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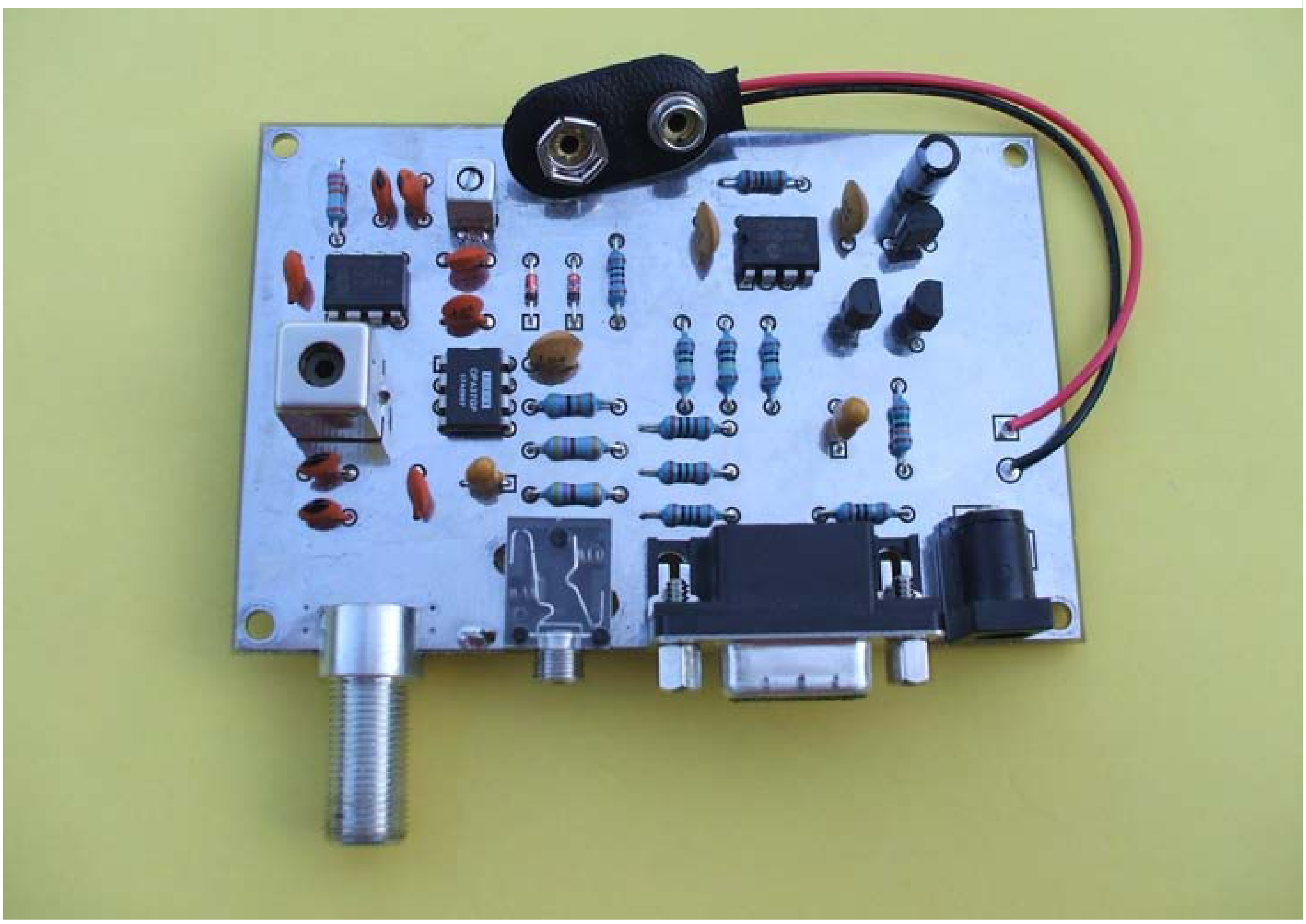

A Space radio for the 21st century from Anthony Monteiro, AA2TX

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Space Radio for Windows

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Abstract

Space Radio is a very low-cost way to receive the voice and data transmissions from the International Space Station on the 2-meter band. It can also be used to receive the packet data satellites that operate on this band. Using about $15 in parts and free, open-source software, Space Radio could offer an attractive entry point for students, hobbyists, and amateur radio operators interested in exploring space communications and software radio technology.

(Figure 1: Space Radio for Windows Control Panel)

Introduction

The Amateur Radio on the International Space Station (ARISS) school contact program has been an outstanding success with hundreds of schools participating and providing an enriching science experience for thousands of students. But, what happens next? No doubt, the afterglow of excitement lasts for several days or even weeks. But once the ham volunteers pack up their equipment, the majority of students will likely have little or no continued exposure to ham radio, space communications or ARISS.

And while the hundreds of school contacts are an impressive achievement, there are more than 160,000 elementary, middle and high schools in the USA alone[i]. This means that only a very minute percentage of students will ever be able to participate in the school contact program. The goal of this project was to investigate the potential of software radio technology to make ARISS communications more accessible.

Software radio technology has historically been driven primarily by common carrier and military applications where the higher costs of a software-based radio has been offset by the desirability of higher performance and increased flexibility and this has generally been true of amateur radio applications as well. But Space Radio uses the exact opposite approach. It employs software radio technology as a way to *reduce* costs while providing sufficient but modest performance and flexibility.

ARISS and Packet Satellite Communications

The transmissions from the ISS and packet data satellites on the 2-meter band use narrow-band, frequency modulation (FM) with a channel bandwidth of 16 KHz. Packet data is modulated on the FM downlink as audio frequency shift keying (AFSK) at 1200 bits per second using the BELL 202 modem standard.

Table 1 provides the key characteristics of the downlink of the ISS and some representative packet satellites. Due to the Doppler-shift, the downlink carrier frequency shown in the table will be seen at the ground station to vary by about ± 3 KHz.

Satellite	Mode	Carrier Frequency (MHz)	Transmit Power (Watts)	Satellite Antenna Type	Estimated Antenna Gain (dB)
ISS	Voice	145.800	5-25	¼-wave whip	0
ISS	Packet	145.825	5-25	¼-wave whip	0
PCSAT	Packet	145.827	3	½-wave dipole	2
RAFT	Packet	145.825	1	Short whip	-2

NOTE: Raft has re-entered and is listed only for reference.

(Table 1: ISS and packet satellite downlink summary.)

The signal level seen at the ground station depends upon the satellite range, (the ISS being included as a satellite,) its transmitter output power, its antenna gain and the gain of the receiving antenna. Based on the information available, the nominal received signal levels of each satellite were calculated. This calculation assumes the lowest transmit power available is used and that the receive antenna is polarity matched with a gain of 0 dB. The results are shown in Table 2 for satellite elevation angles of 0 degrees, 20 degrees and 90 degrees (i.e. overhead.)

Satellite	Altitude (Km)	RX Signal 0 degrees (dBm0)	RX Signal 20 degrees (dBm0)	RX Signal 90 degrees (dBm0)
ISS	360	-105	-98	-90
PCSAT	800	-109	-104	-97
RAFT	360	-114	-107	-99
NOTE: RAFT has re-entered and is listed only for reference.				

(Table 2: ISS and satellite receive signal levels.)

As can be seen from the table, the signal from the ISS is fairly strong. Using the International Amateur Radio Union (IARU) recommendation for S-units, the ISS would be received between S7 and S9 so the receiver sensitivity should not need to be very high to hear the ISS signal. The packet satellites are up to 10dB weaker so they would require higher receiver sensitivity or a gain antenna to allow decoding the AFSK data.

It is important to note that the antenna polarities will generally not be matched due to Faraday rotation unless using a handheld antenna that can be manually pointed. The table provides a starting point for estimating the receive signal levels but the real levels will depend upon the actual receiving antenna system.

Major Project Goals

The main purpose of this project was to test and demonstrate the feasibility of using software radio technology to create a low-cost, 2-meter FM receiver capable of monitoring ARISS voice transmissions. The target audience was intended to include high school and perhaps advanced middle school students as well as electronics hobbyists and ham radio operators. This wide audience constrains certain aspects of the project.

First of all, the required circuit would have to be very easy to build. This was taken to mean no surface-mount parts could be used. The circuit would need to be as simple as possible keeping the parts count low and the parts had to be readily available as well. Since this project could be offered in a kit form, there was not a hard requirement to have parts available in single unit quantities however, this was a secondary goal.

Next, the costs had to be kept low. The electronic components cost goal was $25 or less but not including any battery, enclosure, cables etc. Additionally, all software including all development tools were required to be free.

This would allow anyone to re-use or re-design any aspect of the hardware or software if they were interested. The Space Radio for Windows source code will also be freely available in keeping with the above.

Finally, Space Radio was intended to be sufficiently sensitive to allow monitoring ARISS voice transmissions using only an omni-directional antenna. A secondary goal was to allow sufficient tuning range and sensitivity to allow receiving packet data transmissions from the ISS and digital satellites with at most a small hand-held beam.

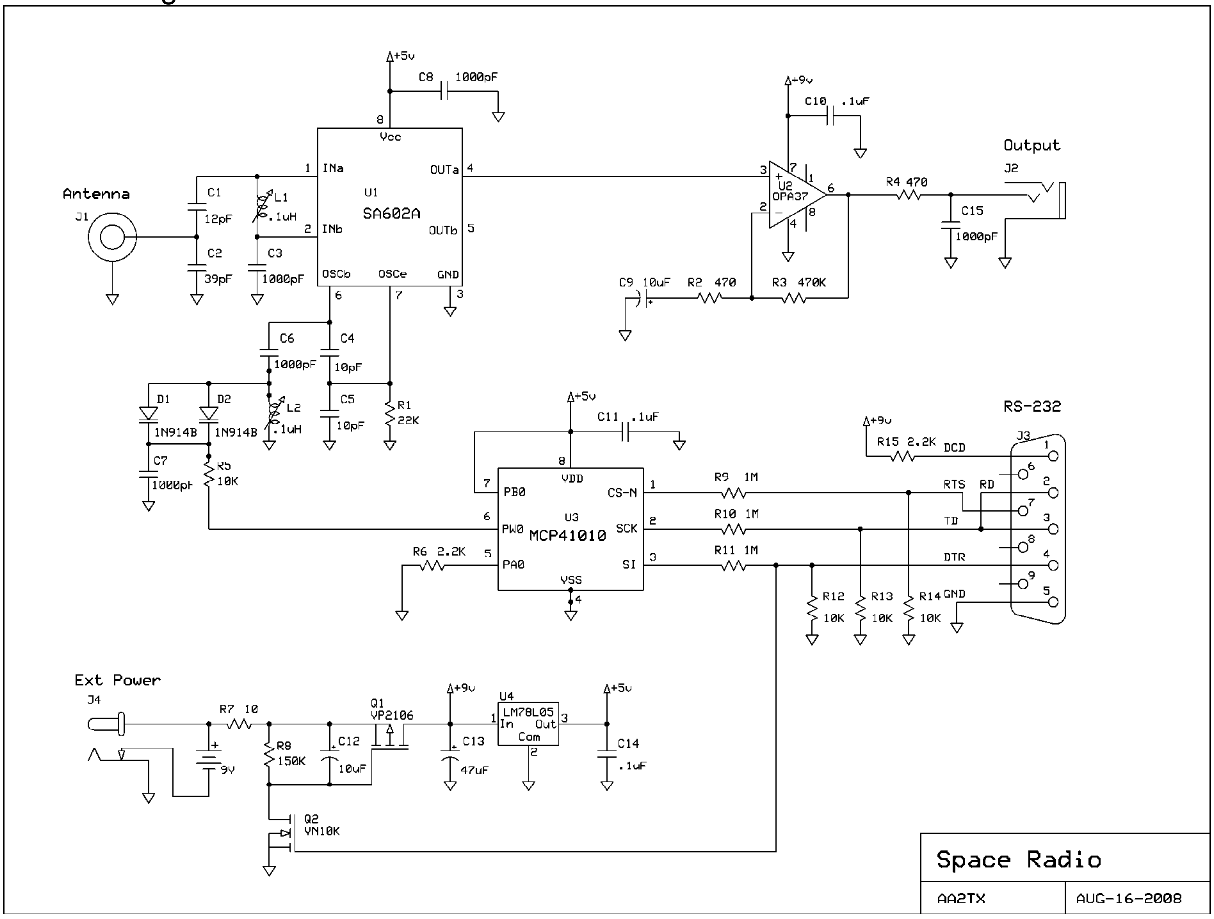
System Design

Any system design requires making tradeoffs. The key design tradeoffs for Space Radio included trying to minimize the circuit complexity and component cost while maintaining adequate performance. The following system parameters were established:

1. Sensitivity: 10dB Noise Figure or better. This is needed to allow receiving ISS voice with an omni antenna
2. Input impedance: 75 ohms. This allows good performance using cheap RG-6 TV coax and a dipole antenna but will also work fine with 50 ohm coax.
3. Intermediate frequency: 8.82 KHz. This IF is approximately in the center of a typical PC sound card pass-band and is conveniently 1/5 of the max sample rate.
4. Use simple (not image-reject) mixer. With the low IF, the image is in the adjacent channel. Since the ISS and satellites are in the space sub-band, there should be little or no activity in the channel adjacent to the ISS or satellites.
5. Use free-running tunable oscillator with automatic frequency control. This keeps costs down and allows automatic Doppler correction once the signal is acquired.
6. Radio will be completely controlled from the PC without even an ON/OFF switch. This is cheaper and more convenient.
7. Use a COM port for PC control of radio. USB would be better but is not reasonable without using surface-mount parts.
8. Use LINE-IN or MIC port on PC for radio IF signal. As above, USB would be better but is not reasonable without using surface mount parts.
9. Radio audio plays through PC speakers.
10. Battery operated with optional AC adapter.

Circuit Design

The Space Radio circuit was designed to meet the system design parameters specified above. Please see the schematic diagram of the Space Radio circuit shown in Figure 2.



(Figure 2: Space Radio schematic diagram.)

The antenna is connected to J1, a 75 ohm F-connector. C1, C2, and L1 provide a match from 75 ohms to the input impedance of U1 as well as providing out-of-band signal filtering. U1, an SA-602A, is a double-balanced mixer IC in an 8-pin dip package. This device provides a noise figure of around 6 dB and about 15 dB of conversion gain. It also includes an extra transistor that is used in this circuit as a Colpitts local oscillator. The base local oscillator frequency is determined by C4, C5, and L2. L2 has an aluminum tuning slug which is adjusted for a nominal local oscillator frequency of 145.813 MHz. Note that L1, the RF input coil, also has a tuning slug. The RF circuit bandwidth is wide enough so that it does not need to be precisely tuned.

D1 and D2, a pair of ordinary 1N914 diodes, are used as variable capacitors to provide radio tuning. The circuit provides about +/- 25 KHz of tuning range. The local oscillator is normally tuned 8.82 KHz above or below the received signal. This provides an intermediate frequency (IF) centered at 8.82 KHz at the output of U1.

The IF signal is applied to U2, an OPA37 ultra-low-noise op-amp in an 8-pin dip package. U2 and its associated circuitry provide 60 dB of gain over the range of 50 Hz to 20 KHz.

The output of U2 is fed to a 3.5 mm stereo jack making it convenient to connect it with a standard patch cable to the LINE-IN jack on a PC sound card. Only the LEFT channel is used (i.e. the TIP.) If a LINE-IN jack is not available, the MIC jack may also be used but this may result in lower fidelity of the received audio.

The tuning of Space Radio is accomplished by changing the bias on the tuning diodes via U3. U3 is an MCP41010 digital potentiometer in an 8-pin dip package. The potentiometer side of U3 is at pins 5, 6, and 7 with pin 6 being the wiper. One end of the pot is connected to 5 volts and the other end is connected to ground through resistor R6 to limit the minimum bias to about 0.9 volts. Adjusting the wiper changes the bias on the tuning diodes which changes their capacitance and the local oscillator frequency. The MCP41010 device has a Serial Peripheral Interface (SPI) port to control the position of the pot wiper. This is a synchronous interface with 0 and 5 volt digital levels. Since most PCs do not have an SPI port, Space Radio uses a regular PC COM port with special *bit-banging*[ii] driver software to implement the SPI protocol. The COM port RS-232 levels are converted to SPI-compatible levels using the resistor network consisting of R9 through R14.

Space Radio is powered by a standard 9-volt transistor radio battery. It draws less than 10 milliamps when turned on so a battery can last quite a long time when it is used only for ISS voice monitoring. For extended operation, J4 is provided to allow using an AC adapter. Space radio will operate over the range of 7.5 to 12 volts.

Power to Space Radio is controlled by the PC COM port via the DTR lead. When the radio is disconnected or the DTR lead is low (-12V,) transistor Q2 is turned off which turns off pass transistor Q1. When the DTR lead is set high (+12V,) Q2 is turned on which charges capacitor C12. This turns on pass transistor Q1 which connects the 9V supply to the radio circuits. The 9 volts is also applied to U4, an LM78L05 low-power, 3-terminal, 5-volt regulator IC which provides a stable voltage for the SA-602 mixer and the MCP41010 digital potentiometer.

Parts and Assembly

The complete list of the electronic components is shown in Table 3. In order to keep the shipping costs low, almost all of the parts were purchased from one supplier; Mouser Electronics[1]. The prices shown in the table are the single quantity prices and were the actual prices paid to construct the prototype unit. In larger quantities, the prices could be significantly lower.

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[1] Mouser Electronics orders can be placed online at www.mouser.com

Part ID	Description	Mouser Part#	QTY	Cost Each $	Cost Total $
B1	9V Clips	121-0426/I-GR	1	0.29	0.29
C1	12pF (NPO)	140-50N5-120J-TB	1	0.06	0.06
C2	39pF (NPO)	140-50N5-390J-TB-RC	1	0.06	0.06
C3,6,7,8	1000pF	140-50Z5-102M-RC	4	0.07	0.28
C4,5	15pF (NPO)	140-50N5-150J-TB-RC	2	0.06	0.12
C9,12	10uF/16V tantalum	80-T356E106K016AT	2	0.48	0.96
C10,11,14	.1uF	581-5ZH104MACJI	3	0.14	0.42
C13	47uF/16V electrolytic	647-UVR1C470MDD1TD	1	0.03	0.03
D1,2	1N914B	512-1N914B	2	0.03	0.06
J1	F-Connector	601-25-7630	1	0.92	0.92
J2	3.5 mm stereo jack	161-3507	1	0.71	0.71
J3	2.1mm power jack	163-5004-E	1	0.63	0.63
J4	DE-9 Female	152-3409	1	1.09	1.09
L1	.1uH	434-1012-3.5CS	1	0.61	0.61
L2	.1uH	***** see Note 3 *****	1	3.02	0.00
Q1	VP2106	689-VP2106N3-G	1	0.34	0.34
Q2	VN10K	689-VN10KN3-G	1	0.32	0.32
R1	22K	660-MF1/4LCT52R223G	1	0.04	0.04
R2,4	470	MF1/4LCT52R471J	2	0.04	0.08
R3	470K	660-MF1/4DCT52R4703F	1	0.03	0.03
R5	47K	660-MF1/4DCT52R4702F	1	0.03	0.03
R6, R15	2.2K	660-MF1/4DCT52R2201F	2	0.03	0.06
R7	10	660-MF1/4D52R10R0F	1	0.02	0.02
R8	150K	660-MF1/4DCT52R1503F	1	0.03	0.03
R9,10,11	1M	660-MF1/4DCT52R1004F	3	0.03	0.09
R12,13,14	10K	660-MF1/4D52R1002F	3	0.02	0.06
U1	SA602A	771-SA602AN/01	1	2.25	2.25
U2	OPA37GP	595-OPA37GP	1	2.56	2.56
U3	MCP41010	579-MCP41010-I/P	1	1.70	1.70
U4	LM78L05	863-MC78L05ACPREG	1	0.20	0.20
		Total Cost			14.05

Note 1: All caps are 50V ceramic disc unless otherwise noted.

Note 2: All resistors are ¼-watt.

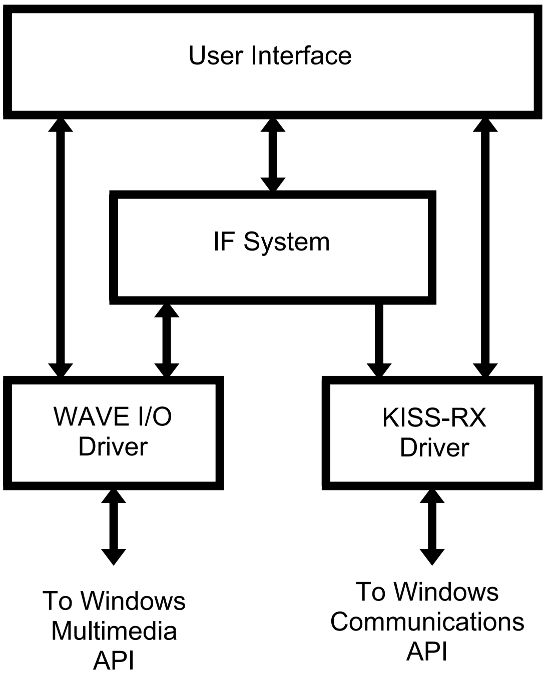
Note 3: L2 is a Coilcraft, 5mm, shielded, tunable RF inductor. Part# 164-07A06SL. See text about free samples.

Note 4: Optional 9V, AC adapter is also available from Mouser Electronics. Part# 552-PLA01A-090-R at a cost of $5.29 each in unit quantities.

(Table 3: Parts List.)

The one part not available from Mouser is the oscillator coil, L2. This part is only available Coilcraft,[iii] its manufacturer. This part was selected because it uses an aluminum tuning slug which has a zero temperature coefficient. Fortunately, this company offers free samples in small quantities to students and design engineers. Please see their web site for more details.

As an aside, several Coilcraft inductors flew in space on the NO-60 “RAFT” satellite (see Table 1) and they performed flawlessly.



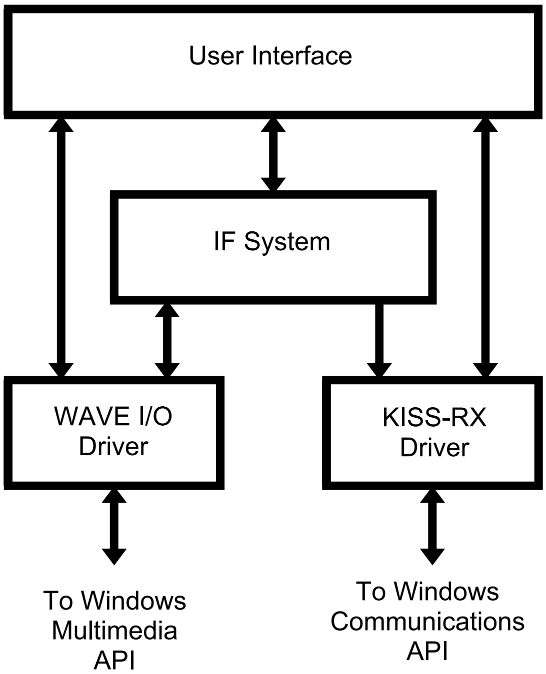
Unfortunately as of August 2008, one of the parts, the OPA37GP op-amp, was back-ordered at Mouser until January 2009. However, Digi-Key[iv] had thousands of these in stock as part# OPA37GP-ND at the same price. Another alternative would be the Linear Technologies[v] LT1037CN8 which is an exact replacement. This part is actually cheaper but has a 2-piece minimum order from the manufacturer.

The Space Radio prototype was constructed on a printed circuit board ordered from ExpressPCB[vi]. This company offers free schematic capture and printed circuit board (PCB) layout design software which can be downloaded from their web site. Since only a very small number of boards were needed for a prototype, the “MiniBoard” service was used. The prototype boards were ordered without solder masks or silk screening. A photo of the assembled prototype circuit board is shown on the front cover.

Software Design
The Space Radio software is a 32-bit Microsoft Windows application. It requires Windows 2000 as a minimum and will run on any later version as well. All of the software was written in C++ and was developed using Visual C++ 9.0 Express Edition which is available for free from Microsoft[vii]. The free Express Edition does not include a resource editor which allows graphically creating and editing icons, dialog boxes, menus, and other visual resources used in a windows program. These can be created using a text editor but it is very tedious. Instead, a free resource editor, “ResEdit” was downloaded and used[viii].

Please see the software architecture diagram shown in Figure 3. The software consists of four major modules; the User Interface, a WAVE I/O Driver, a KISS-RX Driver, and the IF System.

The User Interface module, like a typical Microsoft Windows application program, includes window controls and display components. These are used to interact with and control the operation of Space Radio. And, like all windows applications, the main window provides the entry point for the program and also ties all the other modules together. Unlike a typical windows application however, Space Radio uses a Dialog Box as its main window. This allows the use of a graphical editor to draw the display area and place the controls which is better suited to a radio “Front Panel.”



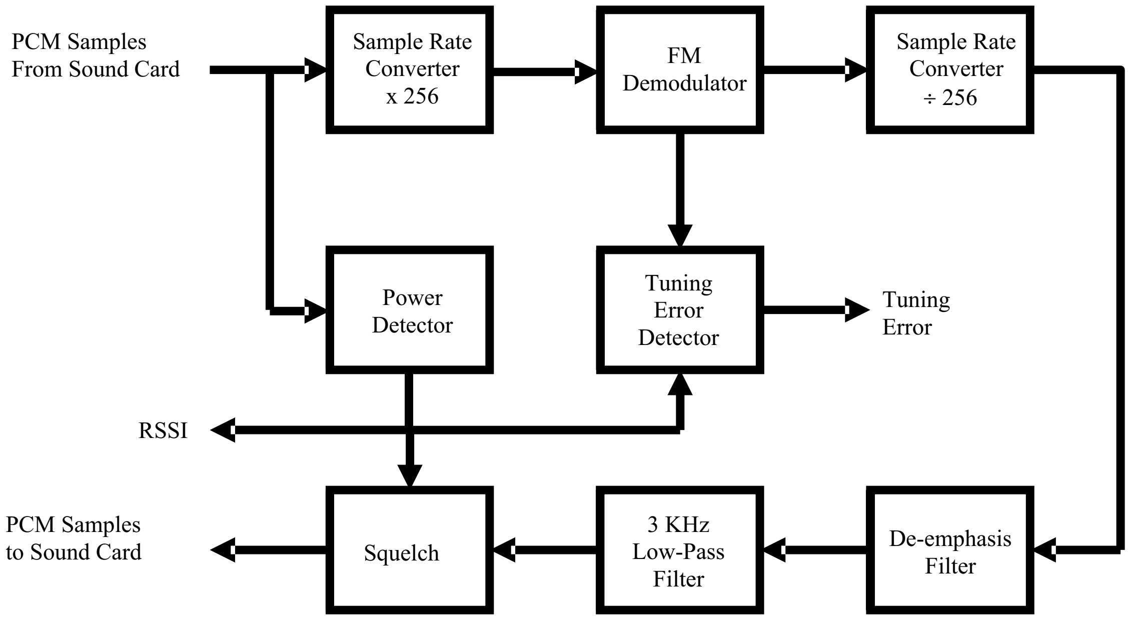
(Figure 3: Space Radio software architecture.)

The WAVE (waveform audio) I/O Driver provides a simple interface to the Windows multimedia Applications Programming Interface (API.) This hides the messy details of the low-level code to drive the sound card and helps simplify the interface to the other modules. The WAVE I/O Driver provides a simple pointer passing ***(Figure 3: Space Radio software architecture.)*** mechanism to blocks of PCM samples.

The KISS-RX Driver runs the Space Radio circuit (nicknamed KISS-RX for "keep it simple...") including power and frequency control. It implements the special bit-banging software to run the SPI protocol over the COM port and converts frequency control commands to the low-level SPI operation and parameter codes needed by the digital pot on the Space Radio circuit board.

Finally, the IF System is the signal processing component of Space Radio. It works much like an intermediate frequency (IF) sub-system IC as found in a typical hardware radio but of course all of the signal processing is done in software.

Digital Signal Processing
The signal processing software in the IF System module is the heart of Space Radio. A block diagram is shown in Figure 4. As shown in the diagram, 16-bit, Pulse Code Modulation (PCM) samples arrive from the sound card at a 44.1K samples/second rate. This is the highest rate that a typical built-in sound card will support. Fancy sound cards will do higher rates but they are not generally included with a typical PC.



(Figure 4: Digital signal processing.)

The input samples are passed to the Power Detector which measures the average power in the input signal. The calculated power is converted to decibels and drives the Received Signal Strength Indicator (RSSI.)

The input samples are also passed to a x256 sample rate converter which includes an up-sampler and linear interpolator. This converts the sample rate to a little over 11M samples/sec. This high rate is needed by the FM demodulator block to provide good fidelity FM detection.

The next stage is the FM demodulator and it uses a zero-crossing detector with a period to frequency converter. The zero-crossing detector counts the number of samples in-between signal polarity changes which provides the instantaneous period of the input signal. The period is then converted to the frequency deviation from the IF center frequency. A zero-crossing detector is used because it has excellent noise rejection without needing a limiter stage and is simple to implement.

The output of the FM detector feeds a sample rate converter block which reduces the sample rate back to the sound card rate of 44.1 K samples/second. This block consists of a 2's compliment integrator, a divide-by 256 rate decimator, and an N=10 comb filter. This function is commonly called a cascaded integrator-comb (CIC) decimator.

The sample rate converter is followed by an N=8, CIC low pass filter which functions as a de-emphasis filter. This filter uses the same cascaded integrator-comb structure as the sample rate converter but with no rate decimator. Though it does not have a perfect de-emphasis shape, it does provide nice sounding audio.

The de-emphasis filter is followed by a 3 KHz infinite-impulse response (IIR) low-pass filter. An IIR low-pass filter works much like an analog resistor-capacitor network and it cleans up any left-over, high-frequency digital processing artifacts without affecting the audio quality.

The recovered audio is then passed through a squelch process before being passed back to the sound card. The squelch block will mute the audio if the received signal strength is below the squelch set level. The squelch may be disabled if desired. Note that there is no volume control block needed. Speaker volume is controlled by sending software commands to the PC sound card.

Finally, the Tuning Error block uses the RSSI signal from the Power Detector and takes zero-crossings from the FM detector to create an output signal that corresponds to the average frequency tuning error when a valid signal is present. This is much like the discriminator-meter output from an FM sub-system IC and it is used to drive the front panel discriminator meter. This signal is also used to provide automatic frequency control of the radio's local oscillator. In this way both oscillator drift and received signal Doppler-shift can be compensated for automatically.

Operation
Space Radio will run under Windows 2000 or later operating systems. On the author's PC, a 2.3 GHz Pentium R running Windows XP, Space Radio requires about 2% of the CPU.

Operating the Space Radio control panel is pretty much like operating any other radio. Please see the control panel image in Figure 1. The user controls include buttons for POWER, MODE, CENTER, and AFC. There is a scroll bar for tuning and sliders to adjust the squelch and the volume. An S-Meter shows signal strength and there is a direct digital readout of the received signal power. A discriminator meter at the top center provides a visual indication of the tuning error. Most of these controls are self-explanatory (i.e. the POWER button toggles the power on and off.)

Tuning Space Radio is accomplished by adjusting the scroll bar labeled "Tune." The box under the scroll bar shows the number of tuning steps from the center frequency. A step is about 200 Hz and the range is +/- 127 steps. The scroll bar thumb can be moved directly by left clicking it and moving it via the mouse. Clicking on the area between the scroll bar ends and the scroll thumb changes the frequency by five steps. Clicking the arrows on the scroll bar ends changes the frequency by one step. The CENTER button returns the scroll thumb back to the scroll bar center position.

The MODE button selects VOICE mode at 145.800 MHz or PACKET mode on 145.825 MHz. The MODE button does not change the radio tuning; it selects high or low side local oscillator injection which allows double the frequency coverage. It was also envisioned that this would activate an AFSK demodulator when in PACKET mode but this software was not completed at the time this paper was written.

The AFC button toggles the automatic frequency control on or off. To use AFC, first adjust the squelch slider to fully mute the audio. Then click the AFC button to turn it on. The radio can then be tuned using the tuning controls. When the radio detects a signal stronger than the squelch level, it will lock on to it automatically. When the AFC is engaged, the software internally saves the squelch level that was set so the squelch slider can be re-adjusted as desired or even disabled and it will have no affect on the AFC action. The AFC will correct for Doppler-shift on a received signal so that no manual re-tuning is normally necessary once the desired signal is acquired.

Lab Testing
The receiver sensitivity was tested using a combination of HP-8903A and HP-8640B test sets. The receiver required 1.8 microvolts at the input for 12 dB SINAD using a 1 KHz modulation tone and 1.67 KHz deviation (i.e. 100% NBFM modulation.) This is equivalent to -104 dBm0 and is well within the expected sensitivity requirement for monitoring the ISS voice and data transmissions with an omni-directional antenna.

On-The-Air
On August 13, 2008, an ARISS school contact was made with the Town of Berkeley Heights, NJ, Summer Playground Camp. This contact was successfully monitored with Space Radio from the Boston, MA area. The antenna was a Lindenblad connected through 200 feet of coax with no preamp.

This pass had a maximum elevation angle of around 45 degrees. Signals from the ISS were detectable at around 10 degrees elevation at 2 minutes into the pass but were very noisy. At 20 degrees elevation, about 3 minutes into the pass, the signals became very clear and fully readable. There were a few short fades during the pass probably due to nulls in the Lindenblad antenna pattern but these were only a few seconds in duration.

The maximum observed signal level was -96 dBm0 and remained fairly constant over the pass between the 20 degree elevation points. This is well within the predicted levels when the antenna elevation gain pattern, mismatched polarity loss and coax losses are considered.

Once the signal was acquired, Space Radio's automatic frequency control successfully maintained the correct tuning over the approximately +/- 3KHz Doppler-shift observed over the pass and no manual tuning was needed.

Since the ISS has not been active in packet mode, it was not possible to test packet data operation on the air. However, the receiver sensitivity measured in the lab test and the performance demonstrated during the school contact appears to be more than sufficient for this to work.

Discussion

This project is not sufficiently developed to consider this paper a construction article. The major purpose was to see if software radio technology could be used to make a really cheap, 2-meter FM radio that could receive the ISS Voice signals. While this was successful, more development work is needed before it could be considered a "turnkey" construction project.

For example, the local oscillator has no temperature compensation. While this worked fine for the demonstration, it is probably not as stable as needed to be really useful. This does not necessarily add anything to the cost but it does require more development work.

Another issue is that the ISS has not been in voice mode very much and the lack of activity reduces the usefulness of Space Radio as a construction project. Perhaps further developing the data capability would make it more interesting as the ISS, PCSAT and a number of other digital satellites such as PCSAT2, RAFT and ANDE, have been much more active on packet in the recent past. Focusing on packet data however might require an increase in the receiver sensitivity as the cubesats are considerably weaker than the ISS. This could be accomplished at a fairly minor cost by adding as RF amplifier stage but there would be in increase in the difficulty of building the circuit. For some satellites, even this might not be sufficient as decoding the data from RAFT and ANDE required having a preamp at the antenna even with an FT-847 radio when using an omni-directional antenna. Perhaps an "active" antenna or a cheap antenna mounted preamp is a better solution.

Yet another issue is the printed circuit board cost. If at least 100 of these were obtained, the cost would be less than $5 per board even with solder-mask and silk screening added. So, a kit might be a good option. But the "MiniBoard" service that was used to make the prototype, at $51 for 3 boards, is probably too costly on its own. Another alternative might be to re-layout the board as single-sided-only and offer it through a hobbyist oriented supplier like Far Circuits[ix].

As long as these and other issues are kept in mind, anyone who is interested and wants to build a copy of Space Radio to try it out and do their own experiments is encouraged to do so. The Space Radio software, schematics, and printed circuit layout files will be made available to anyone who requests them via email.

Free Development Tools

One of the things that worked very well on the Space Radio project was the reliance on free development tools.
All of the tools used can be downloaded via the Internet. Table 4 below provides a list of the tools that were used and their sources.

Tool Use	Name	Web Address
Circuit Simulation	LTspice/SwitcherCAD III	www.linear.com
Schematic Capture	ExpressSCH	www.expresspcb.com
PCB Layout	ExpressPCB	www.expresspcb.com
SW Development	Visual C++ 9.0 Express Edition	www.microsoft.com
Resource Editor	ResEdit	www.resedit.net

(Table 4: Free development tools.)

Conclusions

The goal of the Space Radio project was to investigate the application of software radio technology (SDR) to make a really low-cost receiver for the ISS. This is unlike typical SDR applications which focus instead on high-performance or enhanced flexibility. The Space Radio experiment was a success. The astronauts on the ISS could be clearly heard during a scheduled ARISS school contact on the prototype radio built for under $15 in parts.

While Space Radio is not sufficiently developed to consider it a construction project, it is hoped that the successful demonstration of the concept would be thought-provoking. There are many areas where a limited performance but really cheap radio could be useful and the basic circuit can be used up through 500 MHz. Some other versions could include an APRS monitor, a NOAA Weather radio, an aircraft receiver, or even just a monitor for a favorite 2-meter repeater.

Most recently, there has been significant SSTV activity from the ISS. If this was expected to be continued, an SSTV demodulator could be added to allow watching these transmissions (i.e. make it into “Space TV.”) Or, with a small change to the oscillator circuit, Space Radio could be used to monitor the university Cubesats that have 70cm downlinks. Comments, discussion and suggestions are welcome.

Tony Monteiro, AA2TX, was first licensed in 1973 as WN2RBM and has been a member of AMSAT since 1994. He started his engineering career as a member of the technical staff at Bell Laboratories and has served as an engineering director at a series of high-tech start-up companies. Contact him at AA2TX@amsat.org

Footnotes

[1] Number of public schools from www.publicschoolreview.com. Number of private day schools from www.privateschools review.com

[2] Bit-banging refers to a method of implementing a serial interface by individually setting I/O port bits on and off in software.

[3] Mouser Electronics orders can be placed online at www.mouser.com.

[4] Coilcraft parts are available from www.coilcraft.com.

[5] Digi-Key parts can be ordered from www.digikey.com.

[6] Linear Technologies parts and information are available at www.linear.com.

[7] ExpressPCB software and printed circuit boards are available at www.expresspcb.com.

[8] Visual C++ 9.0 Express Edition is available from www.microsoft.com.

[9] ResEdit Resource Editor is available from http://www.resedit.net/.

[10] Far Circuits circuit boards are available at www.farcircuits.net.