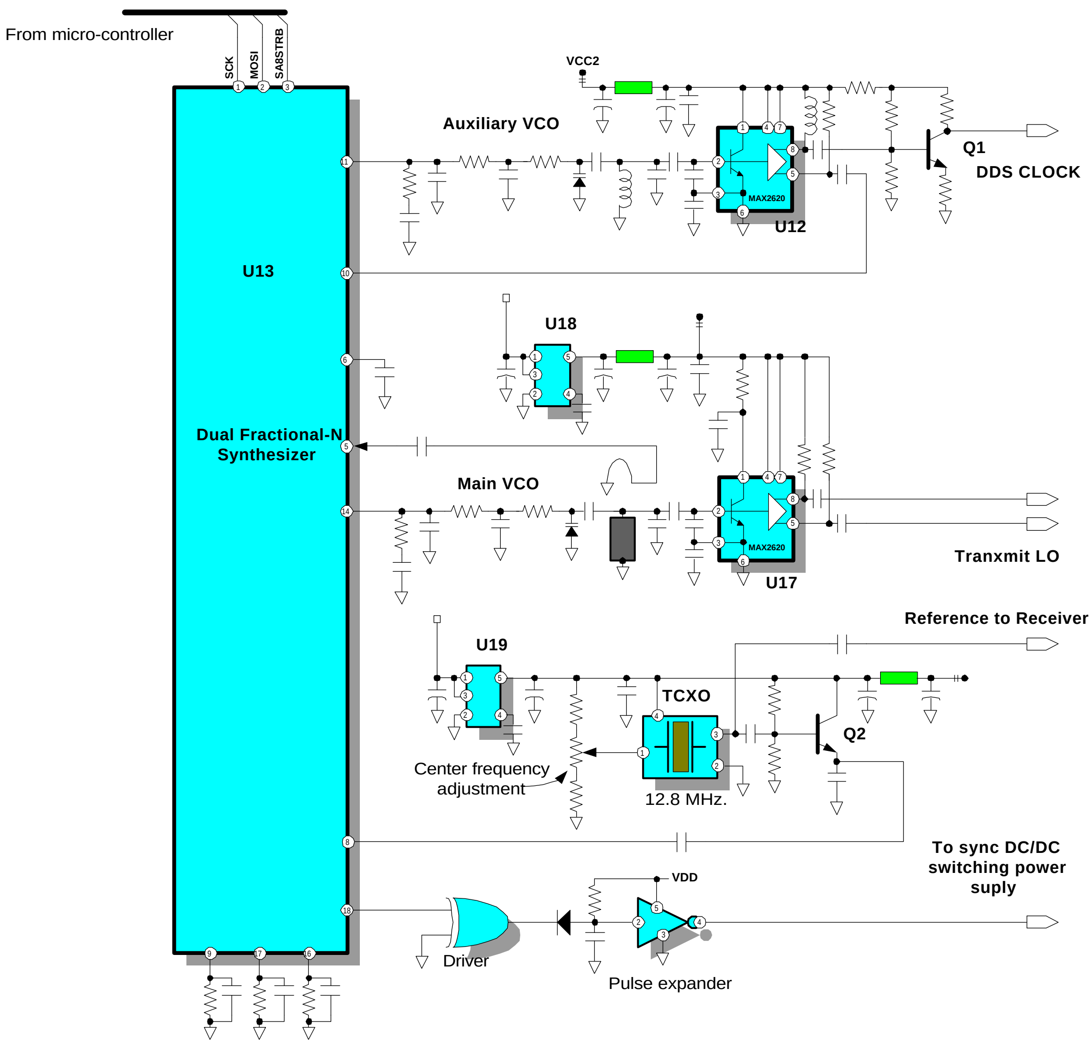


Figure 11

The main VCO is designed to achieve low phase noise by means of ceramic inductors combined with the fractional N feature in the PLL IC's. The loop bandwidth of the PLL is in the vicinity of 3KHz to reduce some micro-phonic noise.

2.5 Micro-Controller

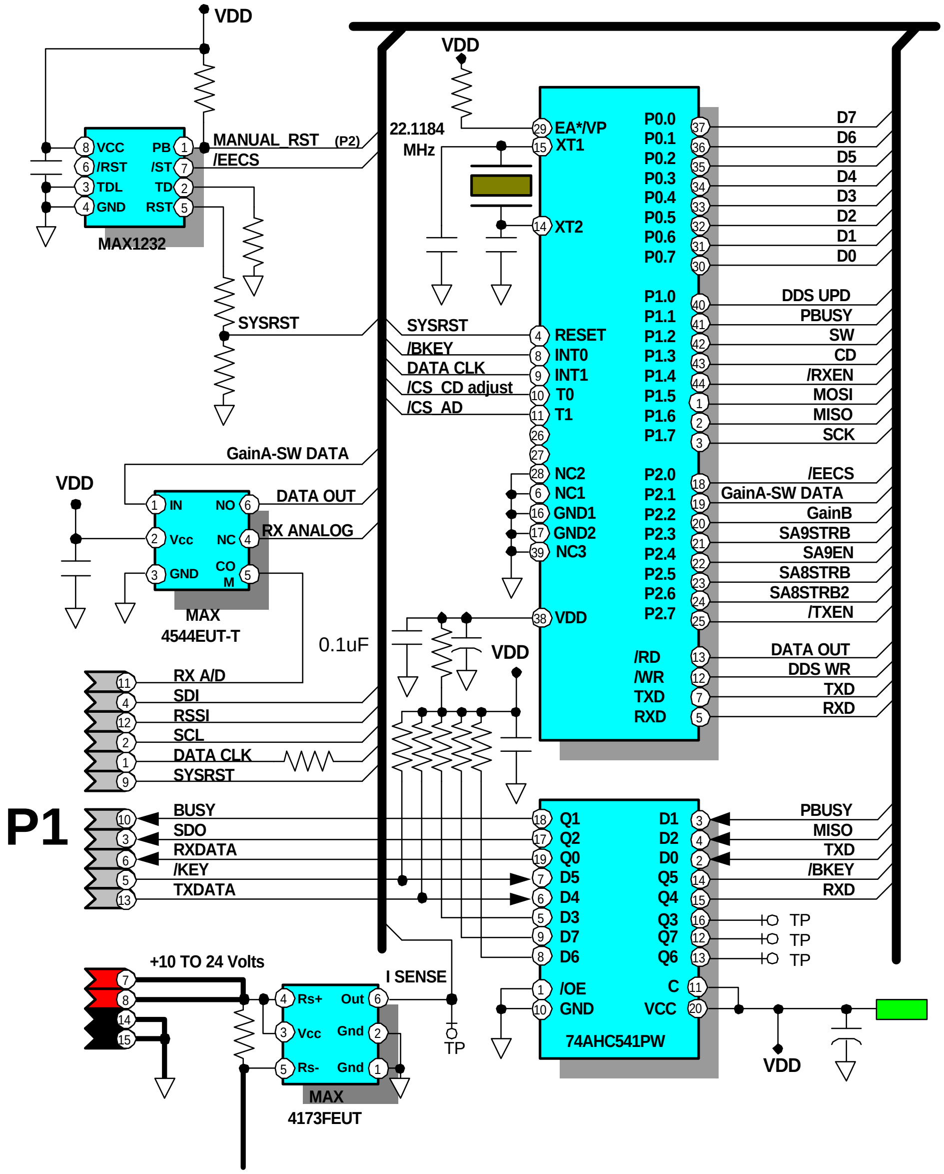


Figure 12

The micro-controller performs the following function:

1- As a communication interface between the modulator and the external encoder board.

2- Digitally controls the FSK modulator.

3- Controls sleep, standby and active mode of several IC’s with the proper timing.

4- Reads the information from the A/D converter.

2.6 DC Power Supply

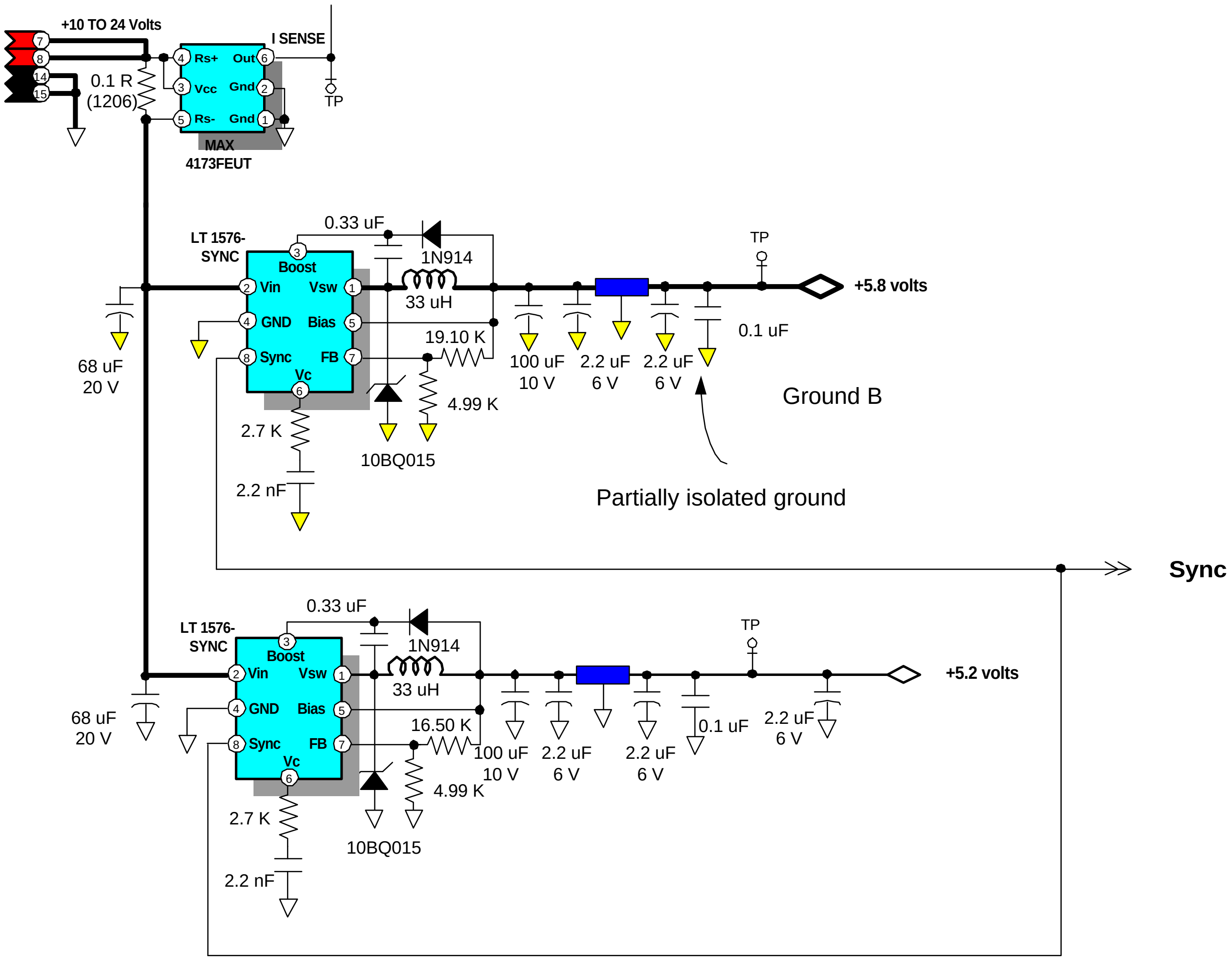


Figure 13

Two DC/DC converters distribute the DC supply. Sections of the radio are isolated from each other by the supply and partially by the ground. The ground is partially isolated to intentionally force a path to the ground current to prevents disturbing other circuits.

All circuits that are related to the RF output from the up-converter to the power amplifier are connected to the 5.8 Volts. The 5.2 volts DC supplies a few low drop out (LDO) regulators in parallel. Each LDO supplies a different section of the radio.

3.0 Transmitter Control Software Description

3.1- Advanced Test Jig:

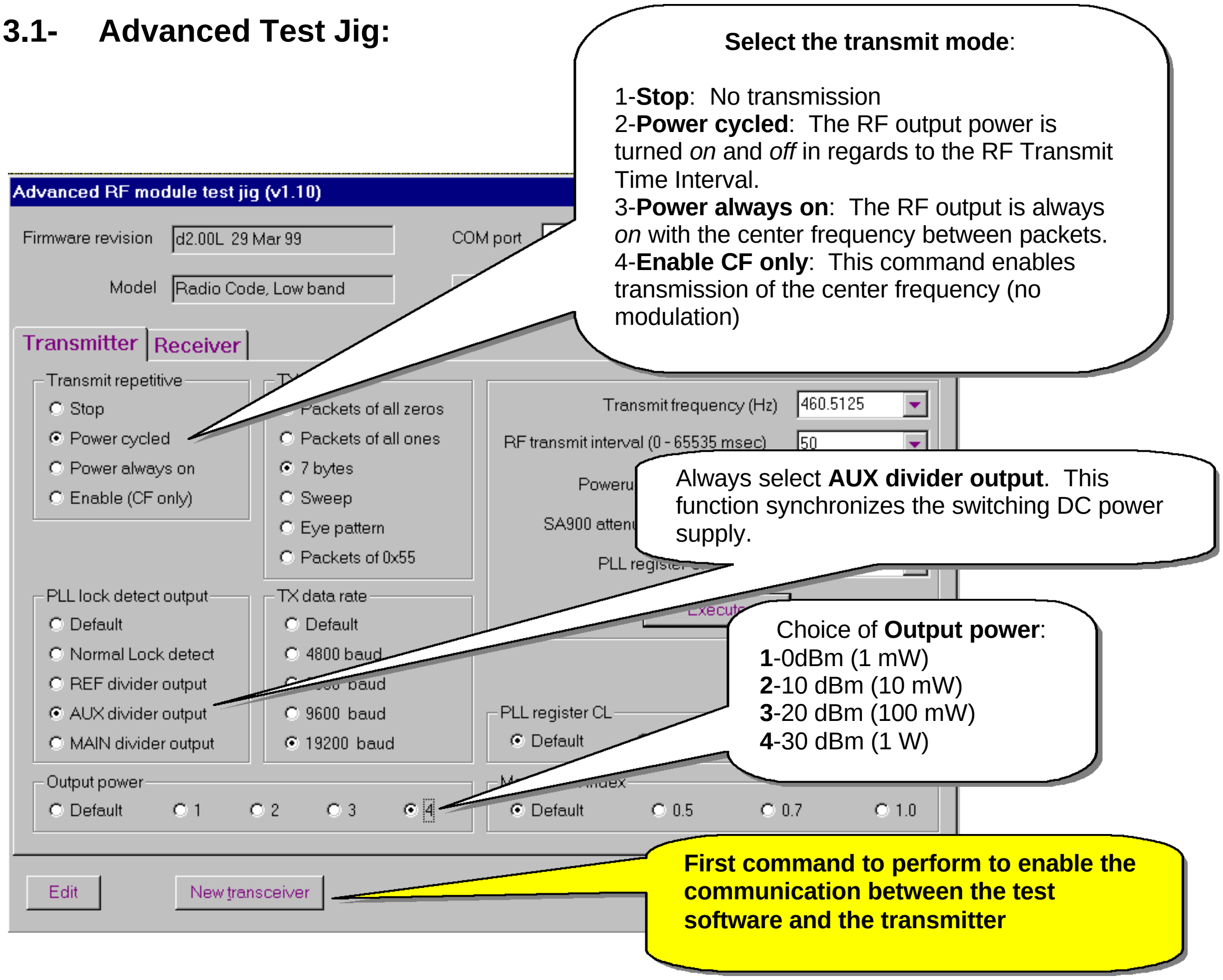


Figure 14

The Advanced RF module test jig allows the engineer or technician to have access and control to most of the parameters of the transmitter and receiver. The first step is to initiate the **New transceiver** command; the Firmware revision and the Model should appear at the top.

The second step is to select the output frequency in the format 465.5125. The dot is important and the frequency can be entered in directly.

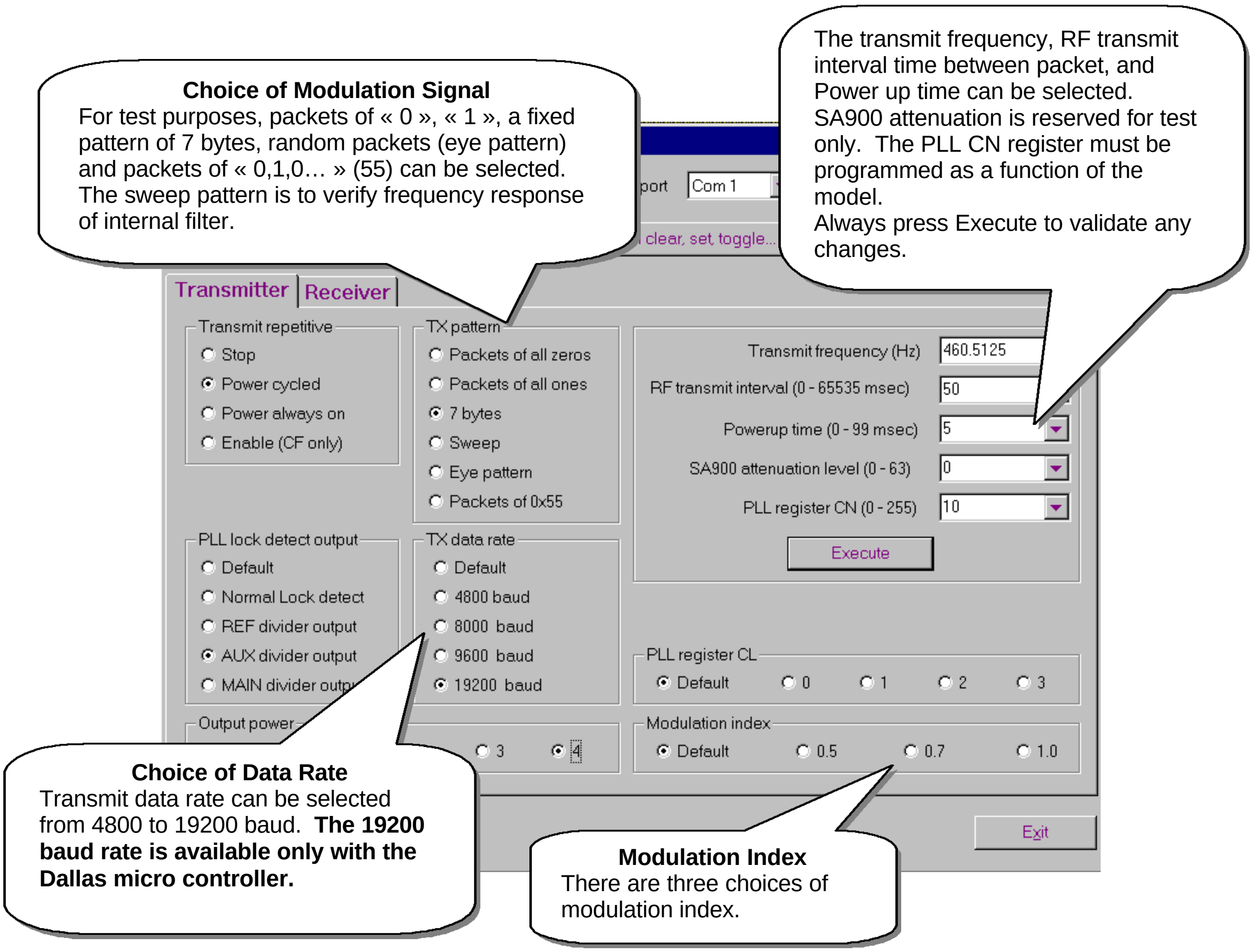

Choice of Modulation Signal
For test purposes, packets of « 0 », « 1 », a fixed pattern of 7 bytes, random packets (eye pattern) and packets of « 0,1,0… » (55) can be selected. The sweep pattern is to verify frequency response of internal filter.
The transmit frequency, RF transmit interval time between packet, and Power up time can be selected. SA900 attenuation is reserved for test only. The PLL CN register must be programmed as a function of the model.
Always press Execute to validate any changes.
port
Com 1
clear, set, toggle...
Transmitter
Receiver
Transmit repetitive
Stop
Power cycled
Power always on
Enable (CF only)
TX pattern
Packets of all zeros
Packets of all ones
7 bytes
Sweep
Eye pattern
Packets of 0x55
Transmit frequency (Hz)
460.5125
RF transmit interval (0 - 65535 msec)
50
Powerup time (0 - 99 msec)
5
SA900 attenuation level (0 - 63)
0
PLL register CN (0 - 255)
10
Execute
PLL lock detect output
Default
Normal Lock detect
REF divider output
AUX divider output
MAIN divider outp
TX data rate
Default
4800 baud
8000 baud
9600 baud
19200 baud
PLL register CL
Default
0
1
2
3
Output power
3
4
Modulation index
Default
0.5
0.7
1.0
Exit
Choice of Data Rate
Transmit data rate can be selected from 4800 to 19200 baud. The 19200 baud rate is available only with the Dallas micro controller.
Modulation Index
There are three choices of modulation index.

Figure 15

4.0 Test Procedure

The test procedure consists of adjusting the TCXO frequency and verifying all of the parameters required for normal operation.

Temperature testing will be carried out on 10% of the production and a burn-in of 12 hours at 60^{o}C will be done on all of the radios before the testing. All measurements will be noted on a spreadsheet for each radio.

4.1 Programming and TCXO Adjustment

4.1.1 Set-up

Test # 1 consists of programming the radio with test firmware 3FSK.bin and adjusting the TCXO. The following set-up is required:

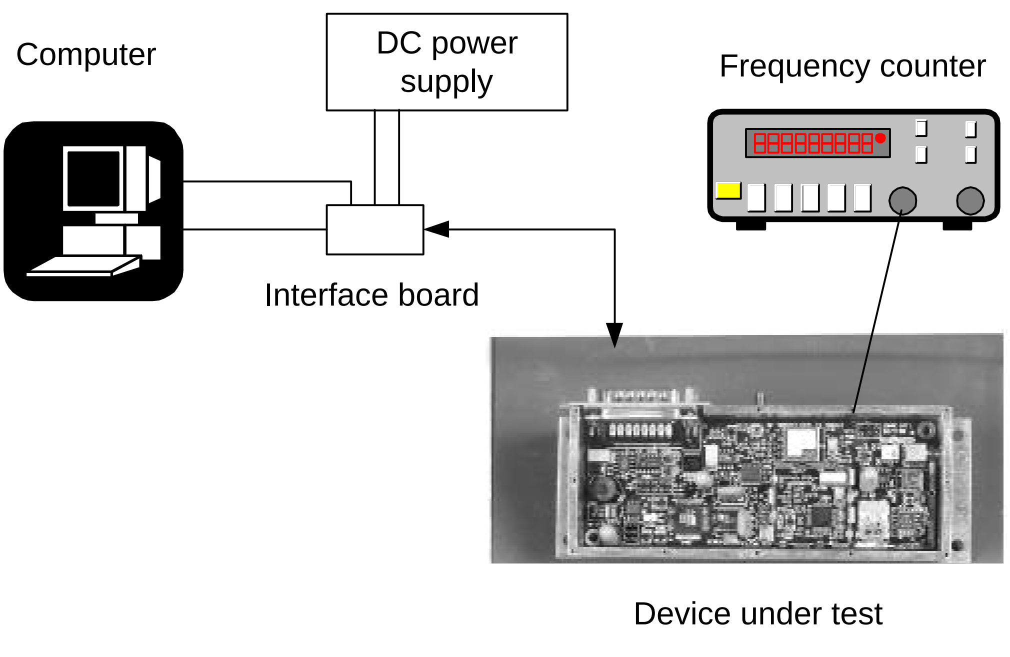


Figure 16

Description of the test jig for adjusting the TCXO

The computer needs the following programs:

- TestComJig.exe Window software for testing
- Software for the ATMEL 8953 and adapter
- Spread sheet software, ex. Excel
- CANAC test firmware 3FSK.bin, BURN.

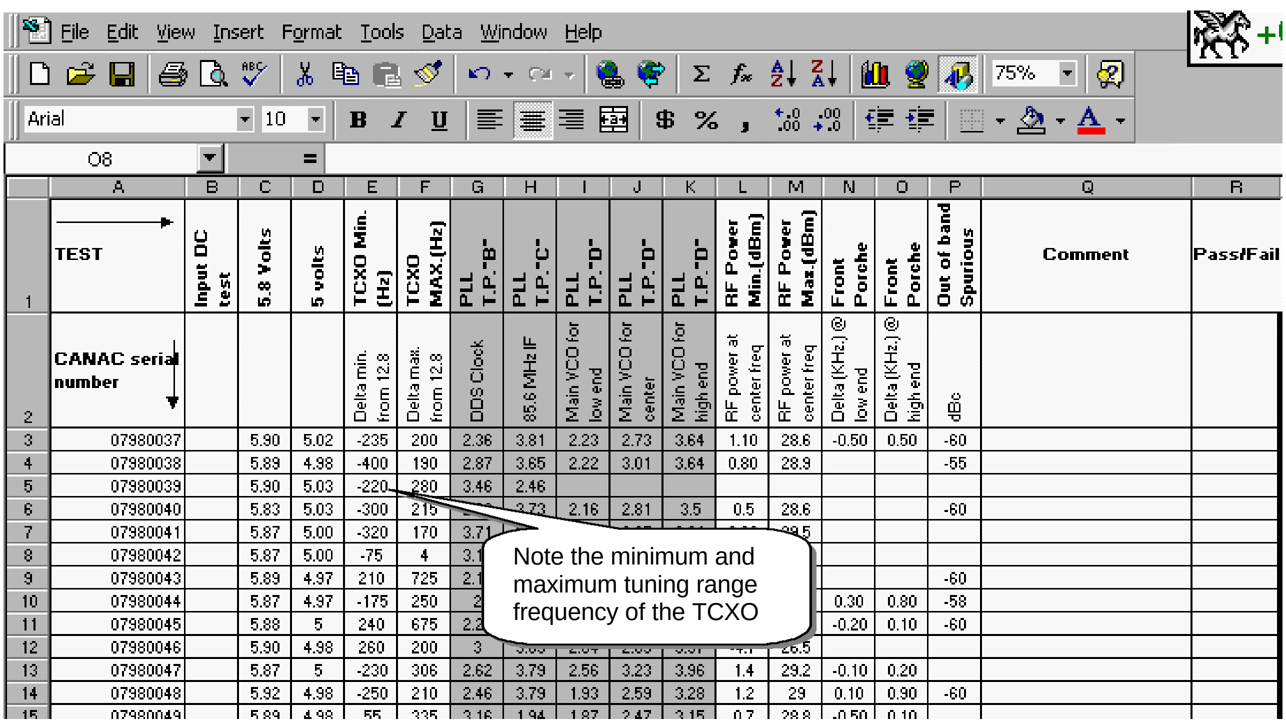
The DC power supply must provide at least 15 volts @ 1 amp. well regulated. The interface board is supplied by CANAC.

4.1.2 Procedure

1- Connect the device under test (D.U.T.) as shown in figure 16 and turn on the power supply. With a voltmeter, measure 5.8 volts +/- 5 % at TP 13. Next, measure 5.2 volts +/- 5 % at TP 1.

2- Download the CANAC test firmware to the radio; 3FSK.bin.

3- Connect a scope probe on pin 7 of P2 to a frequency counter and note the minimum and maximum frequency of the TCXO by adjusting R37 (Figure 11). Check and note the minimum and maximum tuning range of the TXCO, then adjust the frequency to 12.8 MHz better than +/- 4 Hz.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	TEST →	Input DC test	5.8 Volts	5 volts	TCXO Min. (Hz)	TCXO MAX.(Hz)	PLL T.P."B"	PLL T.P."C"	PLL T.P."D"	PLL T.P."D"	PLL T.P."D"	RF Power Min.(dBm)	RF Power Max.(dBm)	Front Porche	Front Porche	Out of band Spurious	Comment	Pass/Fail
2	CANAC serial number ↓				Delta min. from 12.8	Delta max. from 12.8	DDS Clock	85.6 MHz IF	Main VCO for low end	Main VCO for center	Main VCO for high end	RF power at center freq	RF power at center freq	Delta (KHz.) @ low end	Delta (KHz.) @ high end	dBc		
3	07980037		5.90	5.02	-235	200	2.36	3.81	2.23	2.73	3.64	1.10	28.6	-0.50	0.50	-60		
4	07980038		5.89	4.98	-400	190	2.87	3.65	2.22	3.01	3.64	0.80	28.9			-55		
5	07980039		5.90	5.03	-220	280	3.46	2.46										
6	07980040		5.83	5.03	-300	215	[illegible]	3.73	2.16	2.81	3.5	0.5	28.6			-60		
7	07980041		5.87	5.00	-320	170	3.71	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	29.5					
8	07980042		5.87	5.00	-75	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					
9	07980043		5.89	4.97	210	725	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			-60		
10	07980044		5.87	4.97	-175	250	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.30	0.80	-58		
11	07980045		5.88	5	240	675	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.20	0.10	-60		
12	07980046		5.90	4.98	260	200	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	26.5					
13	07980047		5.87	5	-230	306	2.62	3.79	2.56	3.23	3.96	1.4	29.2	-0.10	0.20			
14	07980048		5.92	4.98	-250	210	2.46	3.79	1.93	2.59	3.28	1.2	29	0.10	0.90	-60		
15	07980049		5.89	4.98	55	335	3.16	1.94	1.87	2.47	3.15	0.7	28.8	-0.50	0.10			

Figure 17

This figure is an example of the information accumulated on each transmitter.

4.3 Synthesizer Verification

This verification is to confirm the proper operation of the radio by verifying the range of operation of each PLL.

4.3.1 Set-up

Test # 2 consists of measuring and noting on the spreadsheet the two PLL control voltages when locked (Figure 17). The RF test frequency is a function of the model number; for a 450 to 460 MHz radio, tests will be carried out at 450.0000, 455.0000 and 460.0000 MHz. Always choose the minimum, middle and maximum operating frequency for a given model number.

Set the transmitter in continuous mode with no modulation by enabling CF (center frequency) only. The next figure shows the command to select and the result on the spectrum analyzer for this test

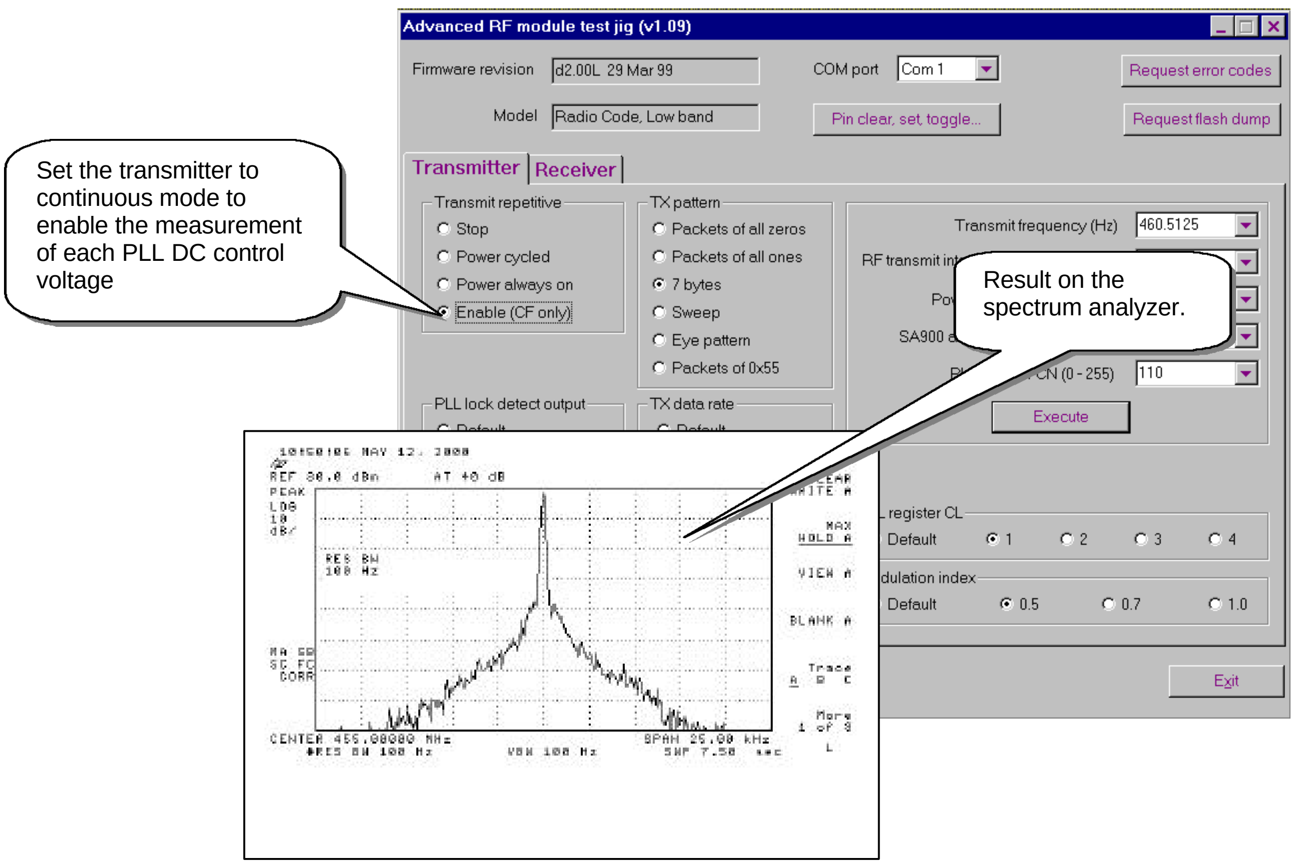


Figure 18

4.3.2 Procedure

1- The first PLL control voltage: This is the 153.6 MHz PLL and the measurement is at TP10. This PLL always remains at the same frequency.
2- The second PLL control voltage: This is the main VCO (IF + RF output frequency) and the measurement is at TP8. Note the control voltage for the minimum, middle and maximum frequency.

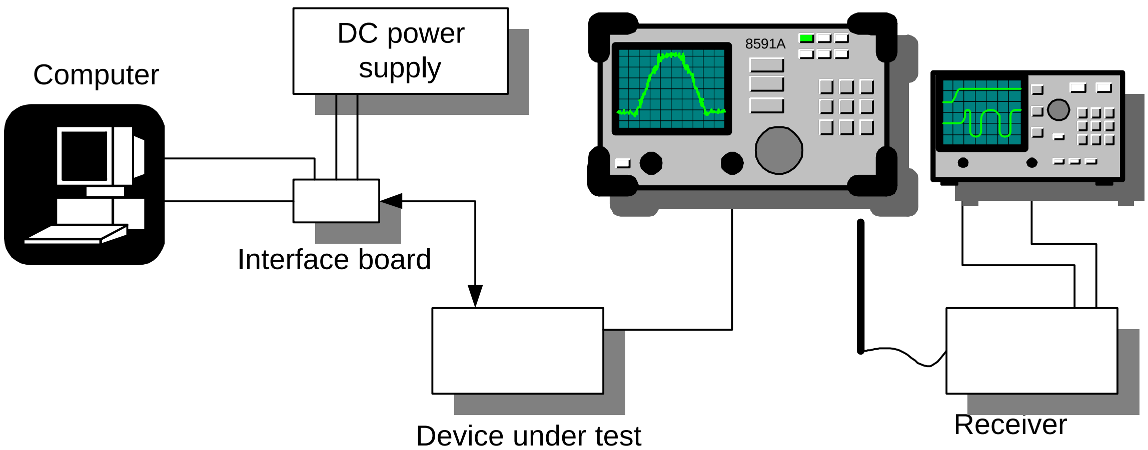
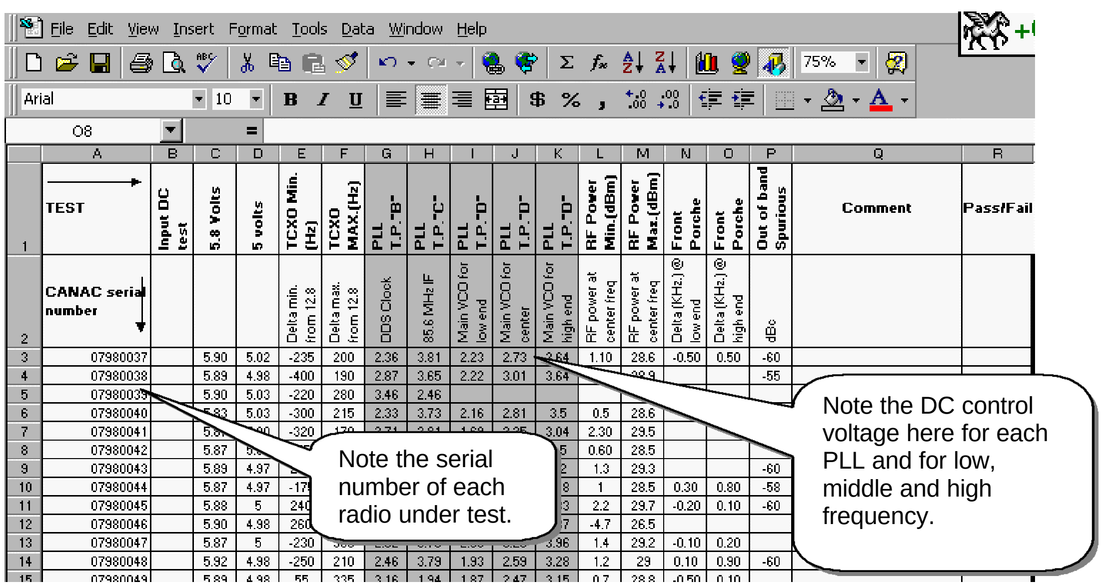


Figure 19

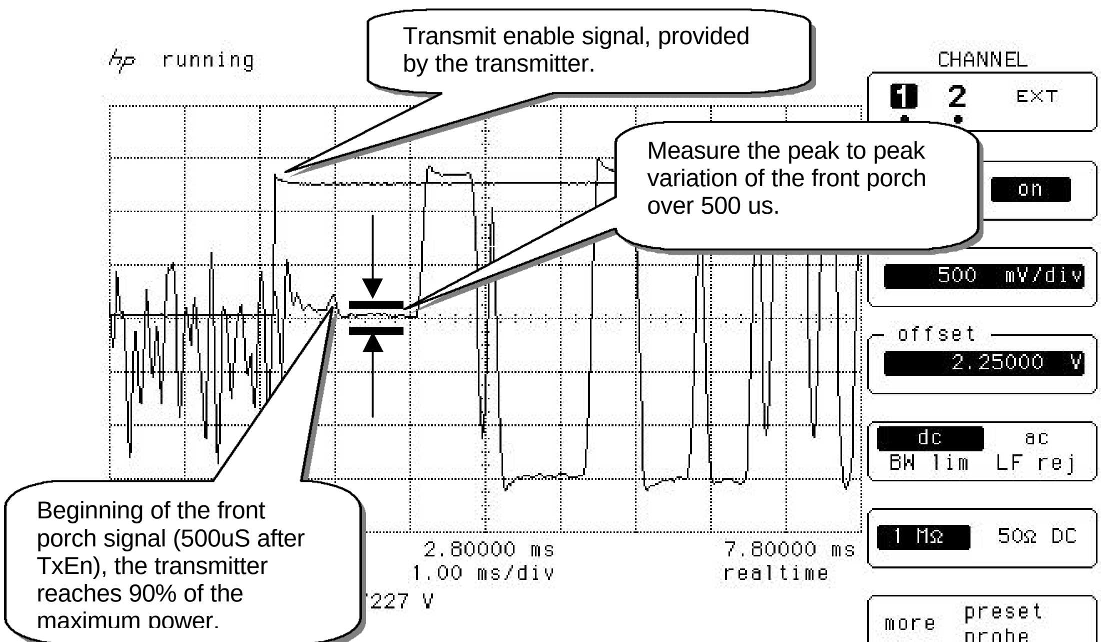


	A: TEST → / CANAC serial number ↓	B: Input DC test	C: 5.8 Volts	D: 5 volts	E: TCXO Min. (Hz) / Delta min. from 12.8	F: TCXO MAX.(Hz) / Delta max. from 12.8	G: PLL T.P."B" / DDS Clock	H: PLL T.P."C" / 85.6 MHz IF	I: PLL T.P."D" / Main VCO for low end	J: PLL T.P."D" / Main VCO for center	K: PLL T.P."D" / Main VCO for high end	L: RF Power Min.(dBm) / RF power at center freq	M: RF Power Max.(dBm) / RF power at center freq	N: Front Porche / Delta (KHz.) @ low end	O: Front Porche / Delta (KHz.) @ high end	P: Out of band Spurious / dBc	Q: Comment	R: Pass/Fail
3	07980037		5.90	5.02	-235	200	2.36	3.81	2.23	2.73	2.64	1.10	28.6	-0.50	0.50	-60		
4	07980038		5.89	4.98	-400	190	2.87	3.65	2.22	3.01	3.64	[illegible]	[illegible]			-55		
5	07980039		5.90	5.03	-220	280	3.46	2.46										
6	07980040		[illegible]	5.03	-300	215	2.33	3.73	2.16	2.81	3.5	0.5	28.6	[illegible]	[illegible]	[illegible]		
7	07980041		[illegible]	[illegible]	-320	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.04	2.30	29.5			[illegible]		
8	07980042		5.87	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.60	28.5			[illegible]		
9	07980043		5.89	4.97	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.3	29.3			-60		
10	07980044		5.87	4.97	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	28.5	0.30	0.80	-58		
11	07980045		5.88	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.2	29.7	-0.20	0.10	-60		
12	07980046		5.90	4.98	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-4.7	26.5					
13	07980047		5.87	5	-230	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.96	1.4	29.2	-0.10	0.20			
14	07980048		5.92	4.98	-250	210	2.46	3.79	1.93	2.59	3.28	1.2	29	0.10	0.90	-60		
15	07980049		5.89	4.98	55	335	3.16	1.94	1.87	2.47	3.15	0.7	28.8	-0.50	0.10			

Figure 20

4.4 Frequency Pulling Verification.

Test # 3 consists of measuring and noting on the spreadsheet the peak-to-peak voltage or the equivalent frequency variation of the front porch signal of the demodulated signal. This will help to characterise the pulling effect at the beginning of a transmission. The limit for Canac systems is +/- 400 Hz.



$$\frac{\text{(Peak to peak variation of the front porch)}}{\text{(Peak to peak DATA voltage)}} \times \frac{\text{Baud rate}}{2}$$

Figure 21

This figure shows how to measure the front porch variation.

4.5 Temperature Testing.

Test # 4 consists of measuring and noting the variation of the output frequency versus temperature. Load the burn-in software for this test.

4.5.1 Set up

Refer to the set up in figure 22 and install the DUT inside the temperature chamber.

4.5.2 Procedure

1. Bring the temperature to –40°C. Allow 5 minutes for stabilisation. Turn on the power supply. After 5 minutes, measure the output frequency with a 1 GHz frequency counter (in continuous mode low power).

2. Tests can be carried out in groups of ten radios. Prepare ten radios with the burn-in software and connect each radio to the DC power supply at the same time. Install all the powered radios inside the temperature chamber and perform frequency measurements as follows on each radio.

3. Stop the cooling system, and note the RF frequency at each 10 ° up to + 60 °C by connecting the RF output to a frequency counter. Fill the temperature test spread sheet (TT1-2MOD-6558) prepared for this purpose.

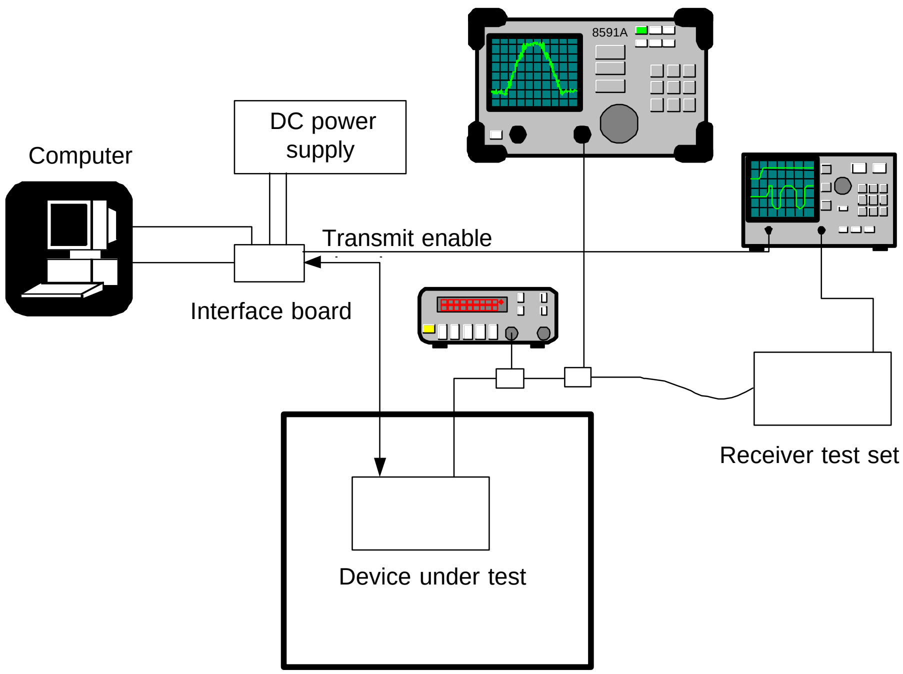


Figure 22

4.6 Out of Band Spurious Emission

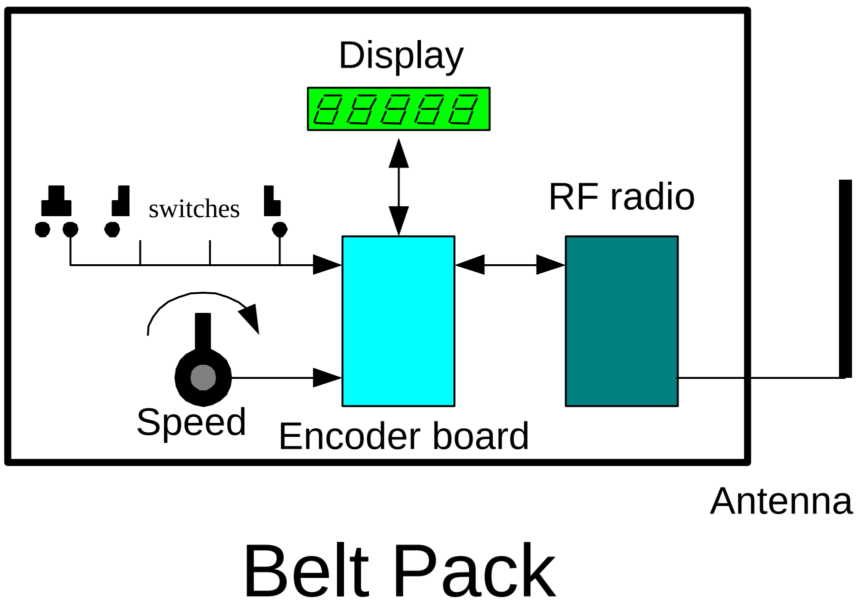
Set the radio for normal operation. Set the SPAN of the spectrum analyzer to **500 MHz** with a resolution bandwidth of 30 KHz at a CENTER FREQ of the test frequency and note the maximum peak energy of any spurious with the MAX HOLD function after 30 seconds.

5.0 FCC Test Report

5.1 Introduction

The radio was tested as a stand-alone unit for the purposes of this report. However, the main application is to transmit data from a CANAC communication board (encoder board) installed in an enclosure (OCU) to remotely control locomotives.

The block diagram of the OCU is shown below.



List of equipment used to prepare the test report:

1- Hewlett Packard 8591A, 1.8 GHz spectrum

2- Hewlett Packard 54504A, digitising oscilloscope

3- Hewlett Packard 5315A, 1 GHz frequency counter

4- Xantrex DC power supply, LQX 30-2

5- Laptop computer (PC Compatible)

RS-232 interface (made by CANAC).

Temperature Chamber: REVCO, VIT-350-A-N-G, from Rheem Manufacturing.

Receiver Test set equipment:, HP 8920B

The Federal Communication Commission Part 90 (10-1-97 Edition) was the reference for this test report.

5.2 Transmitter External Controls:

This radio does not have any external controls and all the parameters like frequency of operation are pre-set by the equipment supplier.

5.3 Supply Voltage and Temperature:

The tests were performed at 15 volts. Proper operation was verified from 12 to 15 volts, which are the voltage, span of the battery in the OCU. Operation was verified from -40^{o}C to +60^{o}C.

5.4 Typical Output Power:

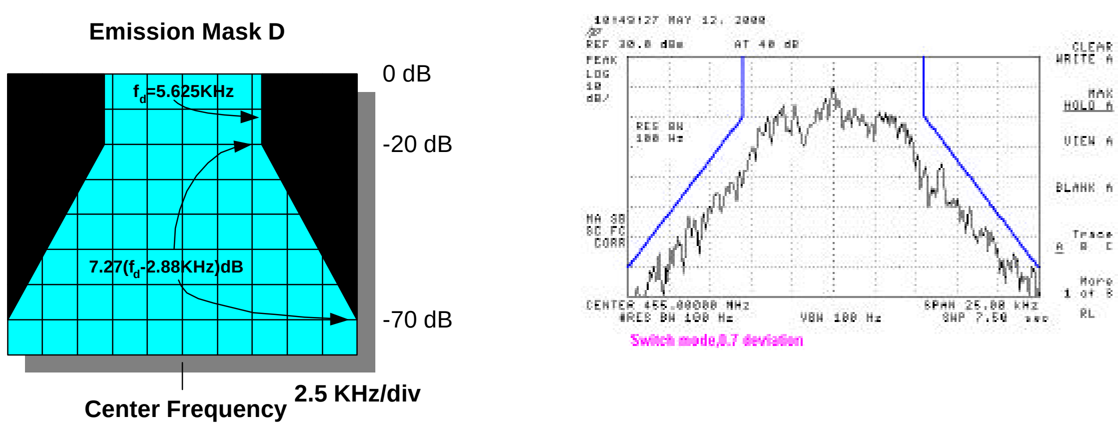
The typical output power measured from the OCU and RPU transmitter is 1 Watt +/- 1 dB.

5.5 Channel Spacing, Authorised Bandwidths, Spectrum Mask and Results:

This radio is intended to be used in a 12.5 KHz channel spacing at 9600 baud (Emission mask D).

Figure 23 A represents the template used in the test and the measured spectrum.

Figure 23 B represents the measured spectrum with a pseudo-random sequence at 9600 Baud in pulse mode.



Figures 23A and 23B

5.6 Spurious Emission

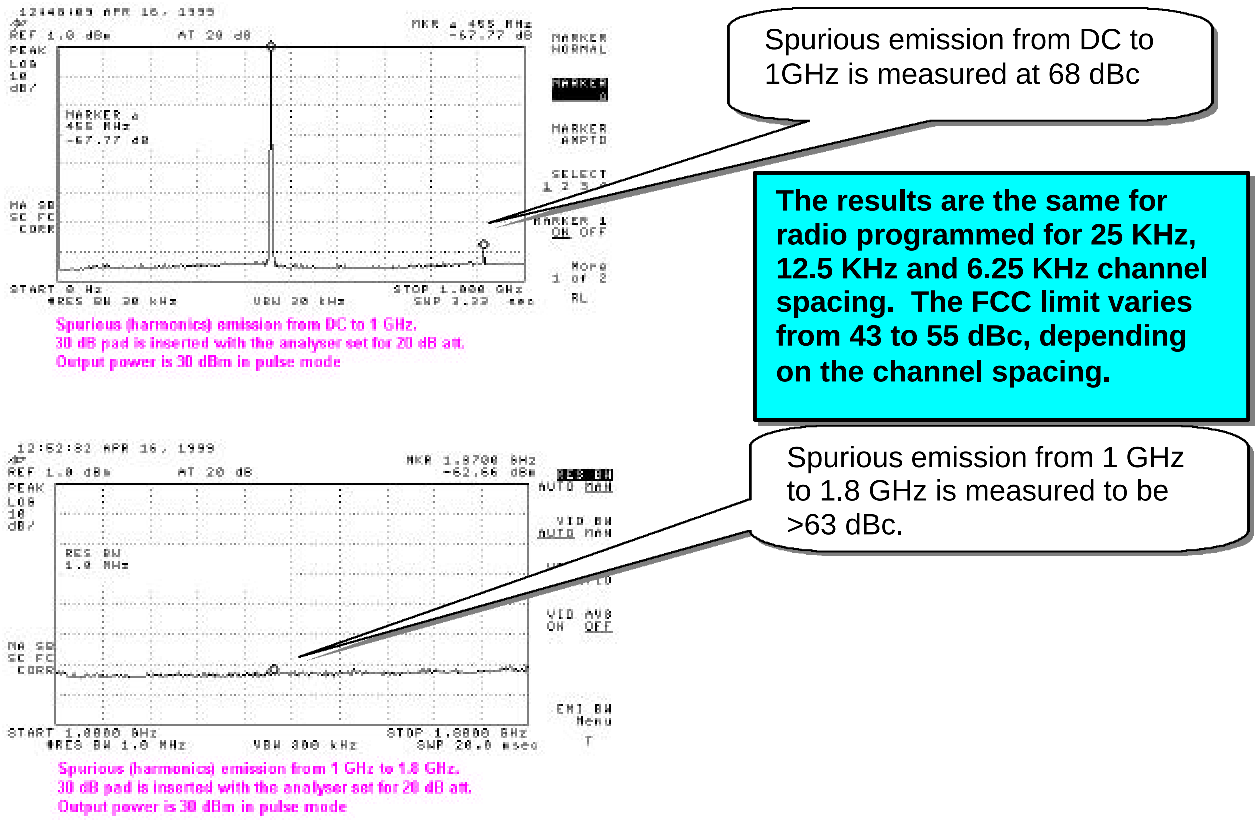
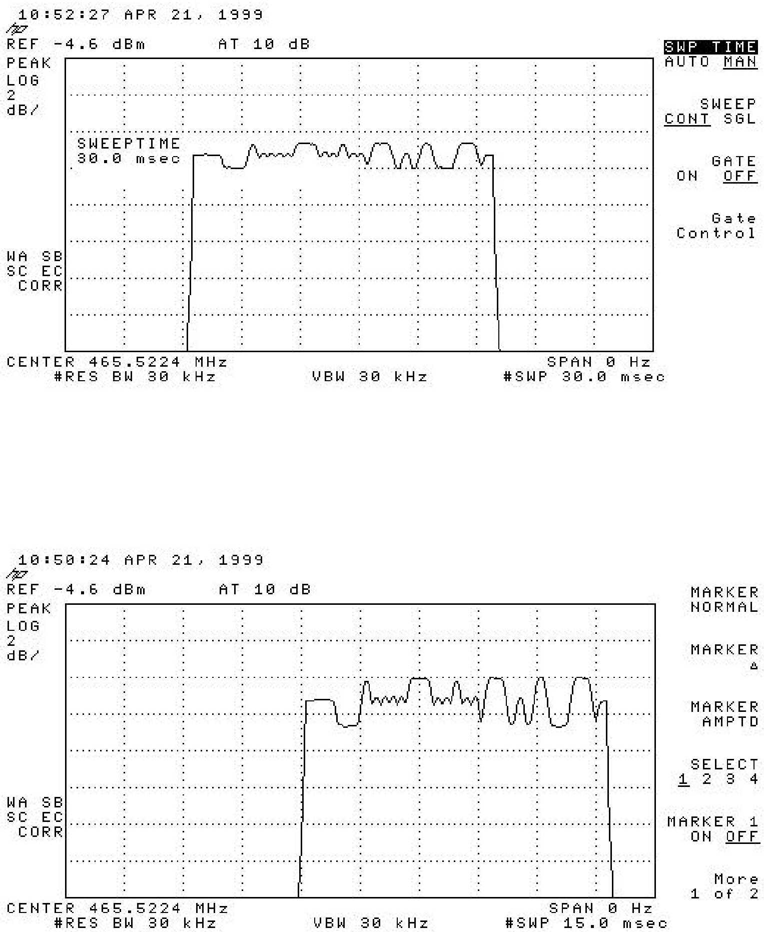


Figure 24

Note: To avoid measuring distortions produced by the spectrum analyzer, a 30 dB pad was used between the transmitter and the equipment. Care was taken to set the spectrum attenuator to 20 dB. The transmitter was set for 1 Watt output.

5.7 Transient Frequency Behaviour

After the transmit signal is enabled (PTT), the RF pulse shaping function takes place over 5 bits time at center frequency. The transmitter is already stable during this time therefore no transient frequency behaviour need be measured later.



The spectrum analyzer is used to demodulate the RF signal in zero SPAN. The center Frequency is slightly untuned to transform FM into AM with a RES BW large enough to include all the modulation frequencies.

The signal transmitted is a 3 FSK partial response for a duration of 7 bytes at 4800 baud (TOP) and 9600 baud (bottom).

It can be seen that the frequency is stable at the beginning of the transmission.

Figure 25

5.8 Voice Input

There is no voice input to this model.

5.9 Frequency Stability

The reference frequency at 12.8 MHz (TCXO) is purchased at 2.5 ppm for 25 and 12.5 KHz channel spacing. For 6.25 KHz channel spacing, a 1 ppm TCXO is purchased.

Temperature tests on several radios were carried out to ensure that the system operates over the required temperature range (–40^{o}C to +60^{o}C).

5.9 Difference Between Models

5.9.1 RF Output Frequency

The RF Transmitter board # 2PCB-6558-B0 can be populated for 400 MHz or 800 MHz applications. In each application, the bandwidth is separated into sub-bands.

1- To build a 450 to 460 MHz radio (Transmitter board **# 2PCB-6558-B411 and B421**), these modifications are needed:

- The main VCO needs to oscillate between 540 and 550 MHz and an extra 10 MHz on each side.
- Install a Helical filter (FILT2) at the output of SA900 to pass 455 +/- 5 MHz.

2- To build a 460 to 470 MHz radio (Transmitter board **# 2PCB-6558-B411 and B421**), these modifications are needed:

- The main VCO needs to oscillate between 550 and 560 MHz and an extra 10 MHz on each side.

Install a Helical filter (FILT2) at the output of SA900 to pass 465 +/- 5 MHz.