VersaBeacon Project

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1 Project Overview

1.1 The Idea

This project began as one of those "Here's a neat chip, what can we do with it?" conversations and grew from there. The heart of the beacon is a relatively new Direct Digital Synthesis(DDS) chip from Analog Devices. The original idea was to use some of the unique features of this DDS chip to implement a simple FSK441 Meteor Scatter beacon. From there it turned into a much more capable and "versatile" signal source.

1.2 Overview

The VersaBeacon is a frequency agile, modulation agile RF source using a DDS chip and minimal support circuitry. It covers a frequency span of 1MHz to 150MHz in 1 Hz steps and provides a variety of modulations including OOK CW, FSK CW, FM CW, FSK441, PSK31, RTTY, and other modes that can be created using phase or frequency modulation.

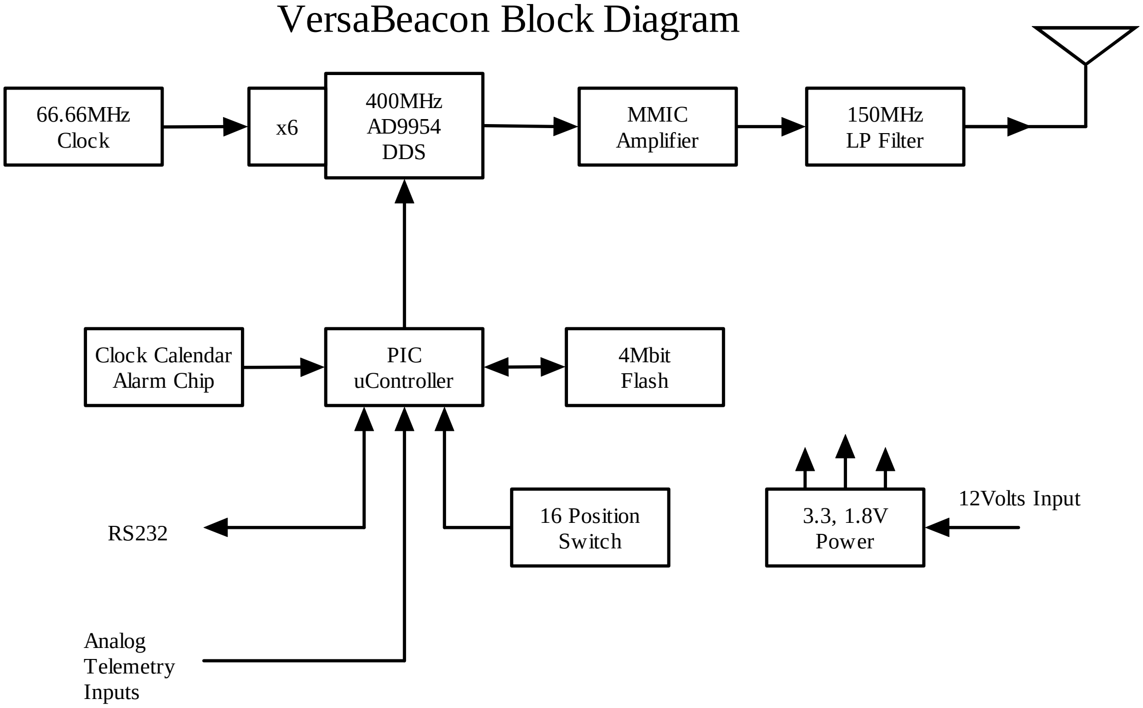
Stored messages can be sent using any of the modulation modes on any frequency continuously or at specified timed intervals. Most modes can also be sent live by sending text using the RS232 serial port and a simple terminal program running on a PC or laptop.

Using the A/D inputs of the Beacon, telemetry data can also be inserted into canned messages such as temperature or battery voltage.

The Beacons firmware or message data is easily updated or customized by downloading new code using the RS232 port.

The beacon's primary components consist of a DDS chip, a PIC processor chip, a 4Mbit FLASH memory chip, and a clock calendar alarm chip.

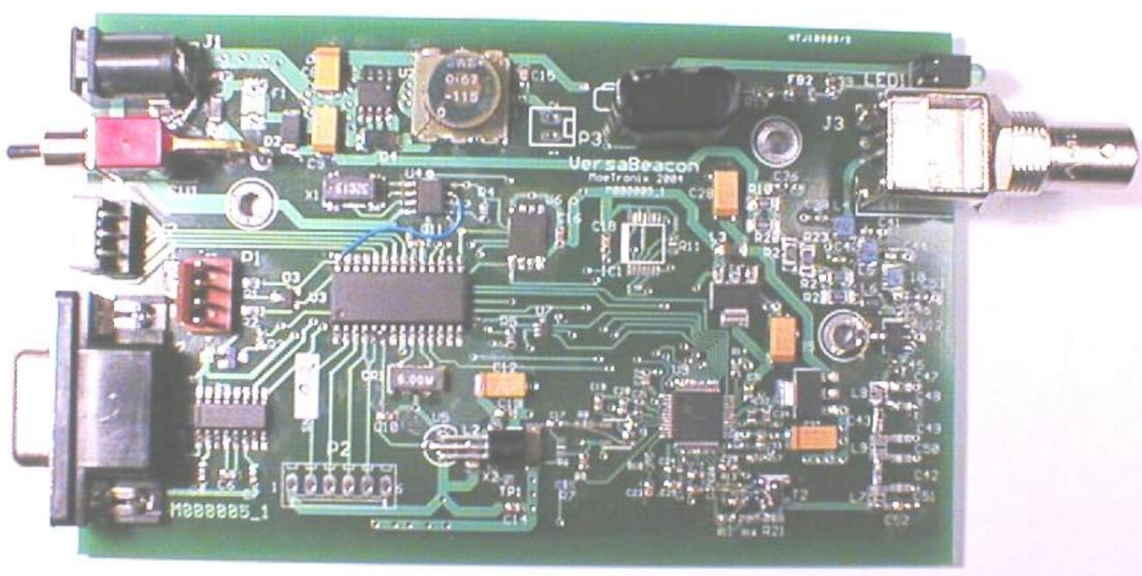
VersaBeacon Block Diagram

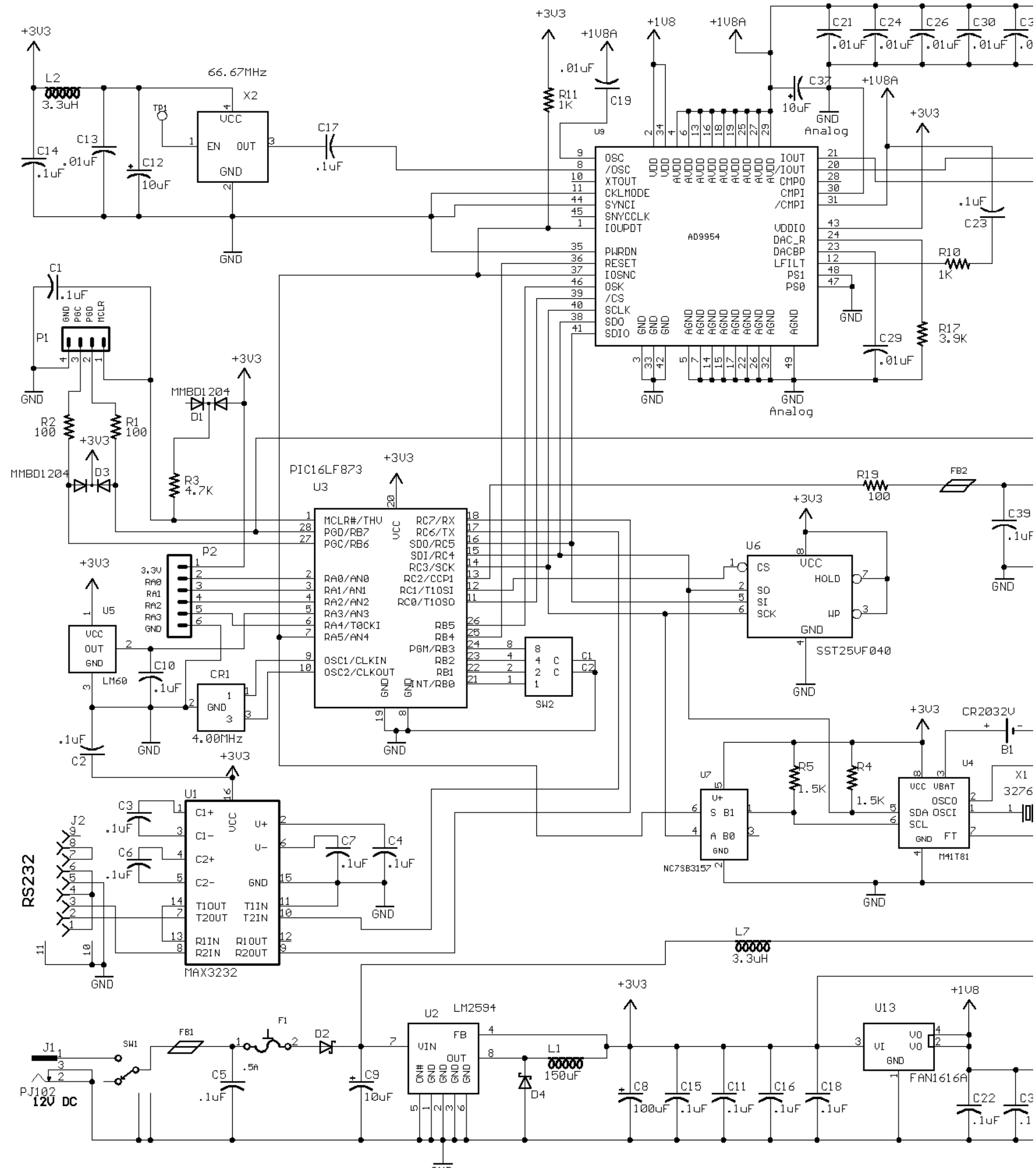


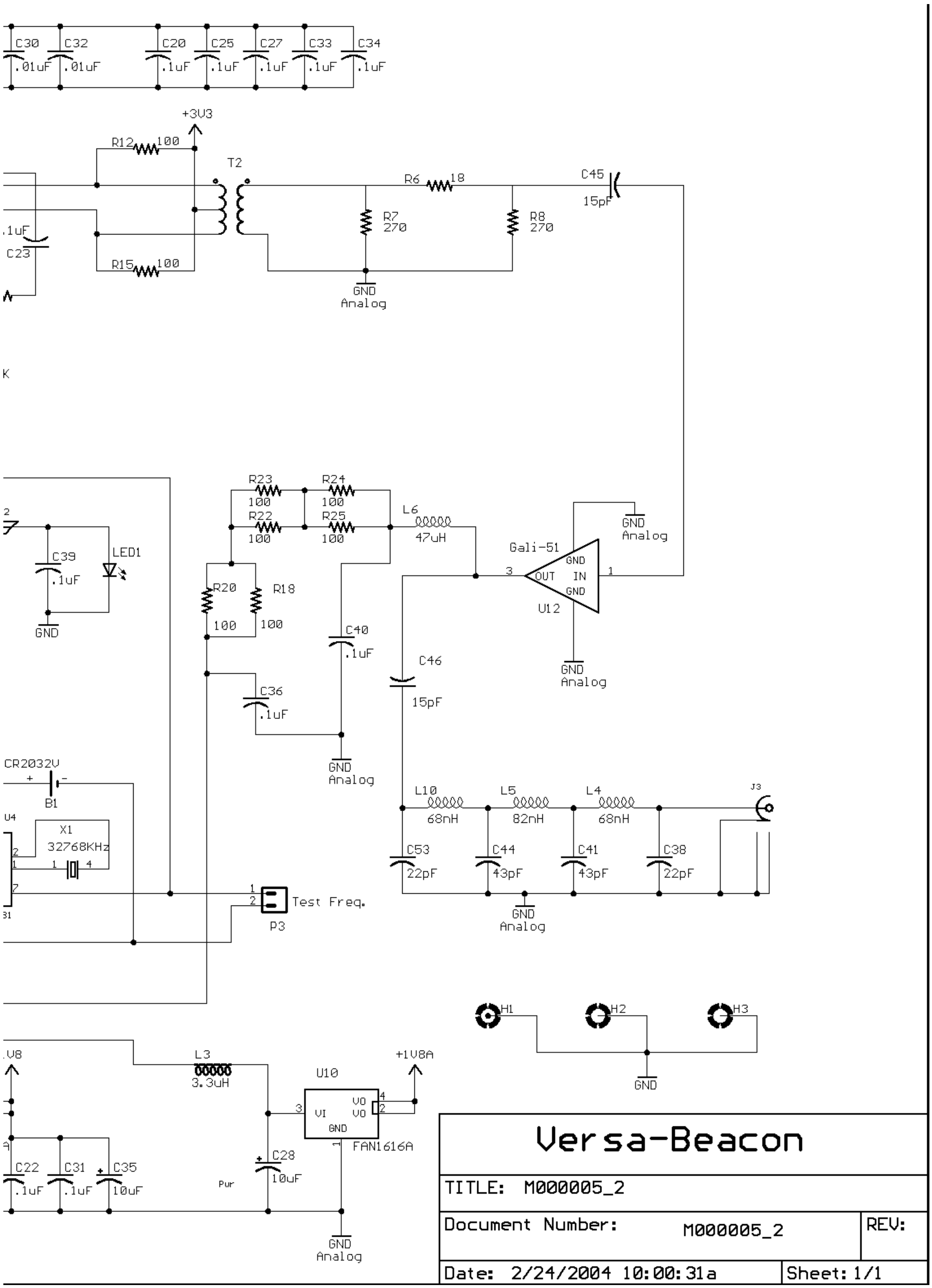
A small PIC microcontroller is used to control the DDS chip over a 3 wire serial port.

The PIC only has 16Kbytes of internal memory so an external 4Mbit serial flash chip is used to provide a lot more storage saving the PIC memory for actual program use.

A 16 position rotary switch can be used to select various program settings.
The PCB is 2.95" by 4.72"(Fits into a Hammond 1455K1202 extruded case)




+3V3
L2
3.3uH
C14
.1uF
C13
.01uF
C12
10uF
TP1
66.67MHz
X2
VCC
EN
OUT
GND
C17
.1uF
R11
1K
.01uF
C19
+1V8
+1V8A
C21
C24
C26
C30
.01uF
C37
10uF
GND
Analog
U9
AD9954
OSC
/OSC
XTOUT
CKLMODE
SYNCI
SNYCCLK
IOUPDT
PWRDN
RESET
IOSNC
OSK
/CS
SCLK
SDO
SDIO
IOUT
/IOUT
CMPO
CMPI
/CMPI
VDDIO
DAC_R
DACBP
LFILT
PS1
PS0
AGND
AVDD
VDD
C23
R10
C29
R17
3.9K
C1
P1
GND
PGC
PGD
MCLR
R2
100
R1
MMBD1204
D1
D3
R3
4.7K
PIC16LF873
U3
MCLR#/THV
PGD/RB7
PGC/RB6
RA0/AN0
RA1/AN1
RA2/AN2
RA3/AN3
RA4/T0CKI
RA5/AN4
OSC1/CLKIN
OSC2/CLKOUT
RC7/RX
RC6/TX
SDO/RC5
SDI/RC4
RC3/SCK
RC2/CCP1
RC1/T1OSI
RC0/T1OSO
RB5
RB4
PGM/RB3
RB2
RB1
INT/RB0
P2
3.3V
RA0
RA1
RA2
RA3
U5
LM60
C10
CR1
4.00MHz
C2
SW2
R19
FB2
C39
U6
CS
SO
SI
SCK
HOLD
WP
SST25VF040
CR2032V
B1
U4
M41T81
VBAT
OSCO
OSCI
SDA
SCL
FT
X1
R5
1.5K
R4
U7
NC7SB3157
U1
MAX3232
C1+
C1-
C2+
C2-
V+
V-
T1OUT
T2OUT
R1IN
R2IN
T1IN
T2IN
R1OUT
R2OUT
C3
C6
C7
C4
J2
RS232
L7
J1
PJ102
12V DC
SW1
FB1
F1
.5A
D2
C5
C9
U2
LM2594
VIN
FB
ON#
L1
150uF
D4
C8
100uF
C15
C11
C16
C18
U13
FAN1616A
VI
VO
C22


C30 .01uF
C32 .01uF
C20 .1uF
C25 .1uF
C27 .1uF
C33 .1uF
C34 .1uF
+3V3
R12 100
T2
R6 18
C45 15pF
.1uF C23
R7 270
R8 270
R15 100
GND Analog
R23 100
R24 100
R22 100
R25 100
L6 47uH
GND Analog
Gali-51
3 OUT IN 1
GND
U12
C39 .1uF
LED1
GND
R20 100
R18 100
C40 .1uF
C46 15pF
C36 .1uF
GND Analog
CR2032V
B1
U4
X1 32768KHz
L10 68nH
L5 82nH
L4 68nH
J3
C53 22pF
C44 43pF
C41 43pF
C38 22pF
Test Freq.
P3
GND Analog
H1
H2
H3
GND
L3 3.3uH
U10
+1V8A
VI VO VO GND
FAN1616A
C22 .1uF
C31 .1uF
C35 10uF
C28 10uF
GND Analog
Versa-Beacon
TITLE: M000005_2
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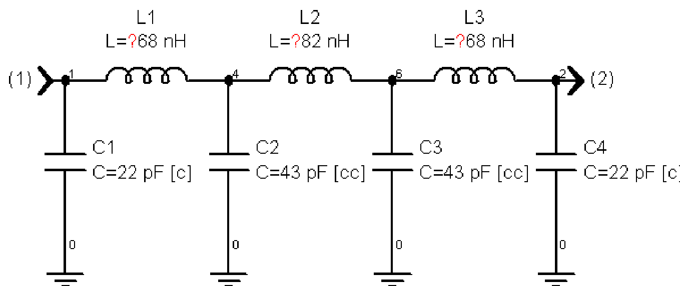
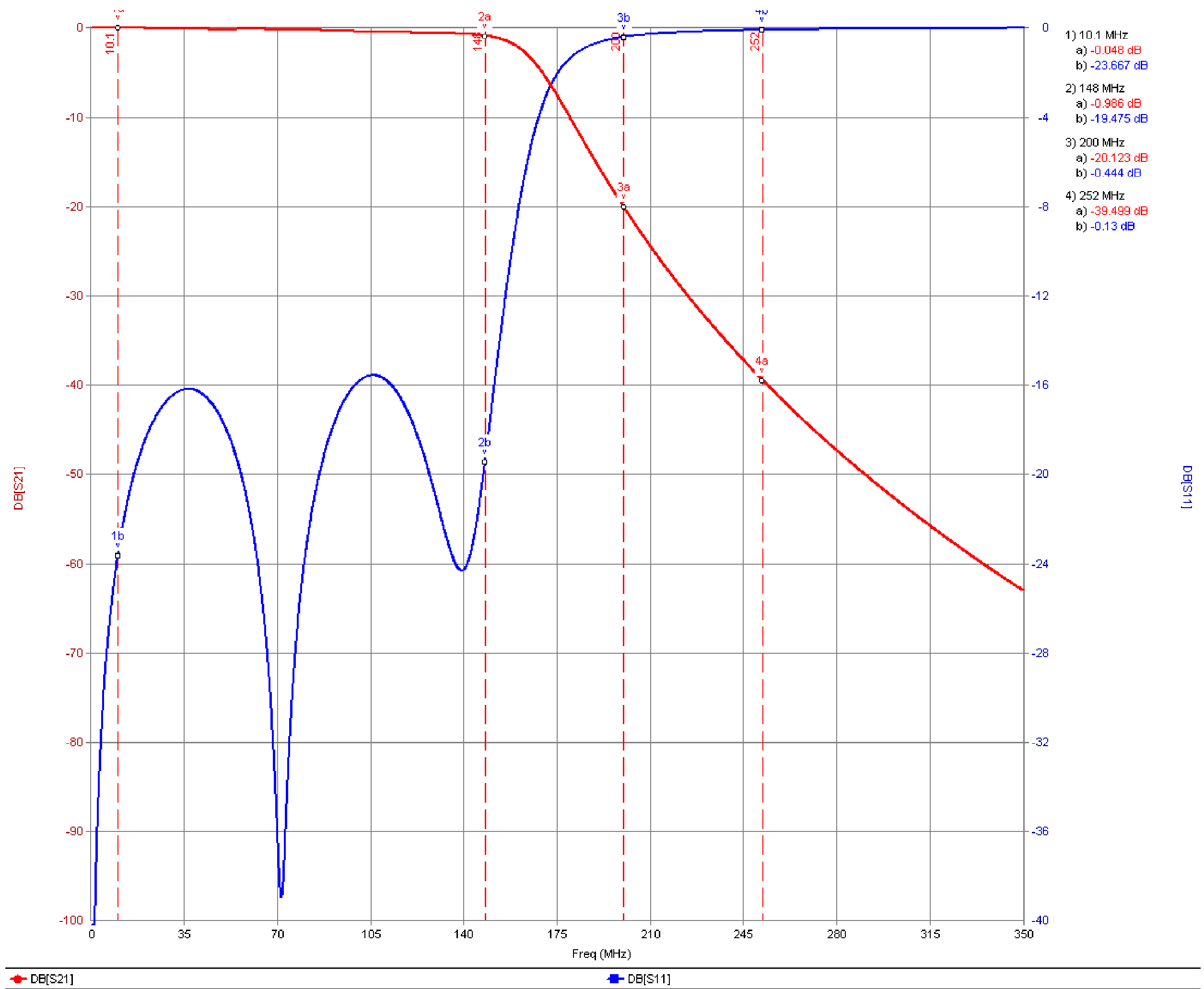
Date: 2/24/2004 10:00:31a
Sheet: 1/1

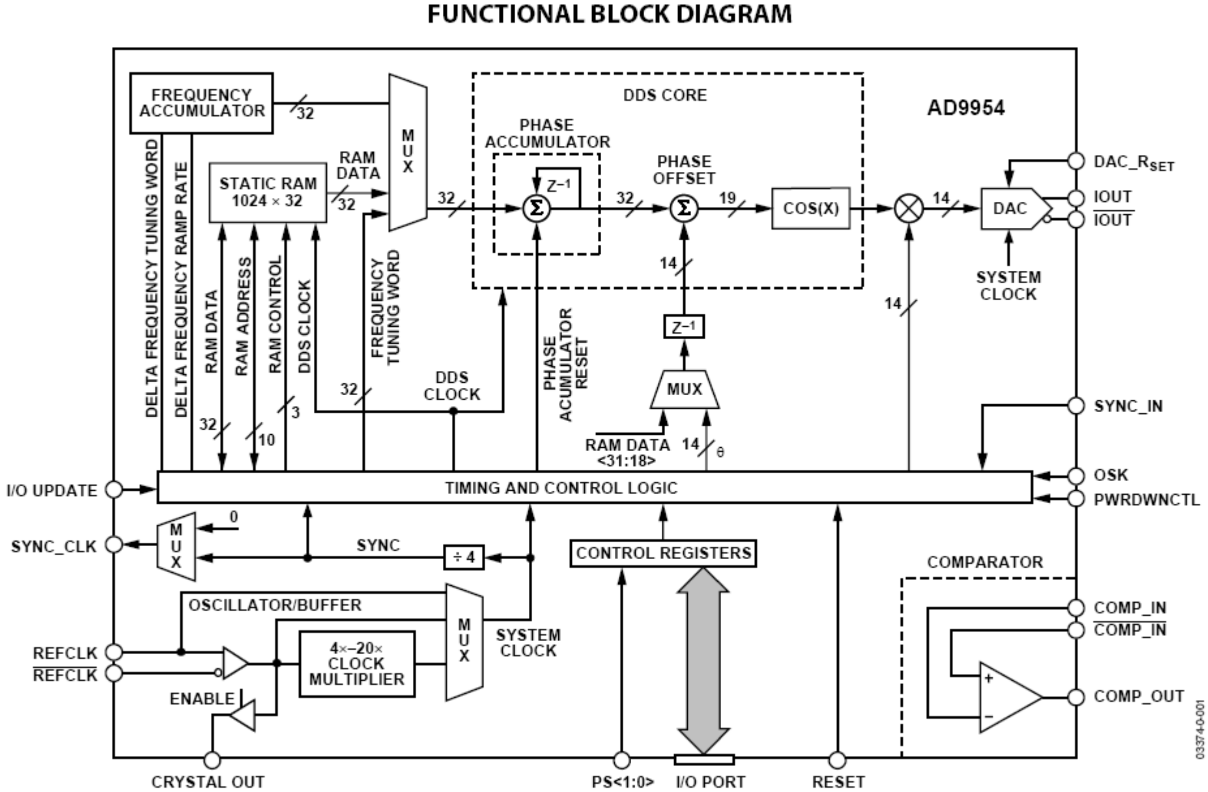
This is a plot of the anti-aliasing filter after the amplifier. The 148MHz alias frequency is attenuated 40dB in addition to the normal sin x/x roll-off of the DDS.





2 AD9954 DDS Chip

2.1 Functional Diagram



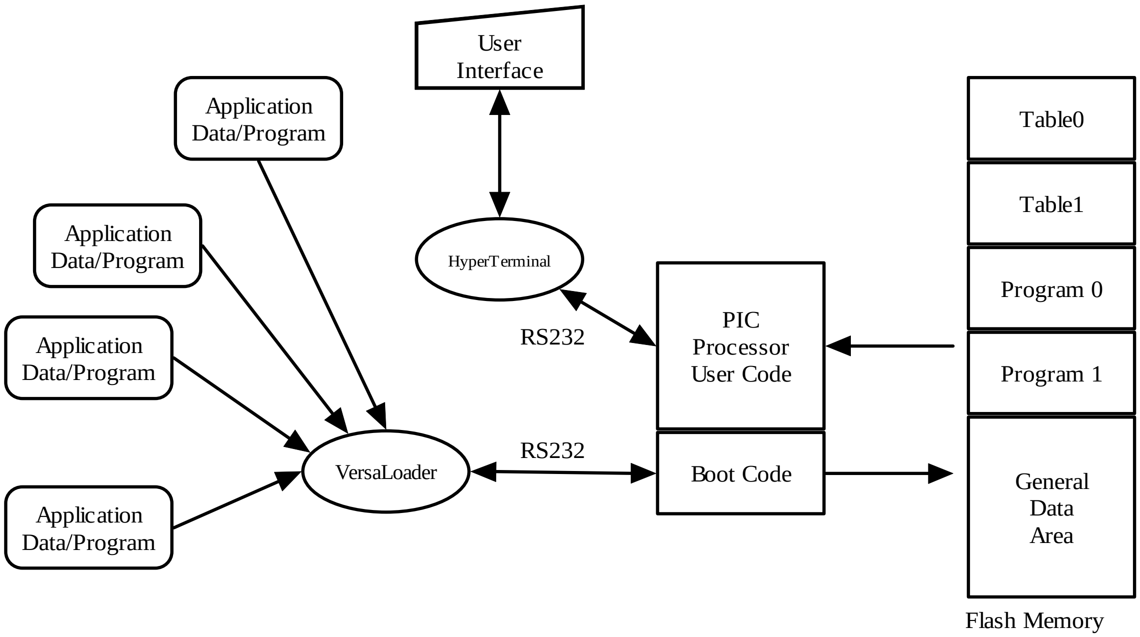
Key Features:

- 400MHz Sample Rate
- 14 Bit DAC
- Low Power <200mW (compared to AD9854's 2 Watt rating)
- Internal Linear Frequency/Phase Ramp capability
- 1K RAM table for custom frequency/phase ramp profiles
- OOK control with built in linear ramp functions

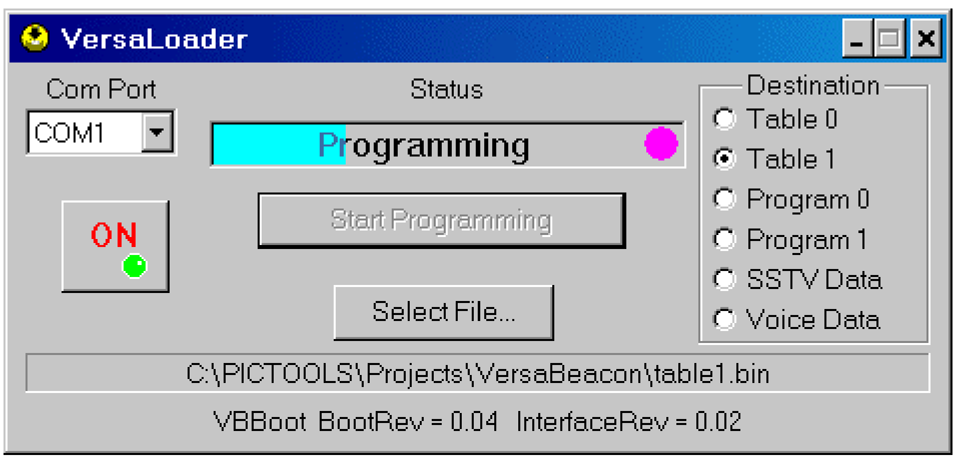
3 Software Architecture

The PIC software is written entirely in 'C' using the CCS PIC C compiler. The code consists of a boot-loader section whose purpose in life is to load specified program code from the Flash memory chip to the PIC internal program code space. It also provides the interface to the RS232 port and the ability to program the Flash memory from an external host PC. It must be programmed initially using a common PIC programming tool.

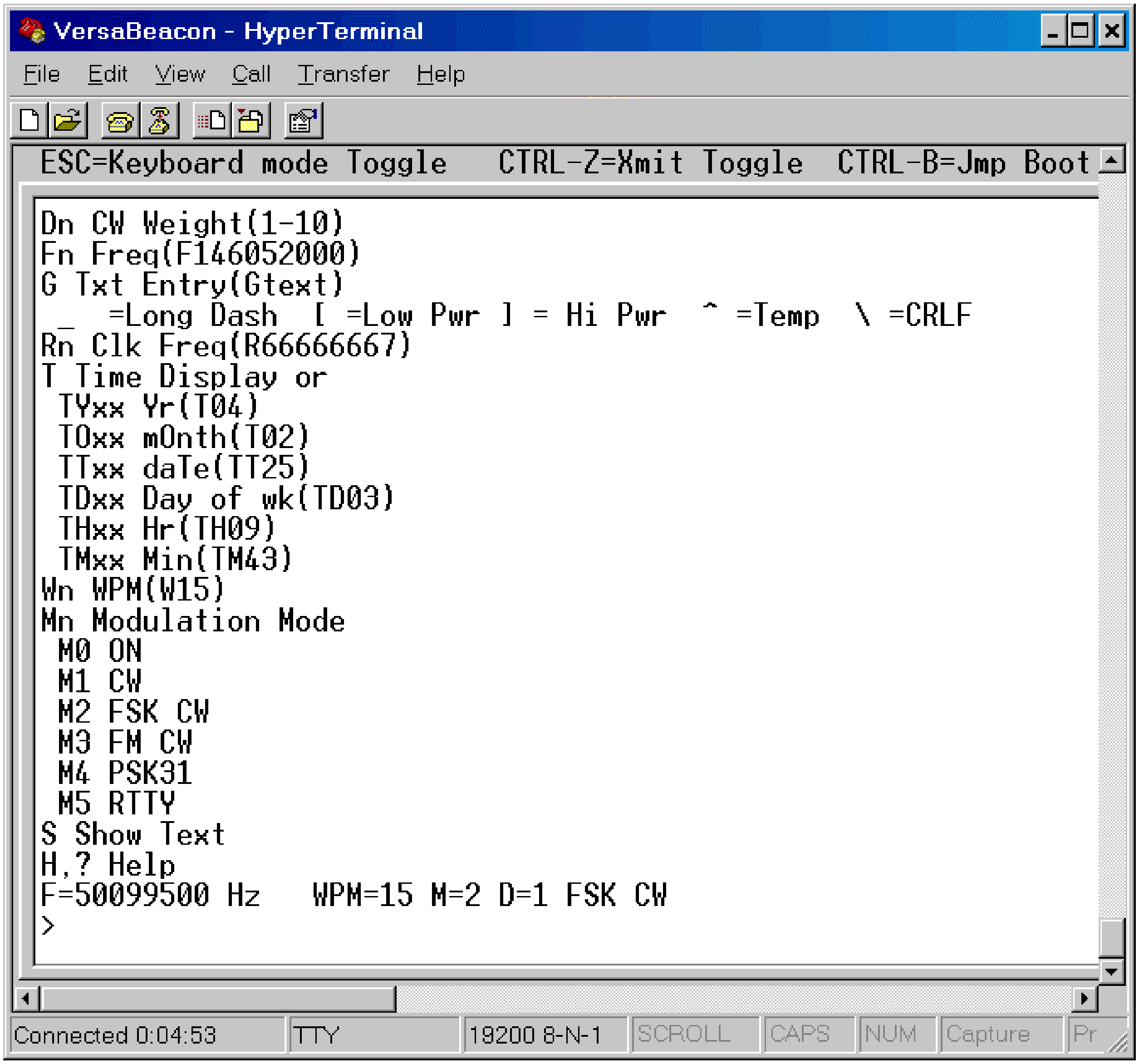
The Flash contains two separate PIC application programs that are selected using switch settings. The Flash also holds various data tables used in the generation of all the modulation modes.
A couple of PC utilities are used to generate data tables and provide a means to download new code and data to the Beacon Flash memory.



The following is the code loader program for downloading new application programs or changing data tables in the Flash memory.



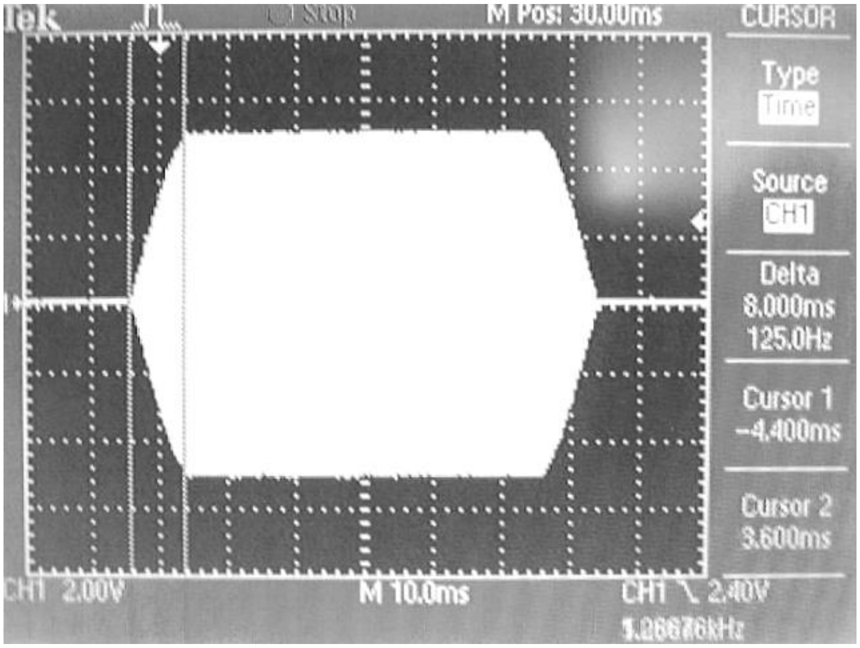
The applications use a simple command line system to change frequency and modes using any RS232 terminal program like HyperTerminal. A help screen is available to help remember the command syntax.



4 Implemented Modes

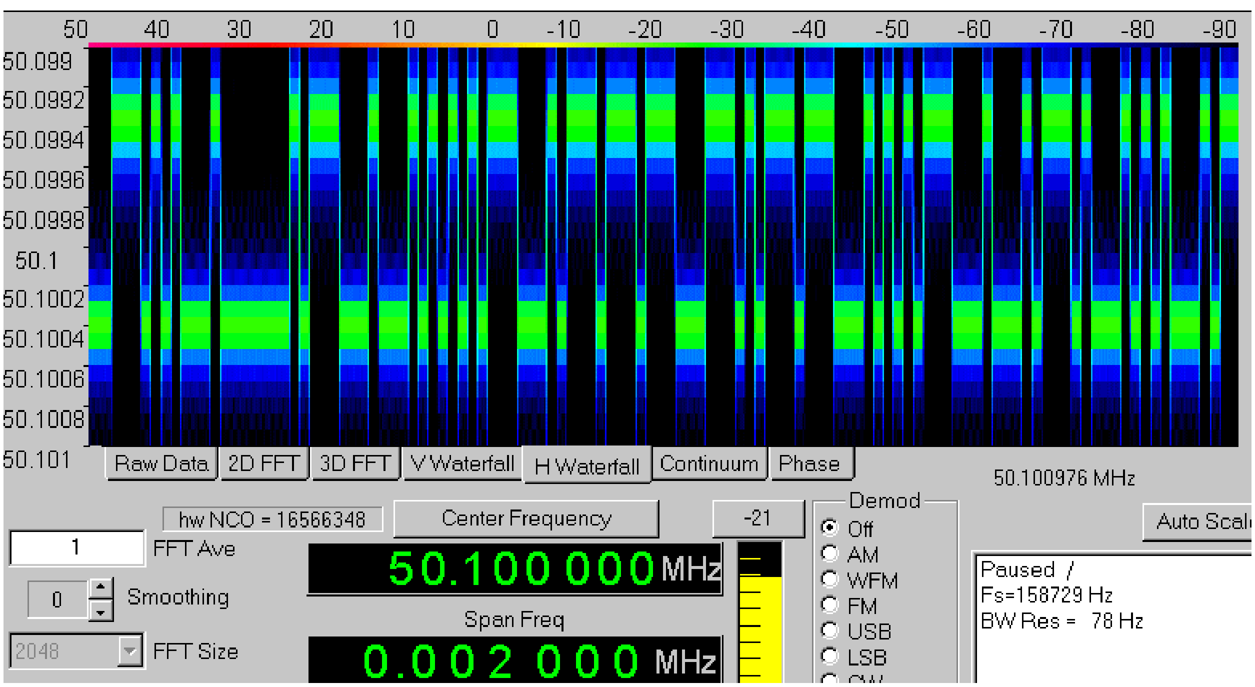
4.1 OOK CW

On-Off CW keying is performed by toggling a control line on the DDS chip. The DDS chip has a mode where it will ramp up to a specified level when the line is high and ramp down to zero when the line goes low. The ramp rate is programmable and in this case it is set to 8 mSec. The linear shaping reduces the amount of key clicks and splatter that would occur if the carrier were just instantaneously turned on to full power.



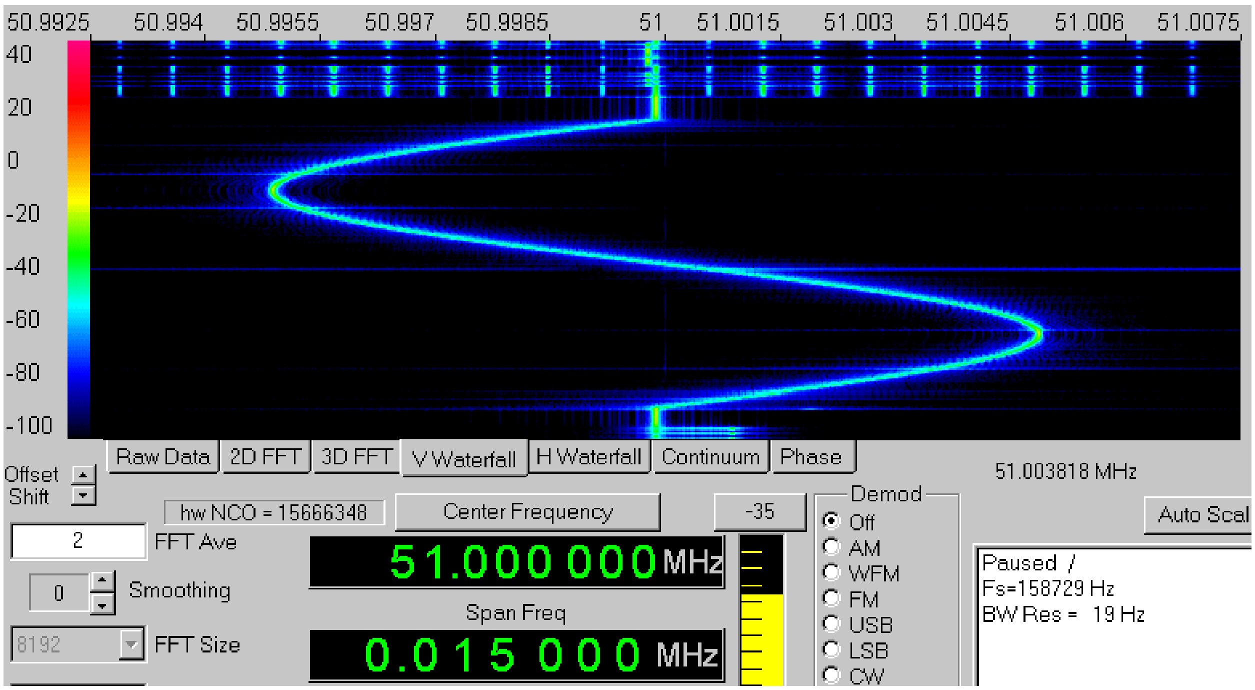
4.2 FSK CW

FSK CW keeps the carrier on and toggles between two frequencies by toggling a control line on the DDS chip. The DDS chip has a mode where it will ramp from one frequency to another frequency depending on the state of a control line. The ramp rate is programmable and the ramping action reduces the amount of splatter as it does in the OOK case.



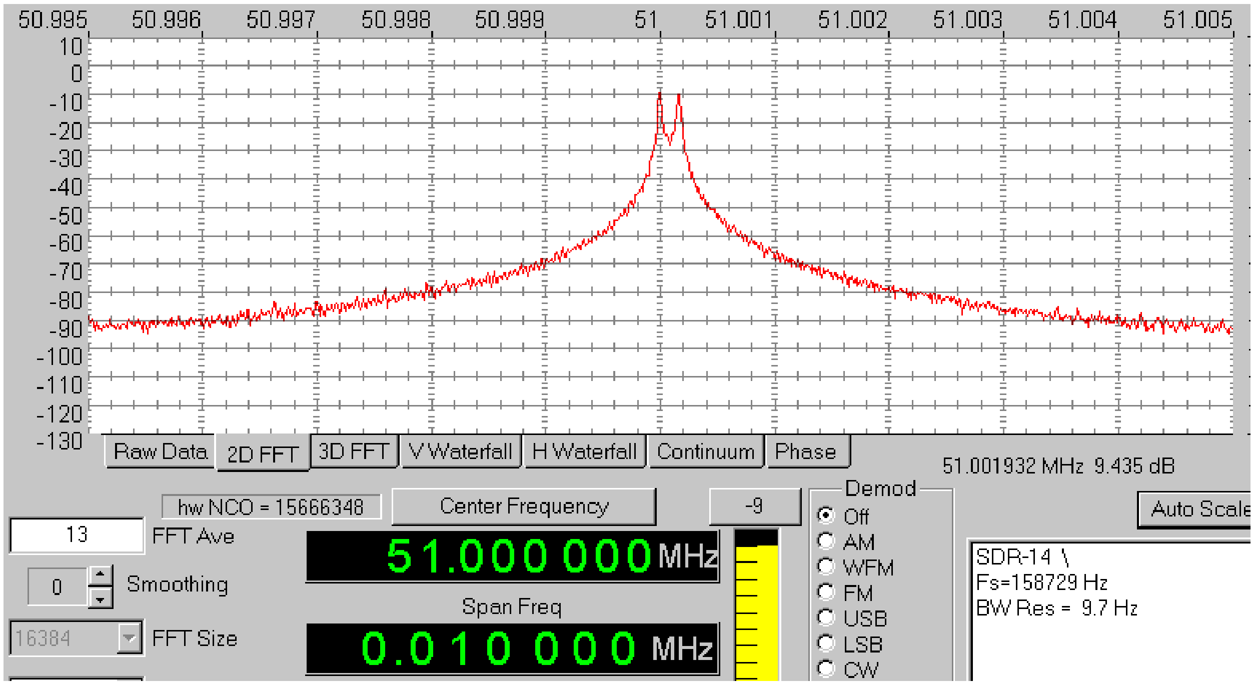
4.3 FM CW

To create an FM CW signal, a sine wave is loaded into the DDS RAM table whose amplitude represents the FM deviation frequency plus the carrier frequency. The DDS chip then sequences through the table loading each new carrier frequency value from the RAM table. The table is cycled through at a 700Hz rate creating an FM modulated single tone signal. Turning on and off this cycling creates the CW encoding.
Below shows a waterfall of the 1000 point RAM DDS table being loaded and the corresponding frequencies of the sin table. Note the sine amplitude is +/- 5KHz which will be the FM deviation value of the tone.



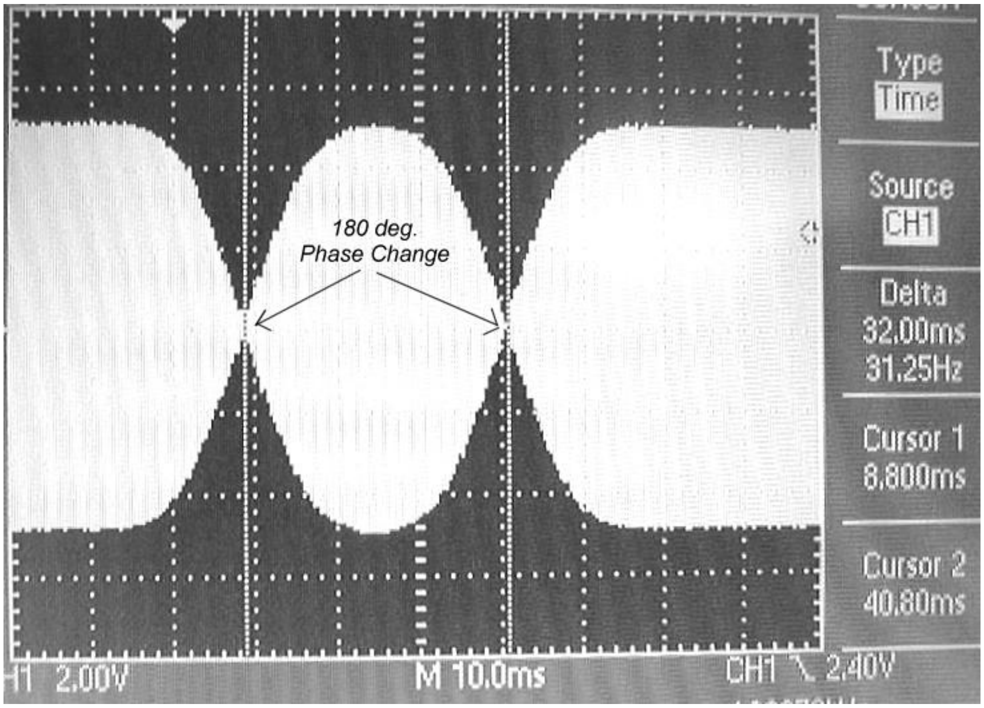
4.4 RTTY

RTTY is easily generated in the same manner as the FSK CW signal. The only difference is in the data encoding and data rate. Only 45.45bps, 170Hz shift mode is implemented.

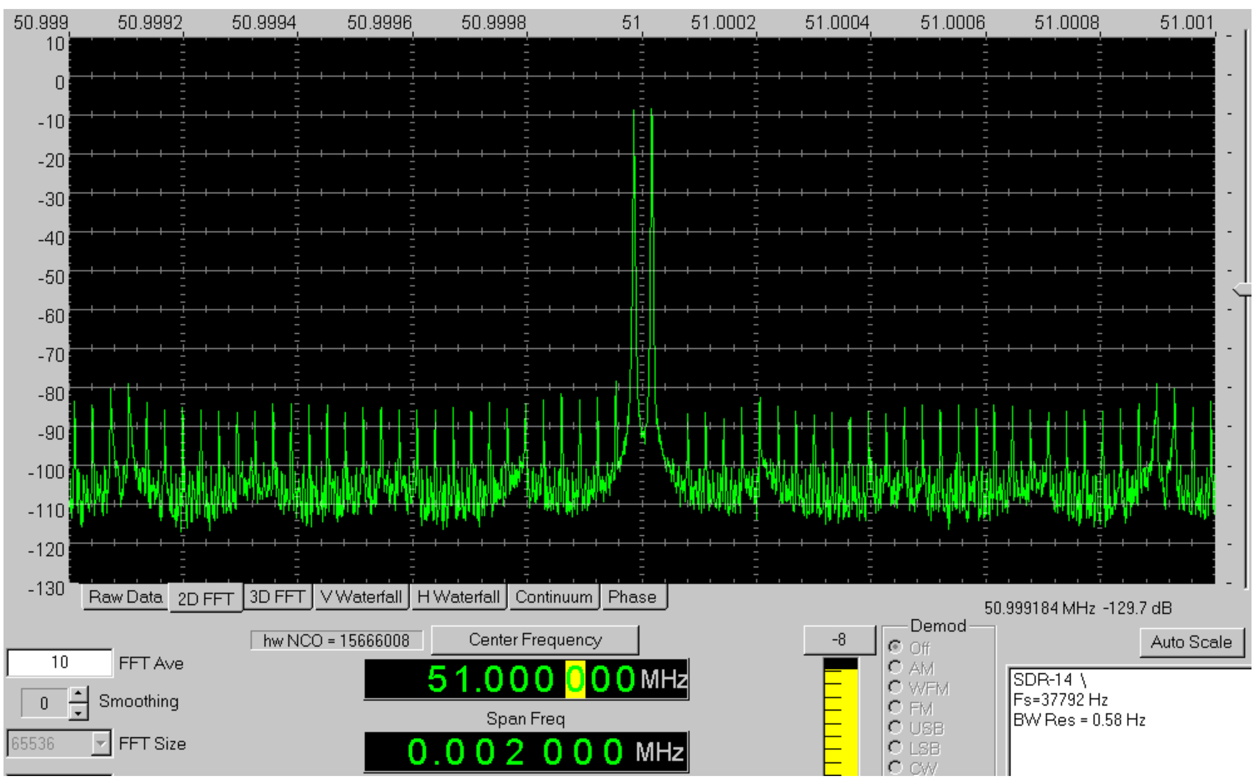


4.5 PSK31

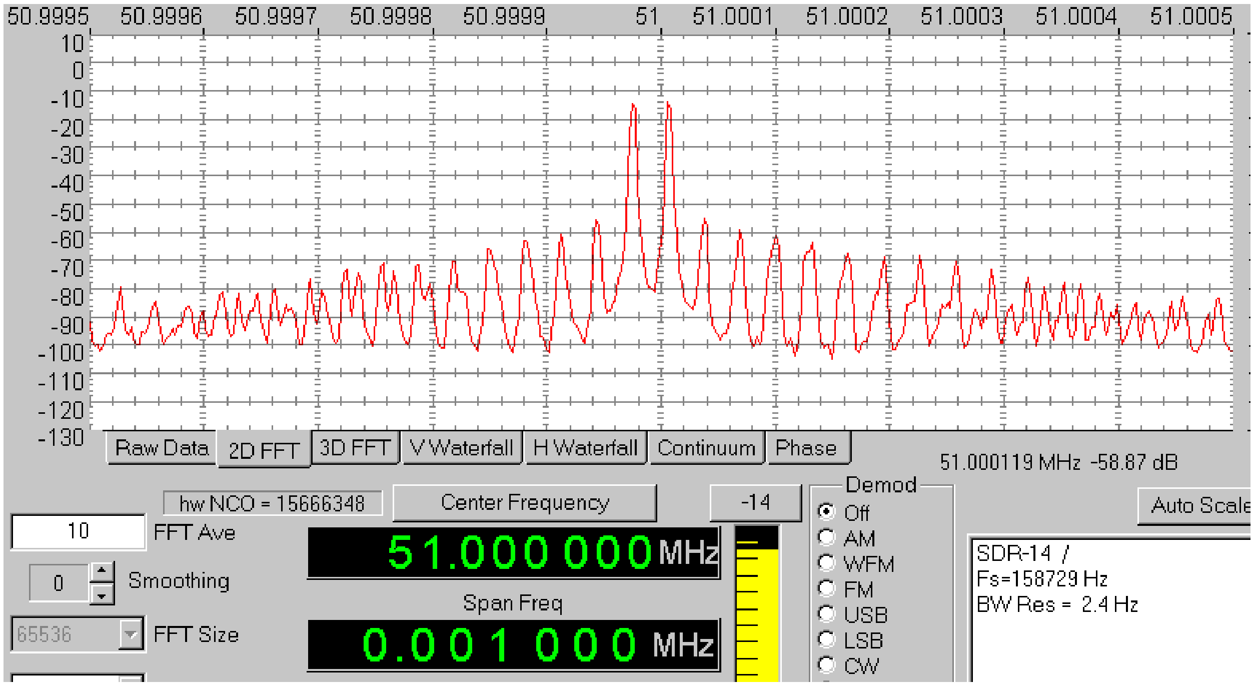
The PSK31 signal is a BPSK signal whose phase changes by 180 degrees for a zero bit and doesn't change for a one bit. The phase change is easily created by just loading a phase offset into the DDS. PSK31 has another characteristic that is more difficult to create using the DDS. With PSK31, when the phase changes, the amplitude is modulated by a cosine shape until the amplitude is zero, the phase is changed, then the amplitude is brought back up to max using the same cosine shape.



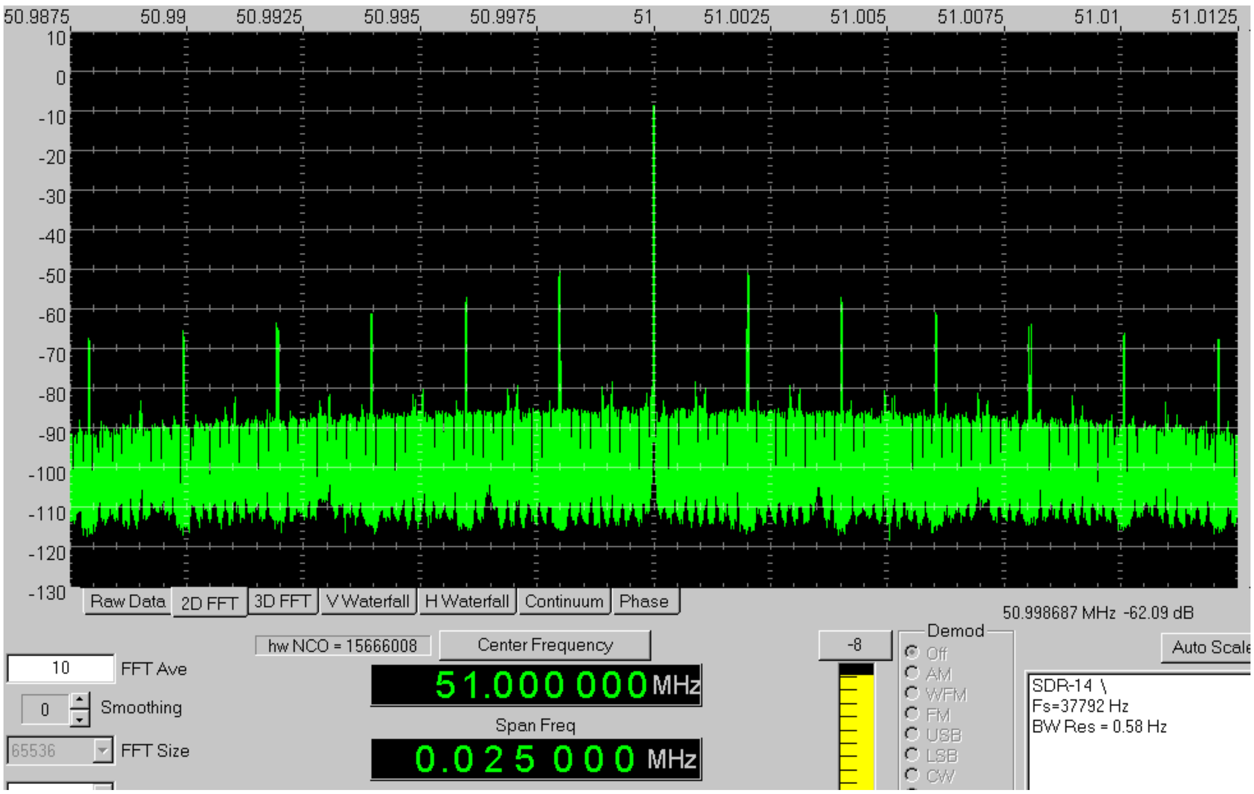
A close in view of the "Idle" signal which is a 2-tone modulated carrier. The IMD is about -70dB. This was taken directly out of the DDS before the amplifier stage.



This is after the amplifier stage. Notice the IMD is now only -40dB due to the non-linearity in the amplifier.



Unfortunately, the DDS RAM table does not connect to the amplitude register so the PIC processor has to generate the shape by loading from a table, and writing to the DDS amplitude register. The PIC is only able to write at about a 2KHz rate so there are some aliasing artifacts in the RF output that are only down -40 dBc. There may be some tricks that can be investigated to try and reduce the aliasing products.



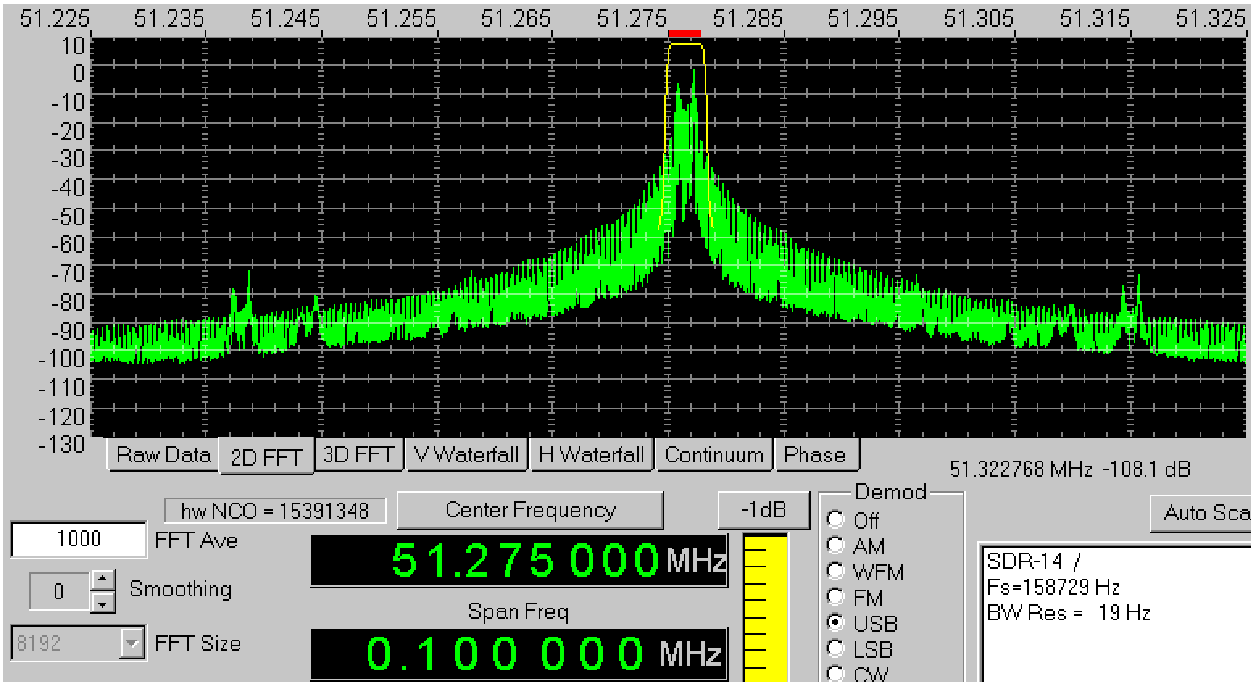
4.6 FSK441

FSK441 is a variation of FSK where there are four separate frequencies used to encode text data for high speed meteor scatter communications. The original idea was to load the entire encoded message frequency sequences directly into the DDS RAM and then have it sequence through the RAM over and over. This would work but it turned out that the PIC could also generate the required frequencies in real time and this gives a little more versatility in that messages can be dynamic and contain variable data such as temperature or other telemetry data.

The following is a code snippet showing how FSK441 is generated by the PIC and DDS chip. This routine is called at the 441Hz rate.

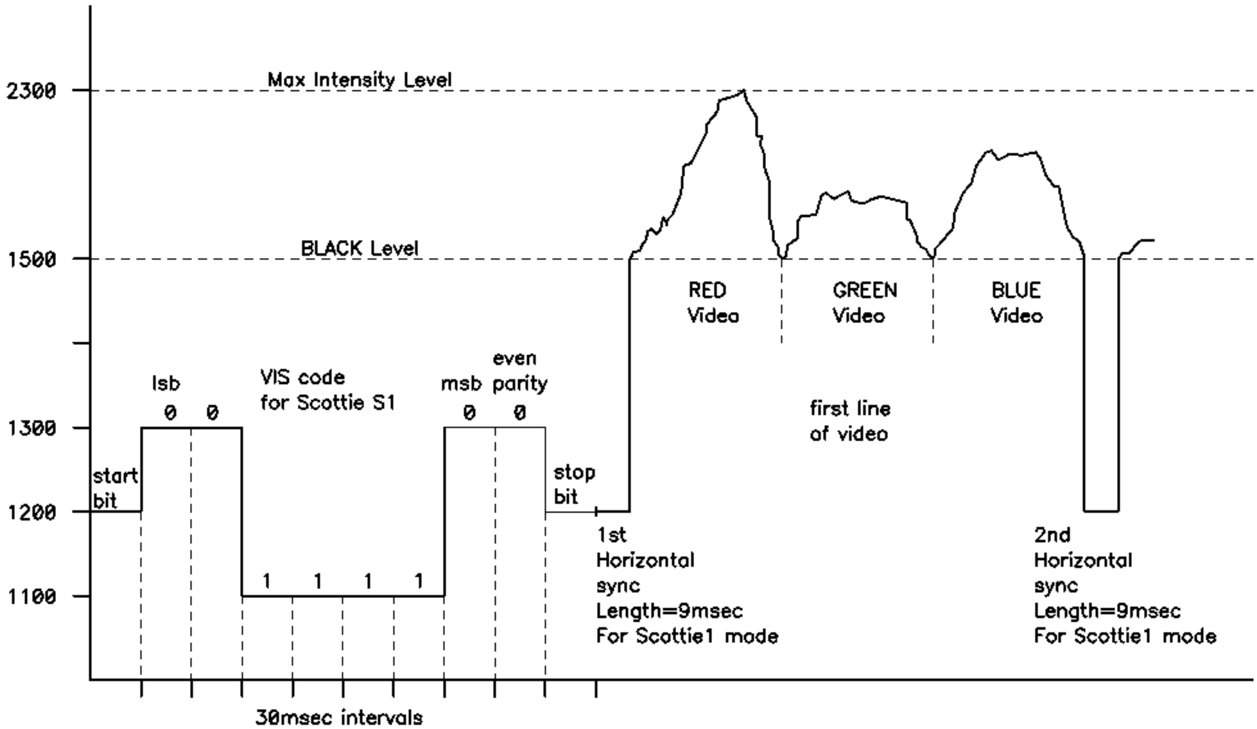
```
#define SYM_PER_CHAR 3  //number of tones per character
#define SYM0_FREQ 882   //These are the four FSK frequencies
#define SYM1_FREQ 1323  //defined by FSK441 in Hz
#define SYM2_FREQ 1764
#define SYM3_FREQ 2205

void ServiceFSK441()
{
      if( ++SymCount >= SYM_PER_CHAR)
      {
            TmpU8 = GetNextChar();        //Get next character to send
            TmpU8 = toupper( TmpU8 );     //make upper case
            SymAcc = FSK441_TABLE[TmpU8]; //get next group of 3 frequencies
            SymCount = 0;                 //to send
      }
      DDSReg.all = SymbFreqTbl[SymAcc&0x03];    //get next DDS value
```

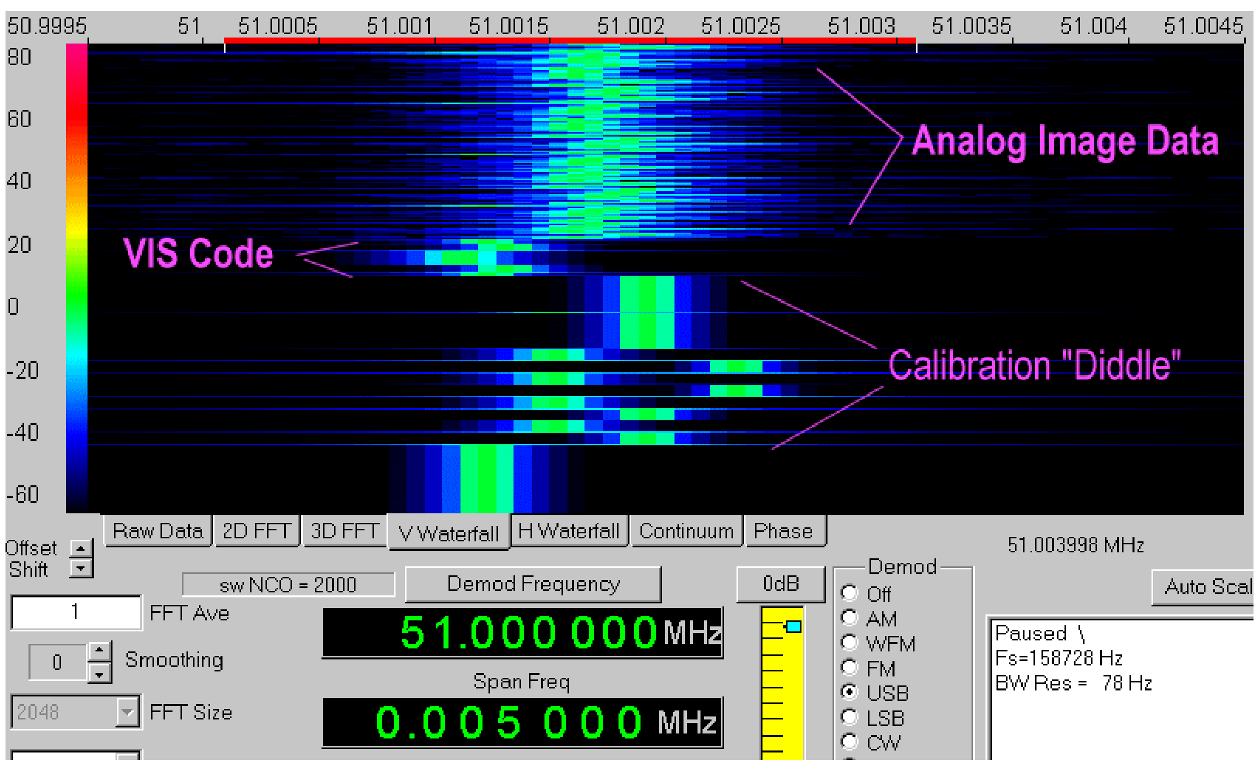
```
        WriteDDS(DDS_FTW0, 4);                          //and send it to DDS
        SymAcc >>= 2;
}
```



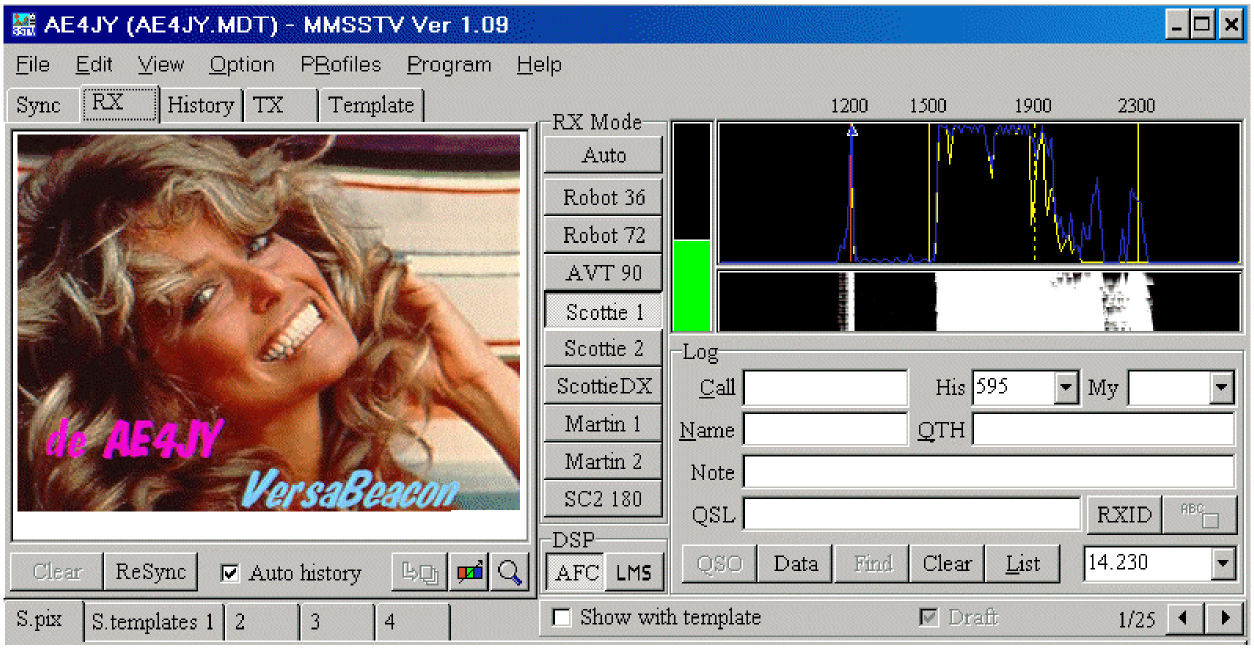
4.7 SSTV

Slow Scan TV is an analog form of FSK. The picture intensity/color elements are encoded as frequency shift and fit in a standard SSB channel width. This mode keeps the PIC busy by reading picture data from the flash, converting it to frequency data, and sending it to the DDS chip. It also must create various sync timing and VIS tones which identify the particular SSTV mode. In this case only "Scottie 1" is implemented.





The following screen shot is from a stored image in the beacon received by the SDR-14, and then decoded using the MMSSTV soundcard software.

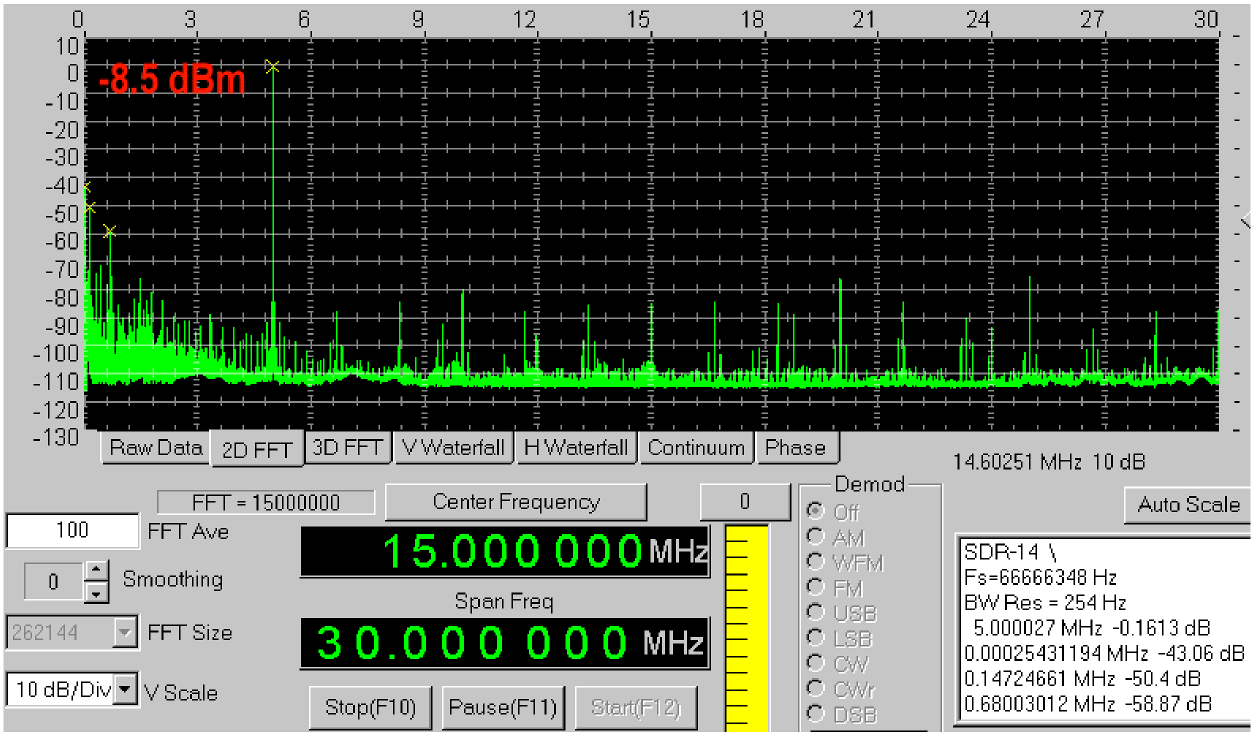


4.8 Modulation Limitations

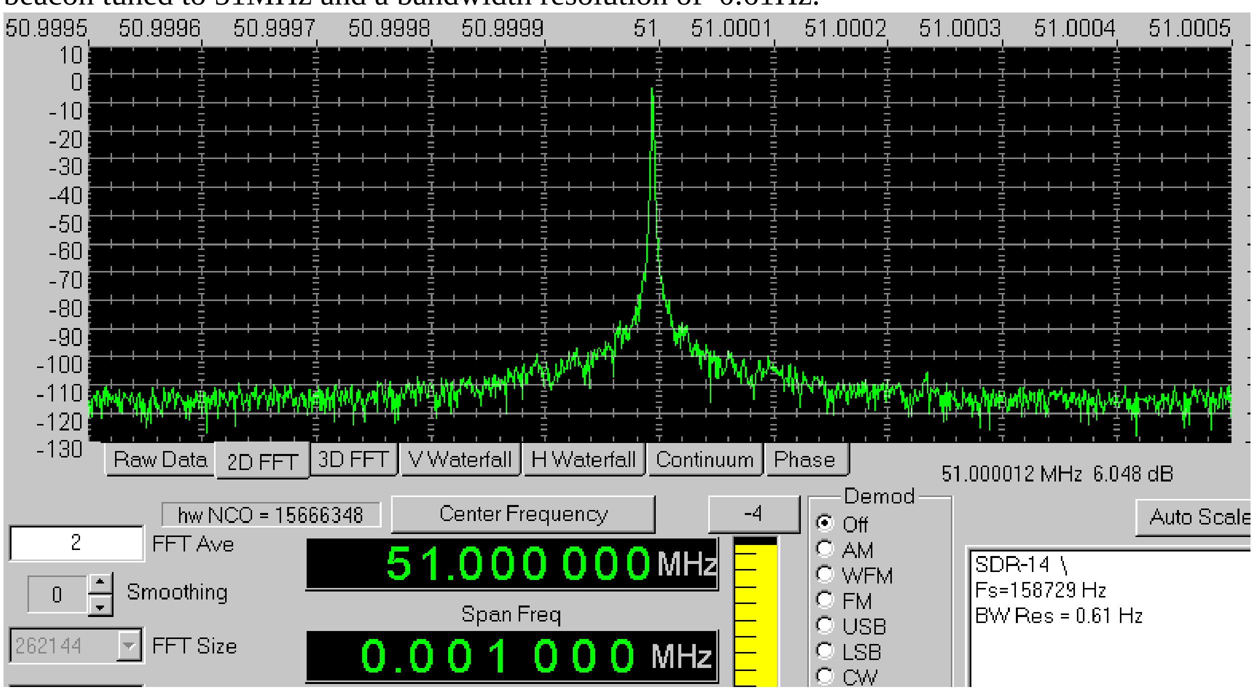
The DDS does not have a good way to easily create amplitude modulation so any mode that requires amplitude variations is questionable. Also the DDS table sequencing has some lower limits making it difficult to use at low data rates.
The PIC isn't capable of high data rates or sophisticated data encoding.

5 RF Output Signal Analysis

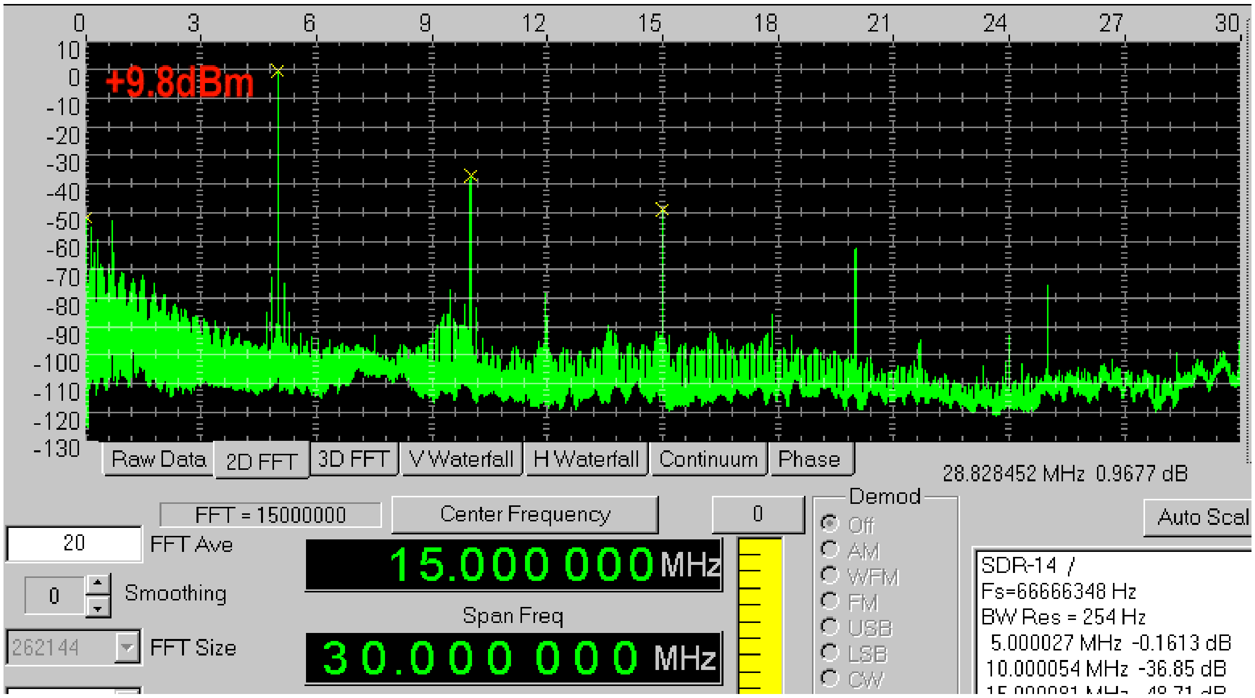
The following plot is looking at the output directly from the DDS before the amplifier stage. The fundamental is at 5MHz. Note the 4th harmonic is around -78dBc. All the other artifacts are below -80dBc. (The trash below 1MHz is broadcast band signal leakage and some external noise in the room.) The power output of the DDS chip is around -8.5 dBm (0.14 mW)



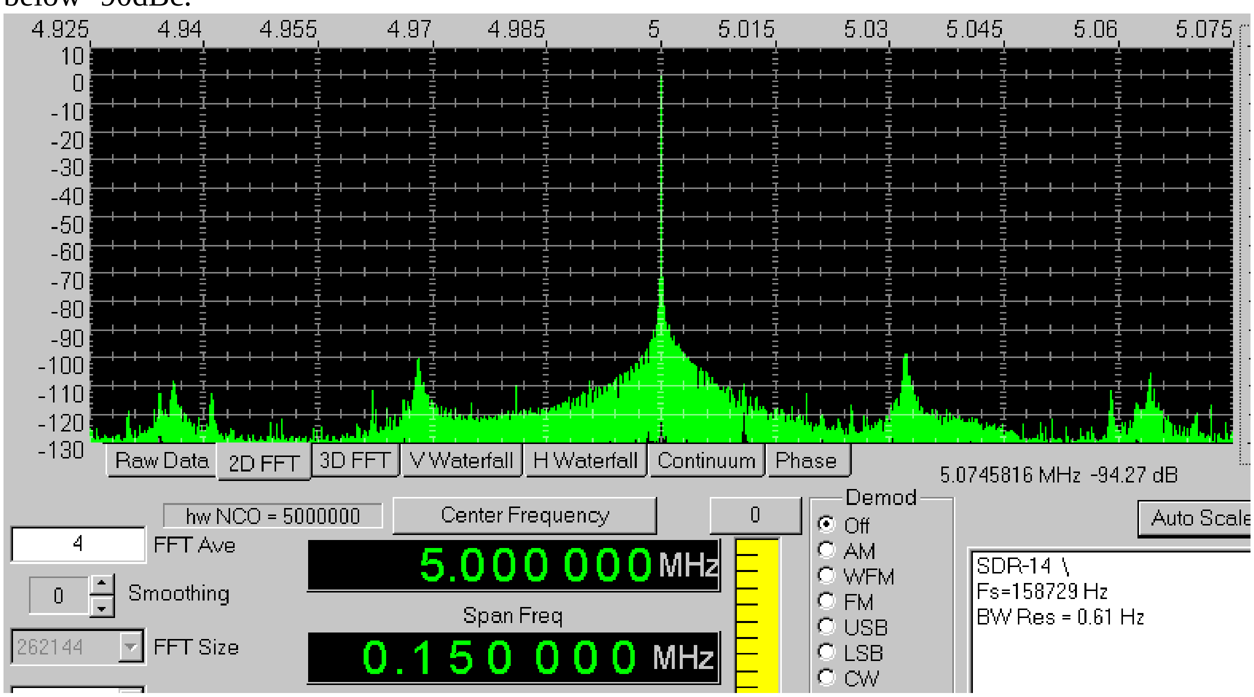
Close in phase noise performance is good. Below is a close in shot after the amplifier with the beacon tuned to 51MHz and a bandwidth resolution of 0.61Hz.



A MiniCircuits GALI-51 MMIC amplifier stage follows the DDS to increase the power output. Below is the spectral output after the amplifier stage. The harmonic output is significant and unacceptable as a transmitter source. Either external filtering would be required or a different amplifier such as a push-pull amplifier configuration is needed. Two meters is actually ok since the aliasing filter reduces all the harmonics by a large amount.



This is a look around the signal after the amplifier with a 150KHz bandwidth. Everything is below -90dBc.



6 Applications

6.1 Propagation Beacon

The beacon could be used for typical VHF propagation use with additional capability of being able to change frequencies and modes on a time based schedule.

6.2 Remote Telemetry Beacon

The beacon could be used as a remote telemetry transmitter due to its ability to insert variable data from analog or digital sources into the beacon text messages. This could be used for a remote weather station where it could send temperature, wind speed, etc. using various modulation modes such as CW and PSK31.

6.3 Stand-Alone Transmitter Exciter or QRP rig

The beacon could be used as an exciter for a transmitter or as a receiver local oscillator source.

6.4 General Purpose Signal Generator

With the addition of a calibrated step attenuator, the beacon could be turned into a general purpose signal generator with various test modulation modes. The DDS chip also has built in linear sweep modes that can be used for sweep generator use.

7 Future

Currently there are two working beacon boards. We would like to use one for a meteor scatter beacon and the other one will probably end up as another piece of test equipment for my workbench.

If there's a lot of interest in this board, it would need to be re-spun to fix a few layout problems and perhaps add or delete some functionality depending on what the primary use would be.

The component cost is probably under a hundred dollars including the PCB depending upon the ability to scrounge and get free samples. As a kit it would require someone with confidence in soldering .5mm pitch surface mount components.