MICROSOFT RESEARCH

The Sora Manual

The Microsoft Research Software Radio (Sora) Project

The Sora Core Team
(Ver 1.7)
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The Microsoft Research Software Radio (Sora) Project is an initiative from the Wireless and Network Group, Microsoft Research Asia.

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Chapter 1. Introduction

The Sora manual provides reference documentation for *Microsoft Research Software Radio*, also known as *Sora*, which is a research project initiated in the Wireless and Networking Group (WNG) at Microsoft Research Asia. Sora is a high-performance fully programmable software radio based on general purpose processors (i.e., CPU) in commodity PC architecture. Sora contains both hardware and software components. The hardware component is a high-speed, low latency Radio Control Board (RCB) that interconnects the RF frontend and the PC memory. RCB is based on PCI-Express interface and is capable of transferring large amounts of digital samples in high speed. All these digital samples are processed by software running on the host CPU. The software component is an SDK, containing critical drivers and libraries for programming and running highly-efficient baseband in real-time on modern multi-core PCs.

The first Sora SDK (Microsoft Research Software Radio Academic Kit), version 1.02, was released to academia in June 2010. An update, version 1.1, was released in November 2010. Sora version 1.5 was released in Sept 2011. Sora version 1.6 was release in Mar 2012. This document contains updated information for the latest Sora release.

More information on Sora is available online:

http://research.microsoft.com/en-us/projects/sora/
http://social.microsoft.com/Forums/en-us/sora

If you want to obtain Sora hardware, please find more information at

http://research.microsoft.com/en-us/projects/sora/academickit.aspx

1.1 What's new in Sora SDK ver 1.7?

The new Sora SDK ver 1.7 supports 64-bits Windows 7. So it now makes full use of the most powerful operating system capability from Microsoft. Some information you need to know before using Sora SDK ver 1.7:

- **Driver Test-Signing.** The 64-bit drivers must be signed before installed on Windows 7. The driver binary shipped with the SDK package is already signed.
- **Set Windows 7 to testing mode to support test-signed driver.** To install test-signed drivers, the target Windows 7 machine must enable test-signing as well. This option can be enabled by using BCDEDIT.EXE (Section 2.2).
- **API changes.** Sora SDK ver 1.7 supports both 32- or 64-bit application through the UMX and Reflection API. Version 1.7 makes very slight changes of Reflection API compared to version 1.6. So your version 1.6 code may not be directly compiled in the new version. But the adjustment is straightforward and rebuilt is needed (Please refer to Section 12.2 for details).

1.2 What's new in Sora SDK ver 1.6?

Sora SDK ver 1.6 newly introduces following prominent features:

- **New UMX API.** Sora SDK ver 1.6 introduces a new set of UMX API that is more flexible, secure and has better performance.
- **UMX Reflection**. Sora SDK ver 1.6 now supports a new *reflection* mechanism that allows the programmer easily integrates the user-mode software radio modem into the Windows network stack.
- **Brick library**. One most prominent feature in Sora SDK ver 1.6 is *the Brick library*. Brick is a modular programming library for high-performance digital signal processing. It is easy to program, flexible and highly extensible.

- **UMXSDRab.** UMXSDRab is a powerful SDR 802.11 modem based on UMX reflection. It supports both client mode and adhoc mode. So it can easily connect to a commercial 802.11 AP or device. UMXSDRab has an easy-to-use interactive interface to configure and monitor the status of SDR modem application.
- **DbgPlot tool**. DbgPlot is a versatile tool that allows a program to dynamically generate various graphics in real-time. It is a very useful tool for real-time monitoring or debugging DSP programs.

1.3 What's new in Sora SDK ver 1.5?

Sora SDK ver 1.5 substaintially changes the implementation of the Sora core library and drivers, providing programmers with a more flexible, robust, and friendly developing environment to build powerful SDR applications. It also fixes almost all known bugs in the previous versions. The key features of Sora SDK ver 1.5 includes:

- **Full compatible with Windows XP**. Previous Sora versions have several compatibility issues across different variants of Windows XP due to an implementation limitation. Sora SDK ver 1.5 has removed this limitation and is compatible to all Win XP versions by implementing a new scheduler that dynamically assigns best cores to the time-critical threads. While a real-time thread may run on different cores, its execution is not interrupted. The new scheduler also greatly improves the responsiveness of the system compared to previous versions.
- **Full-fledged User-Mode Extension (UMX) API.** The UMX API is first introduced in Sora SDK ver 1.1. The new Sora SDK ver 1.5 has completed a full-fledged UMX API to build powerful SDR applications. A new resource isolation and collection mechanism has been implemented to protect the system against unsafe applications. Zero-copy mechanisms are deployed when accessing both hardware Tx and Rx buffers. Therefore, the overhead and latency of sending/receiving signals in user-mode are reduced to minimum. A new UMX-based 802.11a/b/g decoder is included in the SDK to illustrate the usage of the new UMX API.
- **Enriched tools.** Sora SDK ver 1.5 comes with a set of useful tools for SDR development. The package contains software oscilloscopes for both 802.11b DSSS and 802.11a/g OFDM. It also includes a handy Hardware Verification Tool to test your hardware and also help you find the best parameter settings.

1.4 Target Operating Systems

Sora works on Microsoft Windows operating system. After Sora SDK ver 1.7, Sora is able to work on Microsoft Windows XP (32bit) with Service Pack 3 and Microsoft Windows 7 (64bit).

Sora also requires Microsoft Windows Driver Kit (WDK) to be compiled. You can download WDK from Microsoft downloads (http://www.microsoft.com/whdc/DevTools/WDK/WDKpkg.mspx).

1.5 Target Hardware

In theory, Sora should work with any modern commodity multi-core PC with one spare PCIe-x8 or PCIe-x16 slot. Since Sora performs all Digital Signal Processing (DSP) in software, you may want to equip the PC with the latest CPU and as many cores as affordable. As a general guidance, a quad-core CPU clocked at 2.66GHz or higher is recommended to run real-time software radio applications like WiFi. Most Sora DSP software requires Intel SSE3 and above. Therefore, you should double-check your CPU data-sheet to verify that SSE3 instructions are supported (most Intel CPUs in the market should already support it).

Sora requires a compatible Radio Frequency (RF) Front-end to communicate over the air. Currently, two RF boards are supported: RICE WARP RF daughter board and USRP XCVR2450 daughter board. Both are 2.4G/5GHz radios. In the future, we hope to support more and more compatible RF front-ends. Please visit the Sora web site and forums for updated information.

Sora also requires an RF-specific Adaptor Board (RAB) to connect either USRP or WARP daughter board to the RCB. You can find their order information on the Sora web site. The USRP RAB further comes pre-clocked with two different rates: 40MHz or 44MHz, providing a sampling rate of 40MSps or 44MSps respectively. Choosing which clock rate depends on your application. If you mainly work with OFDM like 802.11a/g, you may find it handy to use 40MHz RAB. Otherwise, if you want to work with 802.11b-like system, you can choose 44MHz RAB. WARP daughter board only comes with 40MSps sampling rate.

Table 1 summarizes the hardware requirements for Sora.

Table 1. Hardware requirements for the Microsoft research Software Radio

CPU/Freq	quad-core/2.66GHz (or above)
Memory	1GB or above
PCIe-x8/x16 slot	1
Hard Disk	100M of free space
Radio hardware	Microsoft Research Software Radio Control Board (RCB)
	Compatible RF front-end boards (currently, WARP RF daughter board or USRP XCVR2450 board with respective RF Adaptor Board)

Chapter 2.
Getting Started

2.1 Install Sora SDK

After you download the Sora SDK package, you can simply run **SoraSDK.msi** and follow the on-screen instructions to install software. The Sora SDK package contains the following components:

- The Sora core driver for the RCB.
- The HwTest driver - implementing user-mode extension.
- UMXSDRab – an 802.11 SDR modem based on UMX Reflection
- The sample SoftWiFi driver – a kernel-mode miniport driver implementing full functional IEEE 802.11a/b/g.
- Hardware Verification Tool – helping to test and configure the hardware.
- DebugPlot – a graphic tool for real-time monitoring and debugging.
- Software oscilloscopes for 802.11a/b/g.
- Other samples and tools.

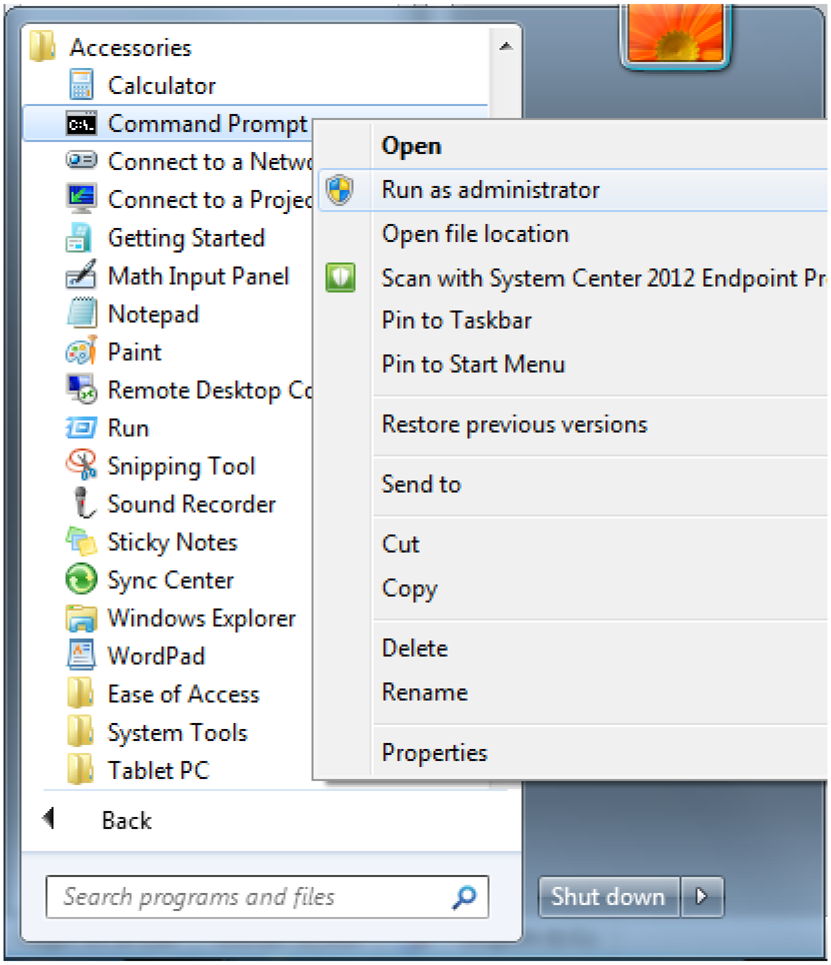
Section 2.5 shows a complete directory tree of the Sora SDK ver 1.7.

2.2 Install RCB Driver and HwTest Driver

2.2.1 Windows 7 Prerequisites

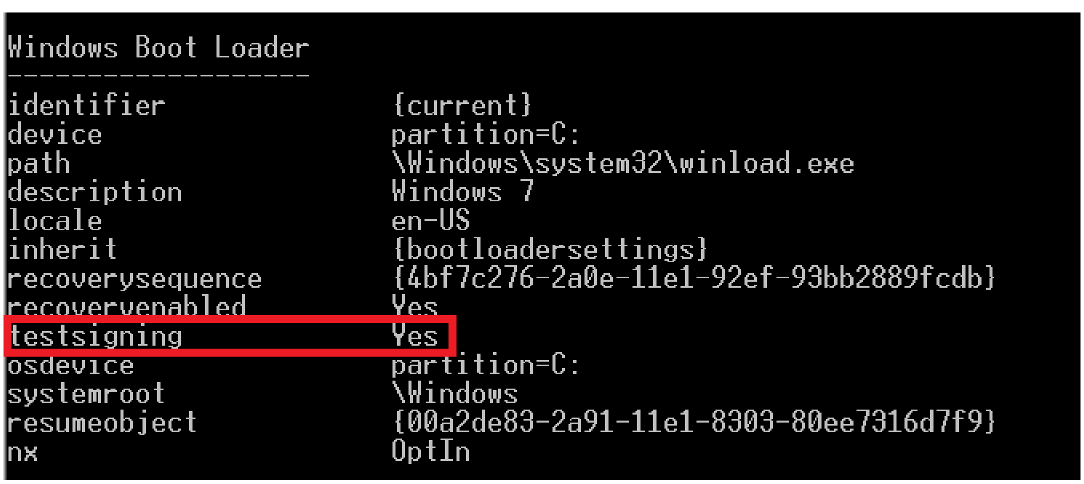
The Sora 64-bit Windows 7 drivers are test-signed by Microsoft Research Asia, so it requires Test-Signing to be set ON before installed on the target Windows 7 platform. This should be accomplished by BCDEDIT.EXE, a built-in tool in Windows 7 platform. Please follow the steps listed below:

1. Run the Command Prompt as administrator



2. Execute **bcdedit /set TESTSIGNING ON**

3. Execute **bcdedit** for confirmation



```
Windows Boot Loader
-------------------
identifier              {current}
device                  partition=C:
path                    \Windows\system32\winload.exe
description             Windows 7
locale                  en-US
inherit                 {bootloadersettings}
recoverysequence        {4bf7c276-2a0e-11e1-92ef-93bb2889fcdb}
recoveryenabled         Yes
testsigning             Yes
osdevice                partition=C:
systemroot              \Windows
resumeobject            {00a2de83-2a91-11e1-8303-80ee7316d7f9}
nx                      OptIn
```

4. Restart the system to take effect

Now, the target system is ready for installing 64-bit PCIE, HWTest and SDRMiniport test-signed drivers.

2.2.2 Installation Progress

Before you install the RCB driver, please make sure that the RCB board is firmly plugged into your motherboard and a RF front-end is properly connected to the RCB. Please follow the instructions in "Sora Device Drivers Installation.pdf" to install and configure the RCB driver.

Then, you can install the HwTest driver. HwTest implements user-mode extension API that allows applications to access the Sora radio resource. You can use Windows Device Manager “Add Hardware Wizard” to install them. You should choose ‘manually add a new driver’ and specify the driver files location. The binary of the HwTest driver is located at **%SORA_ROOT%\bin\hwtest**.

Any time if you want to reset the RCB driver, you should reset the RCB hardware as well. After disabling the RCB driver, you should press the reset buttons on both RCB and the RAB (if you use USRP RF daughter boards) before you re-enable the RCB driver again. These reset buttons are shown in the following Figure 1.

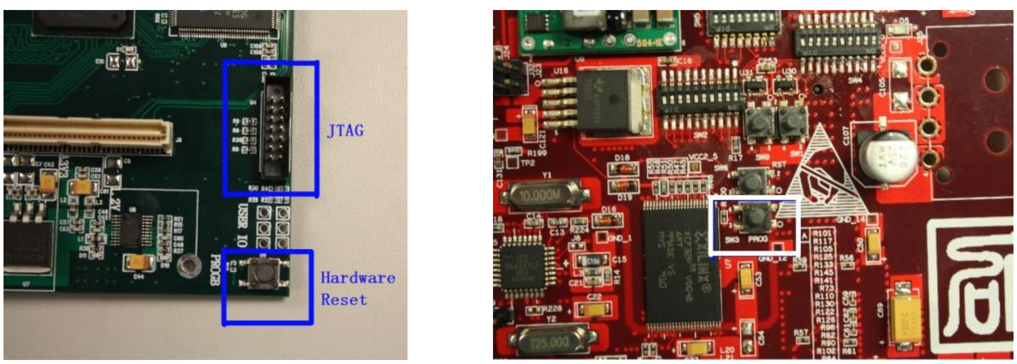


Figure 1. Reset buttons on USRP RAB (left) and RCB (right).

2.3 Test Hardware

2.3.1 Hardware Verification Tool

Sora SDK includes a handy tool for testing your hardware: the Hardware Verification Tool (HVT). HVT allows you to visually verify your RF hardware and tune proper parameter settings (like central frequency offset and Tx/Rx gains).

You need two Sora boxes to run HVT, one as the sender and the other as the receiver. Before starting HVT, you should make sure both the RCB driver and the HwTest driver are enabled. Once you start HVT (HwVeri.exe is located at %SORA_ROOT%\bin), you will see the following window, as shown in Figure 2.

Table 2 provides a reference to each element on the HVT main window.

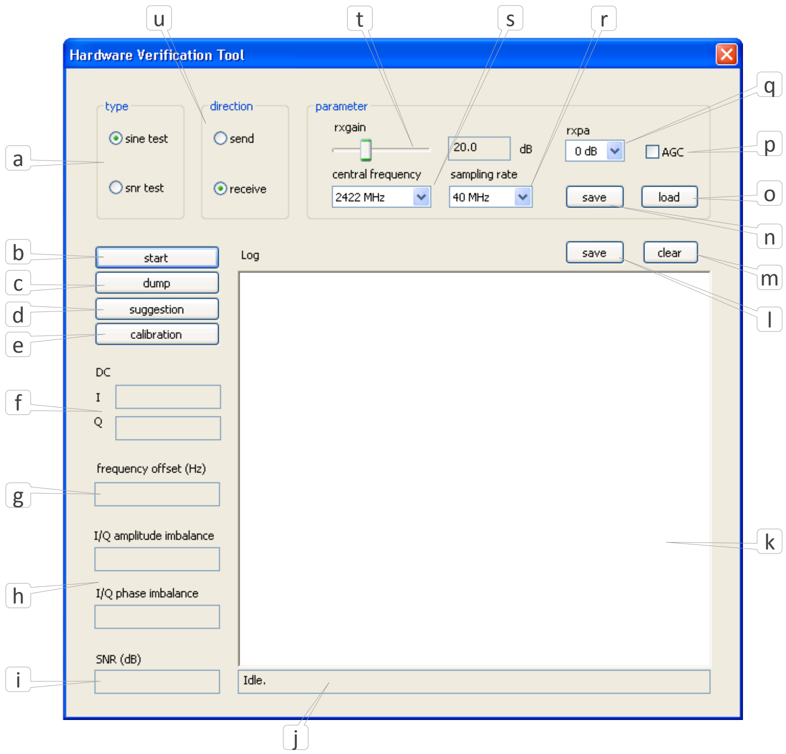


Figure 2. The main window of HVT.

Table 2. HVT Reference.

Label	Name	Remark
a	Test method selection	Select test type (sine test/SNR test).
b	Start button	Start/stop a test.
c	Dump button	Take a snapshot of the received signal and save it to a dump file. It is only available when HVT is working in the receiver mode.
d	Suggestion button	Open a what-to-do document. Only available when HVT is working in the receiver mode.
e	Auto calibration button	Start an automatic central frequency offset (CFO) calibration.
f	DC value	Show the Direct Current value of the received signal.
g	Central Frequency Offset	Show the central frequency offset between the receiver and the sender.
h	I/Q imbalance	Show the I/Q imbalance of the received signal (amplitude and phase). It is only available in the sine test mode.
i	Signal-to-Noise Ratio (SNR)	Show the SNR of the currently received signal. It is only available in the SNR test mode.
j	Status bar	Show the current status message.
k	Log window	Show the full logs during the test.
l	Save log button	Save the logs into a text file.
m	Clear button	Clear the logs.
n	Save parameter button	Save the parameters into a configuration file.
o	Load button	Load the parameters from a configuration file.
p	AGC enable/disable	Check/uncheck to enable/disable AGC (Automatic Gain Control).
q	RxPa selection	Select the value for RxPa. RxPa refers to the Low Noise Amplify (LNA) at the receiving chain of USRP XCRV2450. It has three valid settings: 0 or 0x1000 – 0dB; 0x2000 – 16dB; 0x3000 – 32dB.
r	Sampling rate	Set the sampling rate of the RAB (40/44MHz).
s	Central Frequency	Select the Central Frequency (channel) of the radio.
t	Gain adjustment	Drag to change gain setting. In the sender mode, it changes the Tx gain; While in the receiver mode, it changes the Rx gain of the radio chip.
u	Mode selection	Choose the sender or receiver mode of HVT.

HVT can perform two tests between two Sora boxes: the sine test (single tone test) and the SNR test (wide-band test). In the sine test, the sender transmits one single 1MHz sine waveform. Using this waveform, the receiver can compute the Central Frequency Offset (CFO) between the sender and receiver radio, and reveal the best receiver gain setting. To perform a since test, you can follow the steps listed below:

1. Run HVT on two Sora boxes. Select “sine test” at both machines.
2. Configure one as the sender and the other as the receiver.
3. Select the sampling rate at the receiver that matches your RAB sampling rate.
4. Click “start” at the sender. You may notice the sender’s status bar displays the message “Sending 1MHz sine wave”.
5. Click “start” at the receiver. Now you should be able to see the received signal like Figure 3. The left window shows the energy plot of the signal and the right window shows the constellation plot of I/Q samples. Since the transmitted signal is single sine waveform, the constellation plot is a circle.

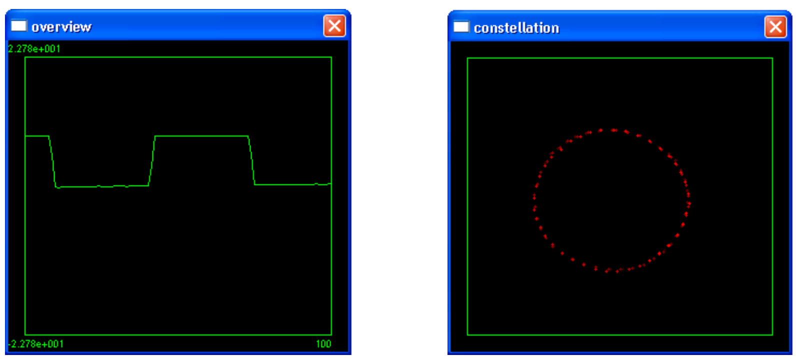
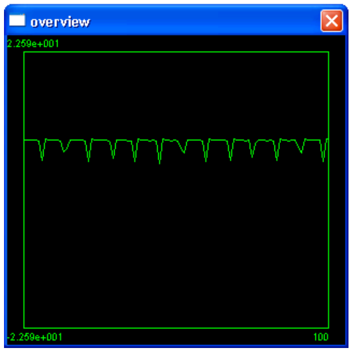


Figure 3. Received signal from the sine test.

You can perform the SNR test by selecting the SNR test mode and follow the similar steps as in the sine test. In the SNR test, the sender transmits a wide-band 16-QAM modulated OFDM signal. Figure 4 shows the received signal in both energy plot and constellation plot in the SNR test. The actual SNR value is displayed in the SNR field in the main window.

You can further use HVT to find the best receiver gain parameters, I/Q imbalance and the CFO between the two Sora boxes. For a complete reference of HVT, please refer to Chapter 11.4.



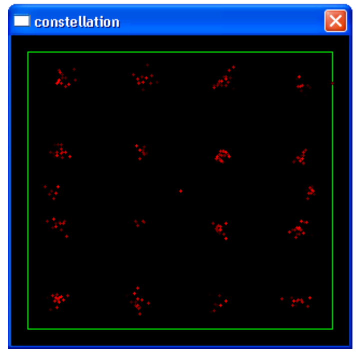


Figure 4. Received signal from the SNR test.

2.3.2 Receiving frames from a commercial WiFi card

If you have only a single set of Sora machine, you can use it as the receiver and use a laptop with WiFi interface as the sender. The laptop should support flexible WiFi configurations (e.g., Atheros NIC with MadWiFi driver) because you will need to set it to ad hoc mode with SSID "sdr" at channel 3 (by default, the HwTest driver configures the RF front-end to channel 3). You will also need a tool like iperf to send out broadcast packets.

At the Sora machine (receiver), you can use **dut.exe** to take a snapshot of the channel with the following command sequence (text following "##" are comments and not meant to be included in the command line).

```
dut start                           ## start the HwTest driver
dut centralfreq --value 2422        ## channel 3 in 2.4GHz band
dut rxpa --value 0x2000
dut rxgain --value 0x1000
dut dump                            ## store a snapshot of channel signal in a dump file
```

The generated dump file is located at **c:**, with the ".dmp" extension. You can easily identify them by examining the file creation time.

You can use the software oscilloscope tools to view the stored signals. These tools are located at **%SORA_ROOT%\bin**. If the source signal is 802.1b (DSSS) signal, you should use **sdscope-11b.exe** to view the recorded signal. Otherwise, you should use **sdscope-11a.exe** to view OFDM modulated signals. After you start the software oscilloscope tool (e.g. **sdscope-11b.exe**), you can press 'o' to bring up an open file dialog window, from which you can select the newly stored dump file. **sdscope-11b** decodes and displays the result in screen as shown inFigure 5.

To view dumped OFDM signals (802.11g rates of 6Mbps ~ 54Mbps) with **sdscope-11a**, you should also specify the sampling rate of the RAB with following command lines,

```
sdscope-11a.exe -s40          ## If your RAB's sampling rate is 40MSps
```

or,

```
sdscope-11a.exe -s44          ## If your RAB's sampling rate is 44MSps
```

Figure 5. Displaying the dump file with sdscope-11b.

2.4 Build and Install SoftWiFi Driver

2.4.1 Build environment

You need to install **Windows Driver Kit (WDK)** before you can compile the sample SoftWiFi miniport Driver. You can download WDK from Microsoft downloads.

The installer of Sora SDK package has created four shortcuts to *build command window* in the start-menu (located in Start\Programs\Microsoft Research Asia\ Software Radio Academic Kit 1.7). Before you can use them, you should configure the WDK path by adding an environment variable, WINDDK_ROOT. This variable should point to the root path of the WDK. Environment variables are configured using Windows Control Panel. Figure 6 shows a screen snapshot when you add a new environment variable on Windows XP.

Then, you can click the menu item of "**x64 Free Build**" to open a command window. You can type the command "**bcz**" to build the SoftWiFi driver (the sample SDR miniport driver), Sora User-mode Extension (UMX) samples and other tools. All target files (like .exe, .dll, .lib, .sys, etc.) are generated in the folder **%SORA_ROOT%\target\ fre(chk)_wxp(win7)_x86\i386(amd64)**. Because the sample SDR miniport driver can be built for both 64bit and 32bit OS, there're dirs files for both configuration. Remember to run **%SORA_ROOT%\src\set_dirs_x86.cmd** before building the 32bit binaries and run **%SORA_ROOT%\src\set_dirs_x64.cmd** for 64 bit binaries.

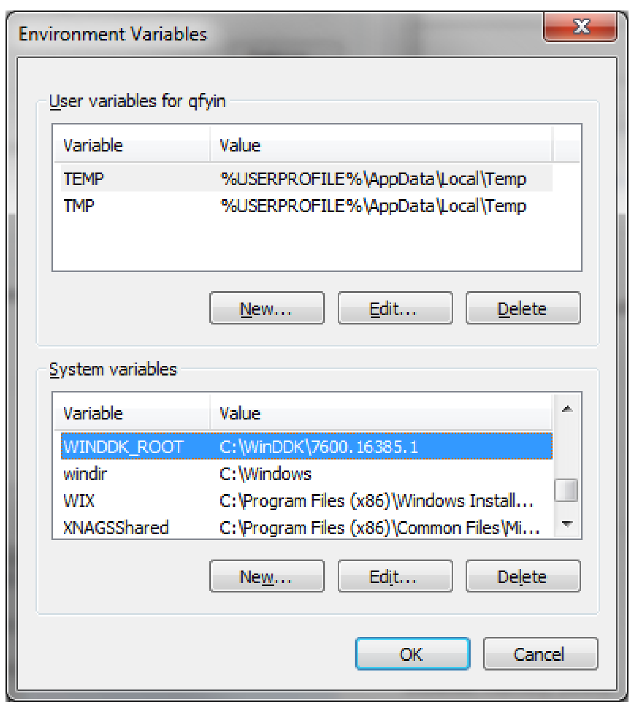


Figure 6. Set WINDDK_ROOT environment variable.

2.4.2 Driver Test-Signing

The Test-Signing is required after successfully built the 64-bit Windows 7 drivers. All the tools used for Test-Signing are released in WDK. Start a build environment command prompt of WDK and follow the steps listed below to acoomplish the process.

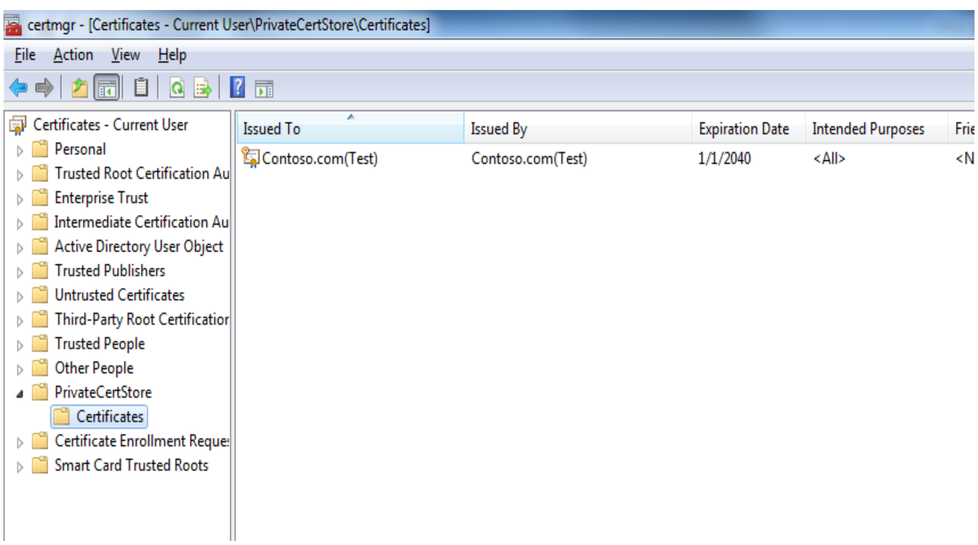
1. **Create a MakeCert test certificate.** A MakeCert test certificate is required first and is used as certificate for digitally signing. Use the **MakeCert** tool as follows:

   MakeCert –r –pe –ss TestCertStoreName –n "CN=CertName" CertFileName.cer

   In the following example, the MakeCert command generates a test certificate named "Contoso.com(Test)", installs the test certificate in the PrivateCertStore certificate store, and creates the Testcert.cer file that contains a copy of the test certificate.

   MakeCert –r –pe –ss PrivateCertStore –n "CN=Contoso.com(Test)" testcert.cer

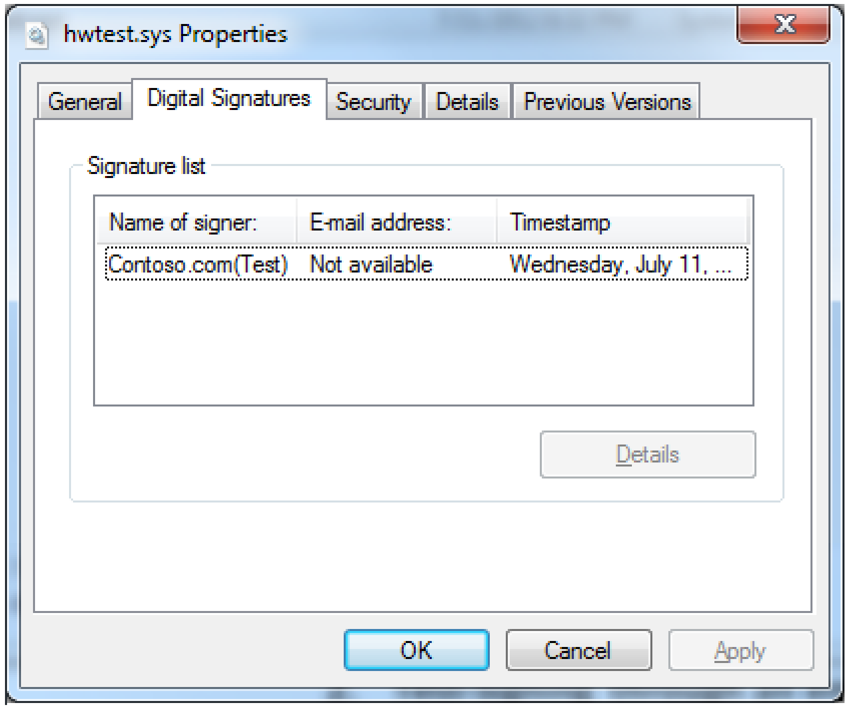
   It's able to find the created MakeCert test certificate by command **certmgr.msc**.



2. **Test-Signing through an embedded Signature. Signtool** is used to digitally sign files, also the drivers. The following command shows how to sign the HWTest driver with the certificate created by MakeCert previously.

   Signtool sign /v /s PrivateCertStore /n Contoso.com(Test) /t http://timestamp.verisign.com/scripts/timestamp.dll HWTest.sys

   The digital signatures can be found in the property windows of the signed file after successfully signed.



There are still other ways to sign drivers. We just provide 1 here. Please refer the WDK help documentation for more detail and the parameters for each releated tools.

2.4.3 Install SoftWiFi Driver

After you successfully build the SoftWiFi source, the driver binary is generated at **%SORA_ROOT%\target\fre(chk)_wxp_x86\i386,** where you can also find the corresponding inf file **(sdr.inf)**. You can use "Add Hardware Wizard" to install them on Windows. You should choose "manually add a new driver" and specify the driver files location. Since the HwTest and SoftWiFi drivers are contending the hardware resources through the RCB driver, they cannot be enabled simultaneously. You should disable the HwTest driver before enabling the SoftWiFi driver. The SoftWiFi driver can be configured into DSSS mode (802.11b) or OFDM mode (802.11a/g). The default mode is OFDM. To change to a different mode, you can modify the **ModMode** registry entry in sdr.inf by specifying value of "802.11a" or "802.11b".

The SoftWiFi driver exposes an Ethernet interface to the operating system. You can try to use the SoftWiFi driver to communicate with a commercial WiFi card in real-time. You should make sure the SoftWiFi driver is configured in a proper mode, i.e. DSSS (802.11b) or OFDM (802.11a/g) (The default mode is OFDM). If you are using OFDM mode, you should also make sure you have specified the same sampling rate in **sdr.inf** file as your RAB. Chapter 2.4.4 lists all configurations to the SoftWiFi driver.

2.4.4 Configure the SoftWiFi driver

The sample SoftWiFi driver can be configured by editing entries in **sdr.inf** file.

Table 3. Configuration with SDR.INF.

Entry Name	**Description**	**Type**	**Value**
NetworkAddress	MAC address	String	The default value is "02-50-F2-00-00-01". This default value will make the driver to randomly select last three bytes as the MAC address. A user can explicitly specifies a MAC address if needed (the last three bytes cannot be "00-00-01")
BSSID	Basic service set identification	String	The driver will automatically replace the value from a valid beacon it receives.
ModMode	Protocol of modulation and demodulation	String	802.11a / 802.11b
11ADataRate	Data rate in Mbps in 802.11a modulation	String of decimal number	6 / 9 / 12/ 18 / 24 / 36 / 48 / 54
DataRate	Data rate in 100 kbps in 802.11b modulation	String of hex-number	0x0A / 0x14 / 0x37 / 0x6E (in unit of 100Kbps)
ModSelect	Modulation option in 802.11b modulation	String of number	0 for CCK, 1 for PBCC
PreambleType	Preamble type in 802.11b modulation	String of number	0 for long, 1 for short
SampleRate	sample rate in MHz of the radio PCB	String of number	40 / 44MSps

2.5 Directory Structure

The directory structure shown here assumes the Sora SDK is installed at d:\SORASDK1.7

D:\SORASDK1.7	
│ AcademicKit-LA.pdf	Agreement to purchase the academic kit
│ MSR-LA.pdf	MSR License agreement
│ Sample Code-LA.pdf	MSR License agreement for the sample source code
│ Readme.htm	The ReadMe file
├–bin	
│ │ dbgplot.exe	DbgPlot tool. Refer to Chapter 11.5 for more information.
│ │ dut.exe	Hardware diagnosis tool. Run dut without any command line parameter for help.
│ │ dot11config.exe	SDR miniport driver configuration tool. See Chapter 9.1 for command line reference. Source code provided in %SORA_ROOT%\src\driver\SDRMiniport\dot11config
│ │ demod11.exe	Command line tool to demodulates 802.11a(b) dump files and displays statistics about data frames. Source code provided in %SORA_ROOT%\src\bb\demod11
│ │ HwVeri.exe	A helpful tool to test and configure Sora hardware components. Refer to Chapter 11.4 for detail.
│ │ umxsdrab.exe	User-mode SDR modem for both 802.11ab. It utilizes the new *UMX reflection* mechanism. Refer to Chapter 8. For details. Source code provided in %SORA_ROOT%\src\umxsdr
│ │ UMXDot11.exe	User mode 802.11 decoder based on UMX. It has a full featured 802.11a/b/g decoder. It is also able to modulate a frame and send it through UMX. Refer to Chapter 7.4 for detail. Source code provided in %SORA_ROOT%\src\bb\UMXDot11
│ │ sdscope-11a.exe	User mode utility which demodulates 802.11a frames from dump file and displays intermediate results in GUI. Refer to Chapter 10.2 for detail.
│ │ sdscope-11b.exe	User mode utility which demodulates 802.11b framesfrom dump file and displays intermediate results in GUI. Refer to Chapter 10.2 for detail.
│ │ SrView.exe	A simple Sora dump file viewer. See Chapter 10.3 for detail.

│ │ IntFiltr.reg	Interrupt-Affinity Filter registry setting
│ │ IntFiltr.sys	Interrupt-Affinity Filter driver
│ │ IntFiltrCmd.exe	Interrupt-Affinity Filter utility
│ ├─Config	Configuration file used by sdscope-11b
│ ├─ProtocolRunInfo	Configuration file used by sdscope-11b
│ ├─HWTest	Test driver used by the diagnosis tool
│ └─PCIE	Radio Control Board driver
├─build	
├─doc	Sora manual and hardware/driver installation guide
├─inc	Software radio framework header files
├─lib	Software radio framework library files
└─src	Sora sample code
├─bb	Baseband library sample
│ ├─Brick11b	802.11b source code, BRICK version
│ ├─dot11a	802.11a source code
│ ├─dot11b	802.11b source code
│ ├─UMXDot11	UMX extension, a full featured user mode 802.11 a/b/g decoder.
│ └─demod11	Sample tools to modulate/demodulate 802.11a/b frames
├─inc	Header files used by the 802.11 a/b sample driver
├─kmsdr	Miniport driver sample
│ ├─ll	Link layer
│ ├─mac	Mac layer
│ ├─phy	Physical layer
│ └─SDRMiniport	
│ ├─dot11config	Miniport driver configuration tool
│ ├─NDIS5	NDIS5 miniport driver
│ └─NDIS6	NDIS6 miniport driver
├─umxsdr	User mode SDR modem for both 802.11a/b.
└─util	Common utilities used by the 802.11 a/b sample driver

Chapter 3.
Sora Fundamentals

3.1 Architecture

The overall system architecture of Sora is illustrated in Figure 7. The RCB interconnects RF front-ends to the PC. The RCB talks to the PC using the PCI-E interface, and with read/write digital signal samples from/to PC memory using direct memory access (DMA). It connects to the RF front-end boards with the Sora Fast Radio Link (SoraFRL). SoraFRL defines the necessary protocol for the RCB to control the RF boards. Any Sora compatible RF boards should implement SoraFRL. For more information on SoraFRL, please refer to the “Sora Fast Radio Link Specification”.

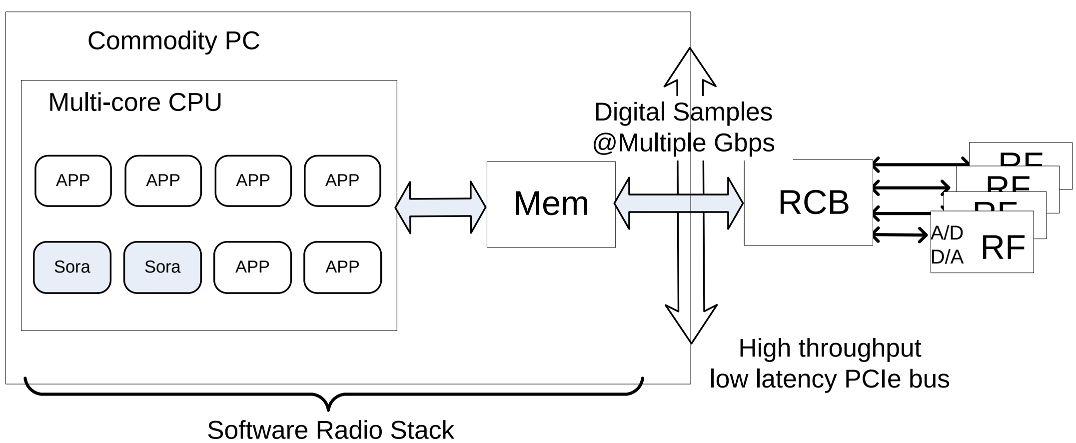


Figure 7. Sora System Architecture.

Figure 8 shows the Sora software architecture. The RCB driver manages the RCB and RF front-end hardware resources and provides APIs to the SDR miniport driver to send/receive digital waveform samples. The SDR miniport driver usually exposes an Ethernet interface to the operating system, so that all network applications can seamlessly use it for communication. In Sora SDK, a sample SDR miniport driver, named SoftWiFi, is provided, which implements the

802.11a/b/g protocol. Alternatively, one can write user-mode SDR application programs that interact with RCB/RF hardware through *Sora User-Mode Extension API (UMX API)*. Sora SDK provides a set of highly optimized UMX API to facilitate high performance and low latency DSP implementation in user-mode, including exclusive thread library, zero-copy sample transport and integration with network stack. This new UMX framework allows programmers to implement sophisticated user-mode SDR drivers, and greatly reduces the development efforts. We provide a sample UMX application that implements a full featured 802.11a/b/g receiver entirely in user-mode.

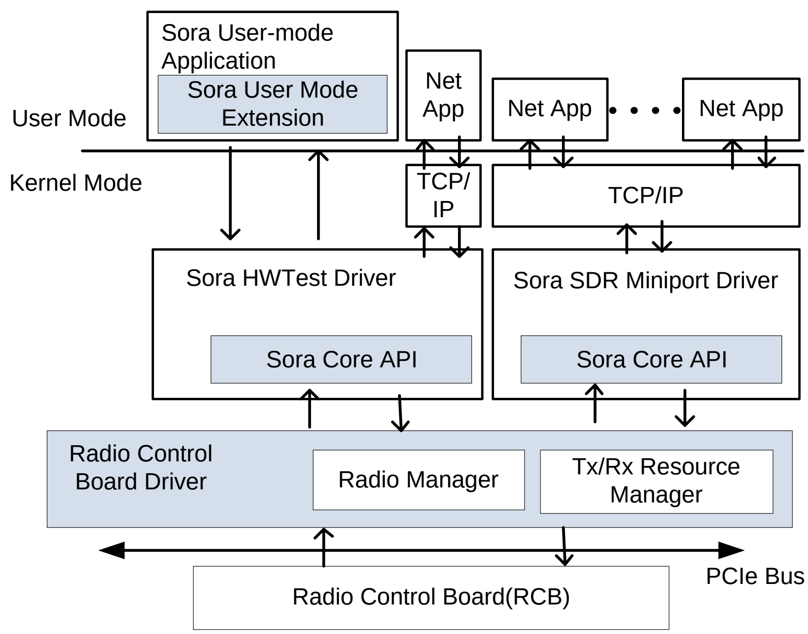


Figure 8. Sora Software Architecture.

Figure 9 shows the architecture of a typical Sora SDR miniport driver. It usually exposes an Ethernet interface to the operating system based on the Windows NDIS framework. A SDR miniport driver should implement the lower three layers, i.e. the link layer, MAC and the physical layer. The link layer performs the frame conversion and encapsulation. For example, in the sample SoftWiFi driver, the link layer converts the Ethernet frames to 802.11 frames and back before and receiving. The MAC layer is basically a finite state machine (FSM) that handles media access protocols. A set of FSM APIs are provided in Sora SDK to facilitate the MAC programming. The Physical layer (PHY) contains all implementation of the baseband signal processing. The basic routines that need to be implemented are modulation, demodulation and channel monitoring (carrier sensing).

For ease of cross-reference, a global context, called SDR_CONTEXT, is used in the sample SoftWiFi driver to pass data across different layers. This SDR_CONTEXT also contains pointers to other useful data structures and is used as the sole parameter for many routines in the SoftWiFi driver.

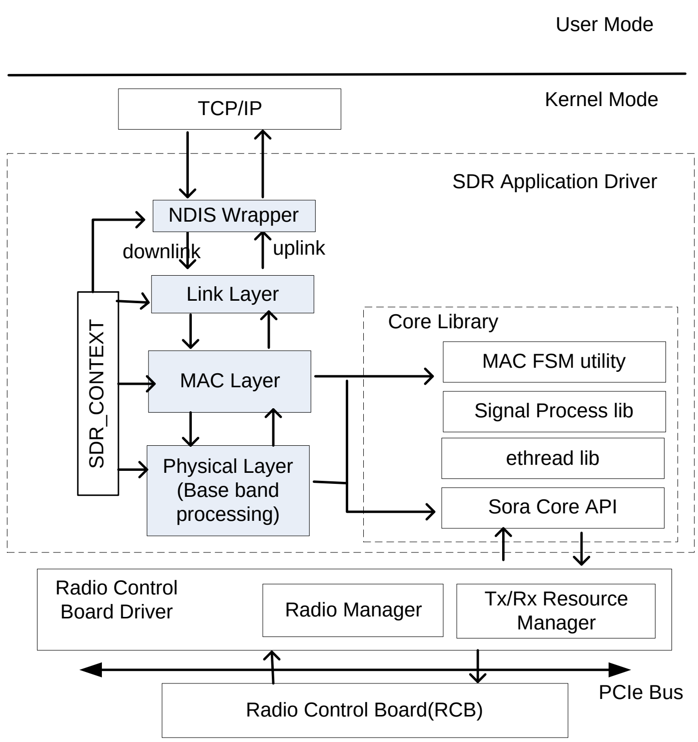


Figure 9. Typical Architecture of a Sora application Driver.

3.2 Abstract Radio and Radio Object

An *Abstract Radio* (AR) is a software abstract of radio hardware. An abstract radio contains a Tx channel, a Rx channel, and a set of control registers. A SDR application – either a SDR miniport driver or a UMX-based user-mode program – is operating on abstract radio objects (ARO). The RCB driver and hardware map every ARO to a real RF front-end. Figure 10 illustrates the Abstract Radio architecture. If a SDR application sets a Control Register of an ARO, the command is transferred to the RAB through the RCB driver and firmware. The RAB firmware is responsible to translate the abstract command into the real operation sequence to the RF front-end chipset. With this architecture, the same SDR application can ran on various RF front-end without modification. Current RCB supports up to eight ARs. These ARs can map to different RF front-ends, or they can be grouped to form a MIMO system.

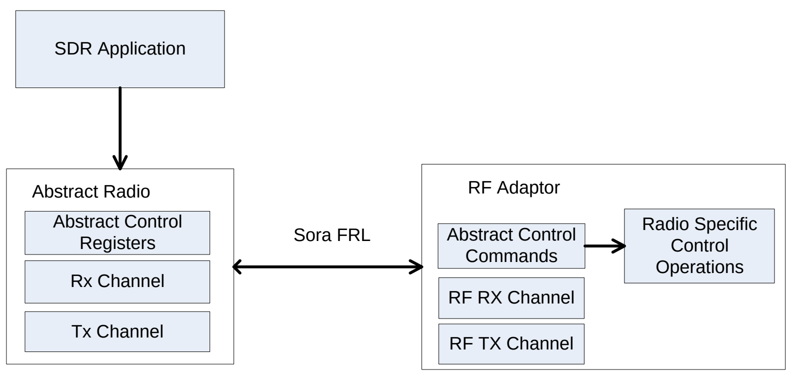


Figure 10. Abstract Radio Architecture.

An ARO is represented as a SORA_RADIO structure. Figure 11 shows partial definition of the structure. The full definition of SORA_RADIO can be found in the header file **_radio_manager.h**. **__ctrl_reg** refers to the abstract control registers, **_rx_queue** manages the Rx channel, and **pTxResMgr** manages the TX channel. Each AR is allocated a unique hardware ID as shown in **RadioID**. To read from the Rx channel, a SDR driver can use a helper object named **SORA_RADIO_RX_STREAM**. The RX_STREAM object hides the structure of RCB DMA buffer and provides a simple stream of I/Q samples received from the RF front-end. Each ARO is allocated single buffer for transmission, called *TX sample buffer*. Any modulated waveform samples are placed in this buffer, from where they are downloaded into the RCB and sent to the RF front-end. The TX sample buffer is initialized at the beginning and is a shared resource. Therefore, when the SDR driver uses multiple threads for modulation, the access to the TX sample buffer from different threads should be properly coordinated by **__TxBufLock**.

The RCB hardware may also send PnP events to software. These PnP events may be passed to a SDR driver as well. In particular, two PnP events should be monitored for a SDR driver. They are:

1) *Power management notification*. This event is defined as **PnPEvent** in a SORA_RADIO object. The SDR driver is encouraged to monitor the event to handle unexpected disconnection or power outage of the RF radio board.
2) *Force release event*. This event is actually generated by the RCB driver when it detects an abnormal behavior of RCB, or if it is being unloaded. When receiving this event, the SDR driver should release the resource immediately. The event is shown as **ForceReleaseEvent** in the SORA_RADIO definition.

```
/*
   SORA_RADIO defines the basic abstract to a hardware radio.
   A Sora radio contains mainly three parts:
   1) A Control channel - control registers
   2) A Rx channel - Rx queues, further wrapped as rx_stream
   3) A Tx channel - Tx buffer, further with Tx resources.
 */
typedef struct __SORA_RADIO
{
   LIST_ENTRY                    RadiosList;

   // control registers
   __HW_REGISTER_FILE    __ctrl_reg;

   // RX Channel
   __RX_QUEUE_MANAGER __rx_queue;

   // Reference to shared Tx Resource manager
   PTX_RM                        pTxResMgr;

   ULONG                         __radio_no; //radio index
   ULONG                         RadioID;    //unique radio id

   __SORA_RADIO_STATUS           __status;   // radio status
   ULONG                         __uRxGain;
   ULONG                         __uTxGain;

   KSPIN_LOCK                    __HWOpLock;//DMA upload and TX lock
   LONG                         __Lock;

   KEVENT                        ForceReleaseEvent;
   KEVENT                        PnPEvent;

   /* Context - usually linked to a PHY bond on the radio */
   PVOID                        __pContextExt;
```

```
    // RX_STREAM to access Rx queue DMA Buf
    SORA_RADIO_RX_STREAM            __RxStream;

    ULONG                       __fCanWork;
    volatile BOOLEAN            __fRxEnabled;

    // TX Channel - Tx Sample Buffer
    PTXSAMPLE                   __TxSampleBufVa;
    PHYSICAL_ADDRESS            __TxSampleBufPa;
    ULONG                       __TxSampleBufSize;
    LONG                        __TxBufLock;    // Lock to access the Tx sample buffer

    //FAST_MUTEX                __ModSampleBufMutex;
} SORA_RADIO, *PSORA_RADIO, **PPSORA_RADIO, __SORA_RADIO, *__PSORA_RADIO;
```

Figure 11. Definition of the RADIO Object.

3.2.1 Radio Allocation and Release

The SDR driver should allocate abstract radios before accessing the radio resources, e.g., TX channel, RX channel, or control registers. Abstract radios should also be released to the system when no longer being used. Function **SoraAllocateRadioFromDevice** is used to allocate one or more radios. Prepare a linked list to hold the returned SORA_RADIO objects before calling the function. A name tag is provided by the caller to track the radio usage.

The SDR driver should call **SoraReleaseRadios** to release the allocated radio objects.

3.2.2 Radio Configuration and Start

After allocating a radio, the SDR driver should call **SoraRadioInitialize** to allocate TX and RX resources for the radio object. After initialization, the SDR driver can call **SoraRadioStart** to enable the abstract radio on the RCB. The function call also provides the Tx/Rx gain settings.

3.2.3 Radio example

Figure 12 shows a code piece that illustrates the allocation and initialization of a SORA_RADIO object. You can find the full function in **sdr_phy_main.c** in the SDK.

```
HRESULT
SdrPhyInitialize( PPHY pPhy,  PSDR_CONTEXT SDRContext, ULONG ulRadioNum   )
{
    HRESULT      hRes          = S_OK;
    LIST_ENTRY*  pRadiosHead    = &pPhy->RadiosHead;
    …
     hRes = SoraAllocateRadioFromRCBDevice (
                pRadiosHead,
                ulRadioNum,
                NIC_DRIVER_NAME);
     If ( FAILED (hRes ) )
     {
          DbgPrint("[Error]SoraAllocateRadioFromRCBDevice failed\n");
```

```
        break;
    }
    // Successfully allocate radio resource..
    hRes = SoraRadioInitialize(
                RadioInPHY(pPhy, RADIO_RECV),  // Get the radio in PHY list
                NULL,  // reserved
                SAMPLE_BUFFER_SIZE,   // buffer size for TX
                RX_BUFFER_SIZE);

     FAILED_BREAK(hRes);

    // Start radio

     hRes = SoraRadioStart(

                RadioInPHY(pPhy, RADIO_RECV),

                SORA_RADIO_DEFAULT_RX_GAIN,

                SORA_RADIO_DEFAULT_TX_GAIN,

                NULL);
    FAILED_BREAK(hRes);
     …
    return hRes;
}
```

Figure 12. Radio allocation and initialization.

3.3 Transfer and Transmission

Before sending out a waveform, a SDR driver should first download the waveform samples onto the onboard memory of the RCB. Then, the SDR driver can issue another command to instruct the RCB to emit the waveform through the RF front-end. The download operation is referred as *transfer*, and we denote *transmission (or simply TX)* the behavior the send out waveform. The benefits of this two-phase operation are two-folds. First, the RCB's on-board memory naturally absorbs the potential burstiness of the CPU processing and the PCIe-Bus communication, thereby ensuring the correctness of the waveform transmission. Second, the RCB memory can also be used to store pre-modulated signals, providing additional flexibility.

3.3.1 PACKET_BASE object

A SDR driver uses a PACKET_BASE object to allocate TX resources of an abstract radio object. The PACKET_BASE object also contains a pointer to the original packet data. Figure 13 shows the definition of the PACKET_BASE object, which can also be found in **_packet_base.h**.

```
typedef struct __PACKET_BASE
{
    PMDL              pMdl;          // memory descriptors for original packet data
    PTX_DESC          pTxDesc;       // Refers to TX channel of an Abstract Radio
    LONG              fStatus;
    ULONG             PacketSize;
    ULONG             Reserved1; //for customized attachment
    ULONG             Reserved2; //for customized attachment
    ULONG             Reserved3; //for customized attachment
    ULONG             Reserved4; //for customized attachment
    PVOID             pReserved;
} PACKET_BASE;
```

Figure 13. Definition of PACKET_BASE ojbect.

A PACKET_BASE object has a pointer to a Memory Descriptor List (MDL) that describes the data in the original packet. MDL is a common data structure in the Windows kernel to describe a memory buffer. For more information of the MDL, the reader may refer to WDK references.

The **fStatus** field tracks the packet's current status. The SDR application driver should check this status before conducting operations on it. The status can be one of following:

- **PACKET_NOT_MOD**: The modulated waveform of the packet has not been generated.
- **PACKET_TF_FAIL**: The *Transfer* operation failed.
- **PACKET_CAN_TX**: The *Transfer* operation succeeded. So the modulated waveform is not in the RCB Waveform Cache and is ready for *Transmission*.
- **PACKET_TX_PEND**: The modulated waveform is being transmitted.
- **PACKET_TX_DONE**: The *Transmission* is done.

If a PACKET_BASE object is in the **PACKET_TF_FAIL** state, the SDR driver should not attempt to transmit it.

3.3.2 Modulation

A SDR driver should call **SoraPacketGetTxResource** to bind a PACKET_BASE object to the TX channel for a radio. **SoraPacketGetTxResource** will initialize the status to **PACKET_NOT_MOD.** Then, the SDR driver can call **SoraPacketGetTxSampleBuffer** to obtain a sample buffer to hold the waveform generated. The structure of this modulation sample buffer is shown in Figure 14. It is basically an array of complex I/Q samples. Each I and Q component is 8-bit. The sample with the smallest address is transmitted first by the RF front-end board.

re_0	im_0	re_1	im_1		re_i	im_i	Re_{i+1}	im_{i+1}	

Figure 14. Structure of the TX sample buffer.

Once the SDR driver gets the modulation sample buffer, it should immediately generate waveform samples from the packet data (modulation). The SDR application driver should call **SoraPacketSetSignalLength** to specify the size of the buffer that is actually filled with the waveform samples. The size MUST be a multiple of 128 bytes. Therefore, some padding may be needed to ensure this.

3.3.3 Transfer and Transmission

A SDR driver calls **SORA_HW_TX_TRANSFER** to download the waveform samples from the Tx sample buffer to the RCB's memory. After the transfer operation, the SDR driver can call **SORA_HW_BEGIN_TX** to instruct the RCB to send out the waveform. After the transmission, the SDR application driver should call **SoraPacketFreeTxResource** to unbind the PACKET_BASE object from the radio's TX channel.

3.3.4 Example

Figure 15 shows a code excerpt for an SDR application driver to bind packets to the radio TX channel and call PHY layer functions to modulate the packet data to waveform samples. The full code can be found in **sdr_mac_send.c**. Figure 16 shows an excerpt where an SDR application driver instructs the RCB to transmit a waveform already stored in the RCB's memory. The full code can be found in **sdr_mac_tx.c**.

```
VOID SdrMacSendThread ( IN PVOID pVoid )
{
    NTSTATUS Status;
    HRESULT hRes;
    LARGE_INTEGER Delay;
    PDLCB pTCB  = NULL;
    PSDR_CONTEXT  pSdrContext  =
                                        SORA_THREAD_CONTEXT_PTR(SDR_CONTEXT, pVoid);
    PMAC pMac = (PMAC)pSdrContext->Mac;
    PPHY  pPhy = (PPHY)pSdrContext->Phy;
    PSEND_QUEUE_MANAGER
        pSendQueueManager = GET_SEND_QUEUE_MANAGER(pMac);
    PSORA_RADIO         pRadio              = NULL;

    // Thread start
    …
    Delay.QuadPart = -10 * 1000 * 10;
```

```
    do
    {
      …
        pRadio = RadioInPHY(pPhy, RADIO_SEND);
        do
        {
            // Try to dequeue a pending packet and do modulation
            SafeDequeue(pSendQueueManager, SendSrcWaitList, pTCB, DLCB);
            if (!pTCB)
            {
                break;
            }

            if (!DLCB_CONTAIN_VALID_PACKET(pTCB)) // invalid packet, pass through the pipeline
            {
                SafeEnqueue(pSendQueueManager, SendSymWaitList, pTCB);
                InterlockedIncrement(&pSendQueueManager->nSymPacket);
                InterlockedDecrement(&pSendQueueManager->nSrcPacket);
                continue;
            }

            // Allocate Tx Channel Resource for a packet
            if (IS_PACKET_NO_RES(&pTCB->PacketBase))
            {
                hRes = SoraPacketGetTxResource(pRadio, &pTCB->PacketBase);
                if (FAILED(hRes))
                {
                    InterlockedIncrement(&pSendQueueManager->nSymPacket);
                    InterlockedDecrement(&pSendQueueManager->nSrcPacket);
                    SafeEnqueue(pSendQueueManager, SendSymWaitList, pTCB); // let it go
                    DbgPrint("[Transfer][Error] insufficient TX resource \n");
                    break;
                }
            }
            else
            {
                KeBugCheck(BUGCODE_ID_DRIVER); //src packet should not own TX resource.
            }

            // Call PHY Modulation Routine
            hRes = (*pPhy->FnPHY_Mod)(pPhy, &(pTCB->PacketBase));

            // Transfer operation
            hRes = SORA_HW_TX_TRANSFER( pRadio,  &pTCB->PacketBase);
            SoraPacketAssert(&pTCB->PacketBase, pRadio); //for verification.

            if (FAILED(hRes))
            {
                SoraPacketPrint(&pTCB->PacketBase);
                SoraPacketFreeTxResource(pRadio, &pTCB->PacketBase);
                InterlockedIncrement(&pPhy->HwErrorNum);
            }

            SafeEnqueue(pSendQueueManager, SendSymWaitList, pTCB);
            InterlockedIncrement(&pSendQueueManager->nSymPacket);
            InterlockedDecrement(&pSendQueueManager->nSrcPacket);
            //both case: let the packet go.
        } while (TRUE);

    }while(!IS_SORA_THREAD_NEED_TERMINATE(pVoid));
    // Thread cleanup
    …
}
```

Figure 15. Modulation and transfer.

```
VOID
SdrMacTx(IN PFSM_BASE StateMachine)
{
    HRESULT              hRes              = S_OK;
    PSDR_CONTEXT     pSDRContext  = SoraFSMGetContext(StateMachine);
    PMP_ADAPTER       pAdapter         = (PMP_ADAPTER)pSDRContext->Nic;
    PMAC                  pMac  = (PMAC)pSDRContext->Mac;
    PPHY                  pPhy   = (PPHY)pSDRContext->Phy;
    PSEND_QUEUE_MANAGER
        pSendQueueManager = GET_SEND_QUEUE_MANAGER(pMac);
    PSORA_RADIO     pRadio = RadioInPHY(pPhy, RADIO_SEND);
    PDLCB                  pTCB  = NULL;

    do
    {
        SafeDequeue(pSendQueueManager, SendSymWaitList, pTCB, DLCB);
        if (!pTCB)
        {
            break;
        }

        if (pTCB->PacketBase.fStatus == PACKET_TF_FAIL) //The packet can't be TX out, so complete it.
        {
            DbgPrint("[TX][Error] I can't tx it out because transfer fail, make it TXDone to complete\n");
            // skip the packet
            …
            break;
        }

        pMac->fTxNeedACK = (pTCB->PacketType == PACKET_NEED_ACK);
        pTCB->RetryCount++;

       // Start transimission
        hRes = SORA_HW_BEGIN_TX(pRadio, &pTCB->PacketBase);
        if (FAILED(hRes))
        {
            DbgPrint("[TX][Error] TX hardware error , ret=%08x\n", hRes);
            SoraHwPrintDbgRegs(pRadio);
            InterlockedIncrement(&pPhy->HwErrorNum);
        }

        if ( !IS_MAC_EXPECT_ACK(pMac) || pTCB->RetryCount > TX_RETRY_TIMEOUT)
        {
            pTCB->bSendOK = (pTCB->RetryCount <= TX_RETRY_TIMEOUT);

            // if retry is not so big, assume it is sent out successufully.
            SoraPacketFreeTxResource(pRadio, &pTCB->PacketBase);
            SoraPacketSetTXDone(&pTCB->PacketBase);

            InterlockedIncrement(&pSendQueueManager->nCompletePacket);
            InterlockedDecrement(&pSendQueueManager->nSymPacket);
            SafeEnqueue(pSendQueueManager, SendCompleteList, pTCB);
            //MarkModulatedSlotAsTxDone(pSendQueueManager); //dequeue the packet from send queue
            SDR_MAC_INDICATE_PACKET_SENT_COMPLETE(pMac); //indicate to complete NDIS_PACKET
            MAC_DISLIKE_ACK(pMac);  // we don't need ACK any more.
        }
        else
        {
            SafeJumpQueue(pSendQueueManager, SendSymWaitList, pTCB);
            //wait for ack to retry or complete
        }
```

```
    } while (FALSE);
    SoraFSMGotoState(StateMachine, Dot11_MAC_CS);
    return;
}
```

Figure 16. Waveform transmission and cleanup.

3.4 Reception

The RX channel of a radio is enabled by **SORA_HW_ENABLE_RX**. The SDR driver can read the RX channel through an RX_STREAM object. The SDR driver can obtain a RX_STREAM object by calling **SoraRadioGetRxStream**. The RX channel of a radio is organized as a stream of signal blocks. Each signal block contains an array of 28 complex I/Q samples. The I or Q component are both 16-bit long. Figure 17 shows the structure of a signal block. Function **SoraRadioReadRxStream** loads a signal block into memory. It is blocking function that will not return until a full signal block is delivered from the RCB (or timeout). The **pbTouched** flag is set when the returned signal block is the last block in the RX channel, ie. the most recently received signal block. The SDR driver can use **SoraRadioGetRxStreamPos** to obtain the current position of the RX channel, and use SoraRadioSetRxStreamPos to change the current position of the RX channel.

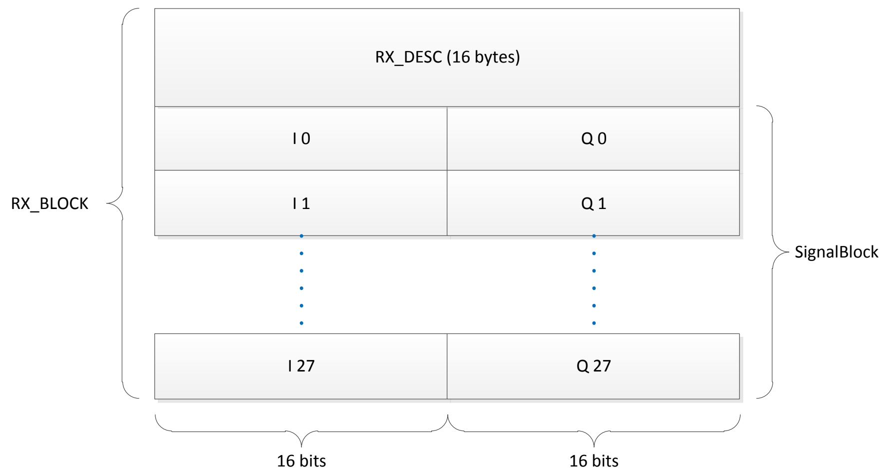


Figure 17. Structure of a signal block.

3.4.1 Example

Figure 18 shows sample code to read from an RX_STREAM object. The full code can be found in **bbb_spd.c**.

```
HRESULT BB11BSpd(PBB11B_SPD_CONTEXT pSpdContext, PSORA_RADIO_RX_STREAM
pRxStream)
{
    // ...
    FLAG touched;
    ULONG PeekBlockCount    = 0;
    HRESULT hr              = S_OK;
    SignalBlock block;
    do
    {
        // ...
        while (TRUE)
        {
            hr = SoraRadioReadRxStream(pRxStream, &touched, block);
            FAILED_BREAK(hr);

            // Estimate and update DC offset
            // ...
            PeekBlockCount++;

            // Measure energy
            // ...

            if (energyLevel != EL_NOISE)
            {
                if (pSpdContext->b_gainLevel == 0 && energyLevel == EL_HIGH)
                    pSpdContext->b_gainLevelNext = 1;
                else if (pSpdContext->b_gainLevel == 1 && energyLevel == EL_LOW)
                    pSpdContext->b_gainLevelNext = 0;
```

```
                pSpdContext->b_evalEnergy = BlockEnergySum[0];
                hr = BB11B_OK_POWER_DETECTED;
                break;
            }

            if (touched && PeekBlockCount > pSpdContext->b_minDescCount)
            {
                hr = BB11B_CHANNEL_CLEAN;
                break;
            }

            if (PeekBlockCount >= pSpdContext->b_maxDescCount)
            {
                hr = BB11B_E_PD_LAG;
                break;
            }
        }
    } while(FALSE);
    // ...
    return hr;
}
```

Figure 18. Example code to read from RX_STREAM.

Chapter 4.
MAC Programming

Sora provides a utility library to program a Finite State Machine (FSM). An FSM is commonly used in the MAC and other protocol implementations. For example, Figure 19 shows a simplified MAC state-machine of 802.11 that contains three states: carrier sense, transmission (TX) and reception (RX).

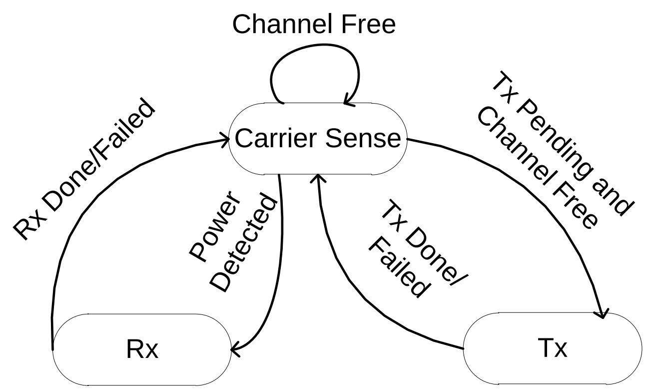


Figure 19. A simplified MAC state machine of 802.11.

4.1 State Machine declaration and initialization

The SDR driver declares an FSM through **SORA_BEGIN_DECLARE_FSM_STATES**, **SORA_END_DECLARE_FSM_STATES**, and **SORA_DECLARE_STATE**. After that, the SDR driver should further declare an FSM type using **SORA_DECLARE_FSM_TYPE**. An FSM instance can then be declared for this FSM type. Each state of an FSM is associated with a state handler. At initialization, the SDR driver should assign these handers to an FSM instance using **SORA_FSM_ADD_HANDLER**.

In Sora, a state machine may usually run in an *exclusive thread* that provides real-time support. The SDR driver uses **SORA_FSM_CONFIG** to assign a parameter to the FSM instance, which will be passed to each state handler. This parameter is usually a pointer to **SDR_CONTEXT**. During initialization, one should also specify the initial state on which the FSM starts using **SoraFSMSetInitialState**.

Figure 20 shows an excerpt from **sdr_mac.h** to declare the simplified 802.11 MAC FSM. Figure 21 shows sample code from **sdr_mac_main.c** to initialize an FSM instance declared as a member of the PMAC object.

```
// Declare MAC FSM states for 802.11
SORA_BEGIN_DECLARE_FSM_STATES(Dot11)
    SORA_DECLARE_STATE(Dot11_MAC_CS)
    SORA_DECLARE_STATE(Dot11_MAC_TX)
    SORA_DECLARE_STATE(Dot11_MAC_RX)
SORA_END_DECLARE_FSM_STATES(Dot11)

// Declare a FSM structure type for 802.11
SORA_DECLARE_FSM_TYPE(DOT11FSM, Dot11)
```

Figure 20. Example to declare an 802.11 MAC state machine.

```
VOID
SdrMacInitStateMachine(IN PMAC pMac, IN PSDR_CONTEXT SDRContext)
{
    // Associate the real state handlers to the FSM
    SORA_FSM_ADD_HANDLER(pMac->StateMachine, Dot11_MAC_CS, SdrMacCs);
    SORA_FSM_ADD_HANDLER(pMac->StateMachine, Dot11_MAC_TX, SdrMacTx);
    SORA_FSM_ADD_HANDLER(pMac->StateMachine, Dot11_MAC_RX, SdrMacRx);

    SORA_FSM_CONFIG (pMac->StateMachine, SDRContext, 0);

    // Set the initial start state
    SoraFSMSetInitialState ((PFSM_BASE)&pMac->StateMachine, Dot11_MAC_CS);

}
```

Figure 21. Initializing an FSM.

4.2 FSM Start, Stop, and State Transition

To start an FSM, the SDR driver should call **SoraFSMStart**, which starts the state machine in an exclusive thread.

A call of **SoraFSMStop** from any state handler terminates the FSM. **SoraFSMGotoState** is called before exiting the current state handler to transit to other states. The state handler of the new state will be invoked by the FSM thread.

4.2.1 Example

Figure 22 shows an example state handler from **sdr_mac_cs.c** for carrier sense. It enters different states based on the result of the PHY sensing function.

```
VOID
SdrMacCs(IN PFSM_BASE StateMachine)
{
    HRESULT hRes                = S_OK;

    //Get SDR context initialized by SORA_FSM_CONFIG;
    PSDR_CONTEXT pSDRContext  = (PSDR_CONTEXT)SoraFSMGetContext(StateMachine);

    // Get all references from SDR context
    PMP_ADAPTER pAdapter = (PMP_ADAPTER)pSDRContext->Nic; //initialized by SdrContextBind;
    PMAC pMac  = (PMAC)pSDRContext->Mac; //initialized by SdrContextBind;
    PPHY pPhy   = (PPHY)pSDRContext->Phy; //initialized by SdrContextBind;
    PSORA_RADIO pRadio = NULL;

    …

    pRadio    =  RadioInPHY(pPhy, RADIO_RECEIVE);
    if(!SoraRadioCheckRxState(pRadio))
    {
        DbgPrint("[MAC_CS] enable Rx for the first time\n");
        SORA_HW_ENABLE_RX(pRadio);
    }

    if (pPhy->HwErrorNum > HW_ERROR_THRESHHOLD)
    {
        DbgPrint("[Error] Reset MAC send \n");
        InterlockedExchange(&pPhy->HwErrorNum, 0);
        //SdrMacResetSend(pMac);
    }

    if(pMac->fDumpMode)
    {
        _Dump(pMac, pRadio);
    }

    hRes = PhyDot11BCs(pPhy, RADIO_SEND);

    if (hRes == E_FETCH_SIGNAL_HW_TIMEOUT)
    {
        DbgPrint("[MAC_CS][Error] E_FETCH_SIGNAL_HW_TIMEOUT \n");
    }

    switch (hRes)
    {
    case BB11B_CHANNEL_CLEAN:
        if (IS_MAC_EXPECT_ACK(pMac))
        {
            hRes = __ExpectAck(pPhy);
            if (hRes != BB11B_OK_POWER_DETECTED)
```

```
            {
                DbgPrint("[MAC_CS][Error]  Ack detect fail, we don't need ACK anymore \n");
                MAC_DISLIKE_ACK(pMac);
            }
            else
            {
                SoraFSMGotoState(StateMachine, Dot11_MAC_RX);
                return;
            }
        }

        DbgPrint("[MAC_CS] channel clean, goto tx \n");
        SoraFSMGotoState(StateMachine, Dot11_MAC_TX);
        return;

    case BB11B_OK_POWER_DETECTED:
        SoraFSMGotoState(StateMachine, Dot11_MAC_RX);
        return;

    case E_FETCH_SIGNAL_HW_TIMEOUT: //Hardware error
        SoraFSMGotoState(StateMachine, Dot11_MAC_TX);
        DbgPrint("[Error] E_FETCH_SIGNAL_HW_TIMEOUT \n");
        //InterlockedIncrement(&pMac->pPhy->HwErrorNum);
        break;

    default:
        DbgPrint("[MAC_CS] CS return %x\n", hRes);
        break;
    }
}
```

Figure 22. An example state handler for Carrier Sense.

Chapter 5.
Real-Time Support

5.1 Using Sora thread

Sora supports real-time behavior via *exclusive threading*. An exclusive thread (or ethread) is a non-interruptible thread running on a multi-core system. In previous versions, an exclusive thread is bound to a dedicated CPU core and the programmer should manually assign CPU cores. Since Sora SDK version 1.5, the core assignment is performed by the library that dynamically allocates CPU cores to ethreads.

The SDR driver should allocate an ethread object by calling **SoraThreadAlloc**. Then, the SDR driver can call **SoraThreadStart** to start the ethread. **SoraThreadStart** takes three parameters: a valid ethread handle, a user-defined thread routine, and a user-defined parameter passed to the thread routine. If the return value of the thread routine is FALSE, the ethread will be terminated; otherwise, the routine will be called from the Sora core library after it re-computes the best core allocation and reassigns each ethread to a proper core. Since the ethreads are scheduled in a cooperative way, the ethread routine must return periodically (usually when critical tasks are done). Note that the dynamic scheduling of ethread imposes minimal overhead.

To terminate an ethread, one should call **SoraThreadStop**. It should be note it is prohibitive to call any Sora Thread API from the ethread routine; otherwise, a deadlock will occur. To exit from the thread, a user-defined routine should return with a FALSE value.

Comments: For user mode applications, the corresponding thread APIs are SoraUThreadAlloc, SoraUThreadStart, SoraUThreadStop and SoraUThreadFree.

Figure 23 shows code excerpts from **sdr_phy_main.c** to initialize and start a Sora thread that performs Viterbi decoding.

```
HRESULT
SdrPhyInitialize(
```

```
    IN PPHY              pPhy,
    IN PSDR_CONTEXT  SDRContext,
    IN ULONG             ulRadioNum)
{
    …
    if (pPhy->PHYMode == DOT_11_A) {
        hRes = NDIS_STATUS_FAILURE;
        pPhy->Thread = SoraThreadAlloc();
        if (pPhy->Thread)
            if (SoraThreadStart(pPhy->Thread, viterbi_proc, &pPhy->BBContextFor11A.RxContext))
                hRes = NDIS_STATUS_SUCCESS;

        if (hRes != NDIS_STATUS_SUCCESS)
            if (pPhy->Thread)  {
                SoraThreadFree(pPhy->Thread);
                pPhy->Thread = NULL;
            }
    }
    …
}

BOOLEAN viterbi_proc(PVOID pVoid) {

    BB11ARxViterbiWorker(pVoid);

    return *((PBB11A_RX_CONTEXT)pVoid)->ri_pbWorkIndicator;
}
```

Figure 23. Using Sora thread.

Figure 24 shows the sample code of a Viterbi work routine from **arx_bg1.c**. The function calls different Viterbi decoding modules based on the data rate. It starts by checking if there is work to do. If not, the routine will immediately return. Otherwise, it will accept the work by clearing the flag and perform the decoding task. After decoding, the routine returns to the state waiting for a new task.

```
void BB11ARxViterbiWorker(PVOID pContext)
{
  PBB11A_RX_CONTEXT pRxContextA = (PBB11A_RX_CONTEXT)pContext;

  if (BB11A_VITERBIRUN_WAIT_EVENT(pRxContextA))
  {
    BB11A_VITERBIRUN_CLEAR_EVENT(pRxContextA);
    pRxContextA->bCRCCorrect = FALSE;

    switch (pRxContextA->bRate & 0x7)
    {
      case 0x3:
        VitDesCRC6(pRxContextA);
        break;
      case 0x7:
        VitDesCRC9(pRxContextA);
        break;

      case 0x2:
        VitDesCRC12(pRxContextA);
        break;
```

```
        case 0x6:
            VitDesCRC18(pRxContextA);
            break;

        case 0x1:
            VitDesCRC24(pRxContextA);
            break;
        case 0x5:
            VitDesCRC36(pRxContextA);
            break;

        case 0x0:
            VitDesCRC48(pRxContextA);
            break;
        case 0x4:
            VitDesCRC54(pRxContextA);
            break;
    }

    _mm_mfence();
    BB11A_VITERBIDONE_SET_EVENT(pRxContextA);
  }
}
```

Figure 24. Example ethread routine.

5.2 Interrupt affinity

With ethread, the SDR application driver can prevent the task from being preempted by other threads. But the task may still be interrupted by hardware. Although most hardware interrupt handlers are very light-weight, some may still require a significant amount of time to finish (e.g., disk access) and thus cause a real-time task to miss deadlines. To address this issue, one could set the interrupt affinity for all hardware devices to avoid sending interrupts to the reserved core. On Windows 7, the interrupt affinity can be configured via the registry. But there is no native support on Windows XP. The Sora SDK includes a tool, called *interrupt filter*, which can configure the interrupt affinity of hardware devices. The tool can be found in **%SDR_ROOT%\bin** folder.

5.2.1 Installing and Configuring Interrupt Filter

To install the interrupt filter driver, first copy **intfiltr.sys** to Windows system driver folder (e.g., c:\windows\system32\drivers). Then, add the registry entries specified in **intfiltr.reg**, and, finally, reboot the machine to enable the interrupt filter driver.

```
D:\SoraSDK\bin>IntFiltrCmd.exe
```

```
-a :
Add interrupt affinity set filter driver

-r :
Remove interrupt affinity set filter driver

-m affinity mask :
Specify the affinity mask
```

Figure 25. Help page of intfiltrcmd.exe.

You can configure the interrupt affinity using **intFiltrCmd.exe**. Type **intfiltrcmd**, and you can see the help page shown in Figure 25. The default interrupt affinity is 0xFFFFFFFF, meaning all cores can be interrupted. You can turn off the bits corresponding to the reserved cores and specify the new affinity using command

```
Intfiltrcmd –a –m <core affinity that allows to be interrupted>
```

To remove the affinity (or reset to default), run

```
Intfiltrcmd –r
```

Chapter 6.
Signal Cache

One key design choice for the Sora system is to provide a large on-board memory on the RCB. This on-board memory can serve as a cache for pre-generated signals. The SDR driver can call **SoraInitSignalCache** to initialize a SIGNAL_CACHE structure. After initialization, a portion of the RCB memory is allocated to the signal cache and the SDR driver can store signals in it. The cache is organized into a number of equal size slots.

SoraInsertSignal adds a signal to a cache entry that is indicated by an 8-byte hash key. The signal can be later retrieved using this hash key by calling **SoraGetSignal**. If the signal exists in the cache, **SoraGetSignal** returns a TX_DESC of the signal, which can be passed to **SORA_HW_FAST_TX** to send out the stored signal.

The SDR driver must clean up the cache before it is unloaded or the cache is no longer used. **SoraCleanSignalCache** will release all resources allocated.

6.1 Example

In the Sora 802.11 sample driver, a signal cache is used to store ACK frames to corresponding senders. It defines an ACK_CACHE_MAN structure that is inherited from the SIGNAL_CACHE. Figure 26 shows the initialization function of the ACK cache from **sdr_phy_ack_cache.c**. The function tries to allocate a SIGNAL_CACHE from the RCB onboard memory.

```
HRESULT SdrPhyInitAckCache(
            OUT PACK_CACHE_MAN pAckCacheMan,
            IN PDEVICE_OBJECT pDeviceObj,
            IN PPHY pOwnerPhy,
            IN PSORA_RADIO pRadio,
            IN ULONG MaxAckSize,
            IN ULONG MaxAckNum
            )
{
    HRESULT hr;

    PHYSICAL_ADDRESS    PhysicalAddress        = {0, 0};
    PHYSICAL_ADDRESS    PhysicalAddressLow   = {0, 0};
```

```
    PHYSICAL_ADDRESS    PhysicalAddressHigh  = {0x80000000, 0};

    NdisZeroMemory(pAckCacheMan, sizeof (ACK_CACHE_MAN)); //constructor
    NdisInitializeEvent(&pAckCacheMan->RemoveEvent);
    NdisAllocateSpinLock(&pAckCacheMan->ReqQueueLock);
    pAckCacheMan->pOwnerPhy = pOwnerPhy;
    do {
        hr = SoraInitSignalCache (&pAckCacheMan->AckCache,
                                  pRadio,
                                  MaxAckSize,
                                  MaxAckNum);
        FAILED_BREAK(hr);

        pAckCacheMan->pAckModulateBuffer
            = MmAllocateContiguousMemorySpecifyCache(
                MaxAckSize ,
                PhysicalAddressLow,
                PhysicalAddressHigh,
                PhysicalAddress,
                MmNonCached
                );

        if (pAckCacheMan->pAckModulateBuffer == NULL)
        {
            hr = E_NOT_ENOUGH_RESOURCE;
            break;
        }

        pAckCacheMan->AckModulateBufferPA =
            MmGetPhysicalAddress((PVOID)pAckCacheMan->pAckModulateBuffer);

        pAckCacheMan->AckModulateBufferSize = MaxAckSize;

        …

    }while(FALSE);

    MP_INC_REF(pAckCacheMan);

    if (FAILED(hr))
    {
        SdrPhyCleanupAckCache(pAckCacheMan);
    }

    return hr;
}
```

Figure 26. ACK_CACHE_MAN initialization.

When MAC detects that a required ACK frame is not in the cache, it will queue a request, wake up a worker thread that does the modulation, and insert the generated waveform in the ACK Cache. The key to identify the frame is the MAC address of the destination. Figure 27 shows the sample code from **sdr_phy_ack_cache.c.**

```
VOID AckCacheMakeThread(
        IN PDEVICE_OBJECT  DeviceObject,
        IN PVOID  Context )
{
```

```
    PACK_CACHE_MAN pAckCacheMan = (PACK_CACHE_MAN)Context;
    MAC_ADDRESS MacAddr;
    PHY_FRAME_KEY Key;
    ULONG Length = 0;
    HRESULT hr;

    UNREFERENCED_PARAMETER(DeviceObject);

    MP_INC_REF(pAckCacheMan);
    do
    {
        int i;
        __Dequeue(pAckCacheMan, &MacAddr);
        Key.QuadKey.u.HighPart = 0;
        Key.QuadKey.u.LowPart = 0;
        for (i = 0; i < MAC_ADDRESS_LENGTH; i++)
        {
          Key.KeyBytes[i] = MacAddr.Address[i];
        }
        Length = SdrPhyModulateACK(
                    MacAddr,
                    pAckCacheMan->pAckModulateBuffer);

        hr = SoraInsertSignal (
                &pAckCacheMan->PhyAckCache,
                pAckCacheMan->pAckModulateBuffer,
                &pAckCacheMan->AckModulateBufferPA,
                Length,
                Key);
        if (hr == E_TX_TRANSFER_FAIL)
        {
            DbgPrint("[TEMP1] Ack insert cache failed, return 0x%08x\n", hr);
            InterlockedIncrement(&pAckCacheMan->pOwnerPhy->HwErrorNum);
        }
        else
        {
            DbgPrint("[TEMP1] Ack insert cache succ, return 0x%08x\n", hr);
        }
    }while(InterlockedDecrement(&pAckCacheMan->PendingReqNum) != 0);

    MP_DEC_REF(pAckCacheMan);
    return;
}
```

Figure 27. Modulate an ACK and insert the waveform in the signal cache.

Chapter 7.
User-Mode Extension

Sora provides a new programming model, called User-Mode eXtension (UMX), which allows user-mode applications to access the radio resources. With UMX APIs, developers can write baseband processing in user-mode, and therefore the programming and debugging efforts are greatly reduced.

7.1 UMX Initialization and Configuration

UMX is based on the HWTest driver (see also Chapter 11.), as shown in Figure 28.

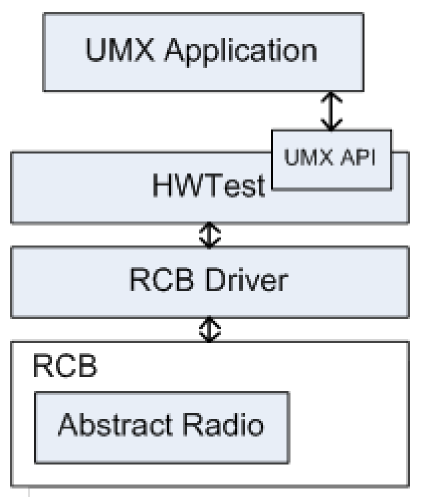


Figure 28. Architecture of Sora UMX.

The UMX application initializes UMX library with **SoraUInitUserExtension**. The function needs the device name of the HWTest driver, which is "\\.\HWTest". HWTest will allocate an abstract radio from the RCB, and the UMX application can configure the radio parameters using the corresponding APIs. After the radio is properly configured, the UMX application can start the radio by calling **SoraURadioStart**. Before exiting, the SDR application should call **SoraUCleanUserExtension** to clean up the resource that has been allocated.

Figure 29 shows the sample code that initializes and configures UMX.

```
void RadioConfig()
{
    SoraURadioStart(TARGET_RADIO);

    SoraURadioSetRxPA    (TARGET_RADIO, SORA_RADIO_DEFAULT_RX_PA);
    SoraURadioSetRxGain (TARGET_RADIO, SORA_RADIO_DEFAULT_RX_GAIN);
    SoraURadioSetTxGain  (TARGET_RADIO, SORA_RADIO_DEFAULT_TX_GAIN);
    SoraURadioSetCentralFreq (TARGET_RADIO, 2422 * 1000);//central frequency: 2422MHz
    SoraURadioSetFreqOffset   (TARGET_RADIO, -5 * 1000 * 1000); //frequency offset: -5MHz
    SoraURadioSetSampleRate (TARGET_RADIO, 40); //sample rate: 40MHz
}

int __cdecl main(int argc, char *argv[])
{
    BOOLEAN isTx = FALSE;

    // Initialize Sora user mode extension
    BOOLEAN succ = SoraUInitUserExtension("\\\\.\\HWTest");
    if (!succ)
    {
        printf("Error: fail to find a Sora UMX capable device!\n");
        return -1;
    }

    RadioConfig();

    …

    SoraUCleanUserExtension();

    return 0;
}
```

Figure 29. Sample code to initialize and configure UMX.

7.2 Reception

To access the RX channel of a radio object, the UMX application should first call **SoraURadioMapRxSampleBuf** to obtain a pointer to the receiving buffer as well as the buffer size. Then, the UMX application can get a RX_STREAM from the receiving buffer using **SoraURadioAllocRxStream**, from which it can read I/Q samples. To read a signal block, the UMX application needs to call **SoraRadioReadRxStream**. Before exiting, the UMX application should call **SoraURadioReleaseRxStream** to release a RX_STREAM and **SoraURadioUnmapRxSampleBuf** to release the memory mapped to the RX buffer of a radio.

Figure 30 shows an example to receive I/Q samples using UMX.

```
void RxRoutine ()
{
    PVOID pRxBuf     = NULL;
    ULONG nRxBufSize = 0;
    HRESULT hr;
    …
    SORA_RADIO_RX_STREAM SampleStream;

    //
    // Map Rx Buffer
    //
    hr = SoraURadioMapRxSampleBuf (
                              TARGET_RADIO, // radio id
                              & pRxBuf,     // mapped buffer pointer
                              & nRxBufSize  // size of mapped buffer
                            );

    if ( FAILED (hr) ) {
        printf ( "Error: Fail to map Rx buffer!\n" );
        return;
    }

    printf ( "Mapped Rx buffer at %08x size %d\n", pRxBuf, nRxBufSize );

    // Generate a sample stream from mapped Rx buffer
    SoraURadioAllocRxStream( &SampleStream,
                        TARGET_RADIO,
                        (PUCHAR)pRxBuf,
                        nRxBufSize );

    // start reading the sample stream and compute the energy
    FLAG fReachEnd;

    int index = 0;
    SignalBlock block;
    …
    for (;;)
    {

        hr = SoraRadioReadRxStream(
                       & SampleStream,      // current scan point
                        & fReachEnd,   // indicate if end of stream reached (you must wait for hardware)
                        block);

        if (FAILED(hr))
        {
            printf("stream ended, hr=%08x\n", hr);
            break;
        }

        QueryPerformanceCounter(&End);
        if (End.QuadPart - Start.QuadPart > Freq.QuadPart / 2)
        {
            Start = End;
            // almost 1s
            // compute the energy
            vcs* pSamples = &block[0];

            // single block contains 28 samples or 7 vector cs
            vi sum;
            set_zero (sum);

            // this is an approximated way to calc energy
            for (int i=0; i<7; i++ ) {
```

```
            vi re, im;
            vcs s = pSamples[i];
            s = shift_right (s, 3);

            conj_mul ( re, im, s, s ); // (a+bj) * (a-bj)
            sum = add (sum, re );
        }

        sum = hadd (sum); // get a sum of the all element on the vector

        int energy = sum[0];
        printf("                                                    \r"); //clean the line.
        printf ( "%d --> Energy %10d \r", index++, energy / 1000);
    }
  }

  SoraURadioReleaseRxStream(&SampleStream, TARGET_RADIO);

  if (pRxBuf) {
    hr = SoraURadioUnmapRxSampleBuf (TARGET_RADIO, pRxBuf);
  }
  printf("Unmap hr:%08x\n", hr);
}
```

Figure 30. Sample routine for receiving using UMX.

7.3 Transmission

To transmit waveform using UMX, the UMX application should allocate the Tx sample buffer to store the modulated samples. It calls **SoraUAllocBuffer** to allocate a Tx sample buffer. After filling the buffer with I/Q samples, the UMX application should call **SoraURadioTransferEx** to store the samples onto RCB memory and also allocate other TX resources for the signal. The stored signal can be later transmitted using **SoraURadioTx.** **SoraURadioTx** can be called multiple times for a stored signal, and **SoraURadioTxFree** will release all TX resources allocated for the signal.

Figure 31 shows the sample routine for signal transmitting with UMX. After allocating the modulation buffer, it calls a user-defined function **PrepareSamples** to fill the buffer with I/Q samples, which in this implementation is simply load from a sample file.

```
void TxRoutine ( char* fname )
{
  // try to load the samples
  HRESULT hr;
  PVOID SampleBuffer = NULL;
  ULONG SampleBufferSize = 4096;
  ULONG TxID = 0;

  do
  {
```

```
        SampleBuffer = SoraUAllocBuffer (SampleBufferSize);
        printf("alloc Tx Sample buffer ret: %08x\n", SampleBuffer);
        If (!SampleBuffer)
            break;

        ULONG TxID;
        ULONG SigLength = PrepareSamples(fname, (char*)SampleBuffer, SampleBufferSize);
        if (SigLength == 0)
        {
            printf("file access violation\n");
            break;
        }
        //
        // First Allocate Tx Resource
        // The size should be a multiple of 128
        //
        ALIGN_WITH_RCB_BUFFER_PADDING_ZERO(SampleBuffer, SigLength);
        hr = SoraURadioTransferEx (TARGET_RADIO, SampleBuffer, SigLength, &TxID);

        printf("tx resource allocated, hr=%08x, id=%d, length=%d\n", hr, TxID, SigLength);
        if (SUCCEEDED(hr))
        {
            //
            // Tx to the radio
            //
            hr = SoraURadioTx(TARGET_RADIO, TxID);

            printf("tx return %08x\n", hr);

            hr = SoraURadioTxFree (TARGET_RADIO, TxID);
            printf("tx resource release return %08x\n", hr);
        }

        FAILED_BREAK(hr);
    } while (FALSE);

    if (SampleBuffer)
        SoraUReleaseBuffer (SampleBuffer);
}
```

Figure 31. A sample routine to send with UMX.

7.4 Sample: UMXDot11

UMXDot11 is a simple 802.11 decoder based on UMX. UMXDot11 can generate (modulate) and send, as well as receive and demodulate frames using UMX. You can find the source code at **$SORA_ROOT$\src\bb\UMXDot11**. UMXDot11 relies on the SoftWiFi modulation/demodulation library. UMXDot11 is configured through a file named **umxdot11.ini**. Both ".exe" and ".ini" files should be under the same folder. Figure 32 shows a sample ini file. The file defines the modulation method (802.11a OFDM or 802.11b DSSS), the data rate, and a frame length. It also specifies the sampling rate of your RAB.

Command “umxdot11 rx” will launch umxdot11 in the receiving mode. Based on the configuration, the umxdot11 searches OFDM or DSSS signals. However, it tries to demodulate and decode frame with any valid rate.

Command “umxdot11 tx” will put umxdot11 in sending mode. It will continuously send a random generated frame with the modulation method and the size specified in the configuration file.

Note that you should use command “dut start” to enable the HwTest driver as well as the UMX library.

```
;; Protocol:       802.11a / 802.11b
;;
;; Configuration for 802.11b / 802.11b.brick
;; Data Rate:        1000/2000/5500/11000
;;
;; Configuration for 802.11a
;; Data Rate:        6000/9000/12000/18000/24000/36000/48000/54000
;;
;; Sample Rate: 40 | 44
;;

[Modulation]
Protocol = 802.11a
DataRate = 6000
PayloadLength = 1000

[Hardware]
SampleRate = 44
```

Figure 32. A sample umxdot11.ini.

Chapter 8.
UMX Reflection

Since Sora ver 1.6, a new mechanism, called *UMX reflection*, is supported. UMX reflection allows a user-mode SDR application (SDR modem) to be seamlessly integrated into Window's network stack. Therefore, any network application can use the SDR modem to communicate in a wireless network. Figure 33 shows the architecture of UMX reflection. The HwTest driver acts as a virtual Ethernet card to the operating system. When a frame arrives at the virtual NIC interface, the HwTest driver will *reflect* the frame data to user-mode, where the UMX SDR modem can modulate and send the signal through Sora hardware platform. On the other hand, when the UMX SDR modem demodulate a frame, it can insert the frame inside the reception queue of HwTest driver, which then will deliver it to upper layer in the network protocol stack.

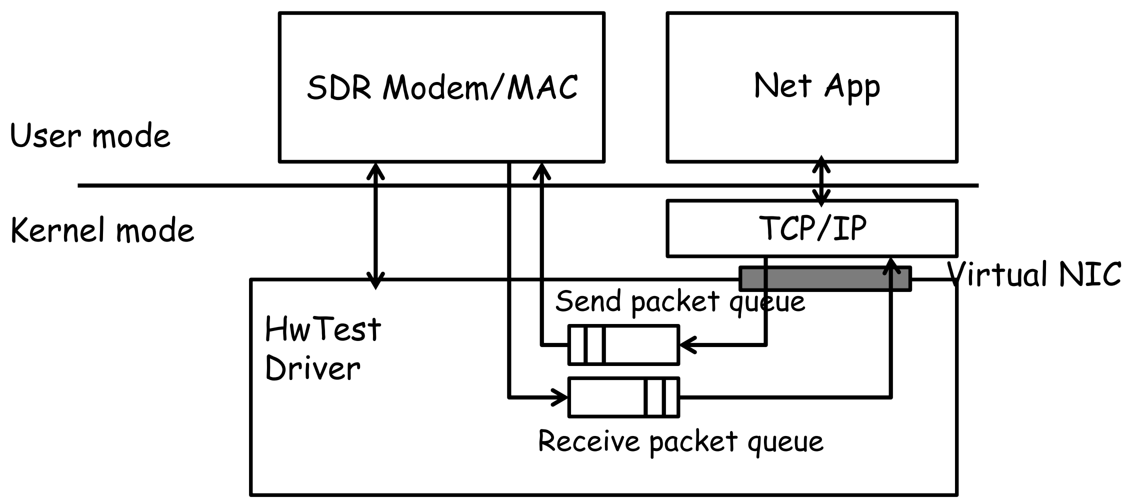


Figure 33. Sora UMX Reflection.

8.1 UMX Reflection Operations

Before a SDR modem can get a frame sent to the virtual NIC interface, it should can **SoraUEnableGetTxPacket** first. To get a queue in the virtual NIC's sending queue, the SDR modem should call **SoraUGetTxPacket**. The function will return the address of frame data and a handle to the frame. The SDR application should keep the handle until it finishs processing on the frame data. Then, it should return the handle to the HwTest driver by calling **SoraUCompleteTxPacket**.

To insert a received frame into to the reception queue of the HwTest driver, the SDR application should call **SoraUIndicateRxPacket.**

8.2 UMXSDRab – a user-mode SDR modem

UMXSDRab is a new UMX reflection SDR modem application. It supports both 802.11a/b protocol and has an interactive interface to configure and monitor the status of the modem. The source code of UMXSDRab can be found **\\%SORA_ROOT%\src\umxsdr**. Figure 34 shows a screen snapshot of the interactive console of the UMXSDRab. Table 5 summaries the keyboard commands supported in the interactive console window.

UMXSDRab can work in both client and ad hoc mode. When it is in client mode, it will automatically search and associate to the first AP that beacons with a SSID starting with “SDR”. Currently, only the very basic association and authentication mode is supported. So please make sure your access point is working in open association mode and without any security feature enabled. When in ad hoc mode, UMXSDRab automatically creates an ad hoc network named “SDRAdhoc” and uses a default BSSID. You may let a laptop with a commercial NIC or another Sora node to join this ad hoc network. UMXSDRab also implements a simple automatic gain control algorithm to track the best gain setting to an associated AP.

Note that this auto-configuration algorithm just works “as is”. It is not guaranteed to work in any circusmtence. When you find the algorithm stucks somehow, you can always turn off/on the auto-configurate by pressing “a” key. Then, you can manually configure the modem, like receiving gain or the association process.

Table 4 summarizes the command line parameters of UMXSDRab.

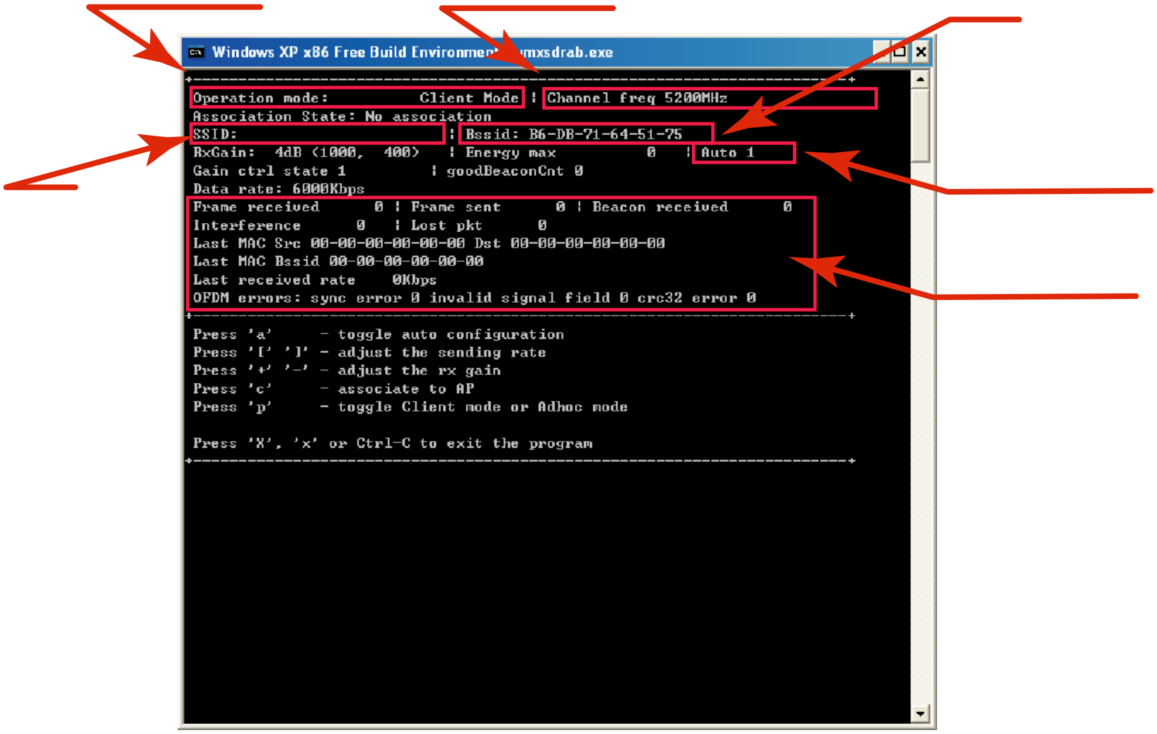


Figure 34. The interactive console of UMXSDRab.

Parameter name	Comments
-s [40|44]	Specify the sampling rate of the underlying hardware. It should be either 40MHz or 44MHz. Please refer to your hardware specification.
-f freq	Specify the central frequency in, unit of MHz. For example, channel 3 in 2.4GHz band is centered at 2422MHz.
-r rate	Specify the initial modulation (sending) rate. The default uses the lowest rate. You may change this parameter later in the interactive console window.
-b	Specify the 802.11b PHY is in use.
-o [0|1]	Specify the mode of the console window. If one is set, the status window is not displayed. This option is for debug purpose only.
-h	Display the usage.

Table 4. Command line of the UMXSDRab.

a	Toggle the auto configuration.
[	Increase the modulation (sending) data rate.
]	Decrease the modulation (sending) date rate.
+	Force to increate the rx gain.
-	Force to descrease the rx gain.
c	Associate to AP, only valid in client mode.
p	Switch umxsdrab mode between client and adhoc.

Table 5. Commands for the interactive console.

Chapter 9.
Vector1 Library

Vector1 is a template library for SIMD programming since Sora SDK 1.1. Vector1 library provides new vector data types and vector operations to accelerate PHY signal processing. Vector1 provides a general vector abstraction that is rather independent from the real processor architecture. Therefore, it improves the portability of algorithms implemented using SIMD instructions. When porting to a new SIMD processor, only a new implementation of Vector1 library is needed, while the algorithm implementations can remain unchanged (or with only minor modification). Currently, Vector1 is implemented based on C++ SSE4 intrinsic functions, which are supported in most modern C++ compiler. The implementation of Vector1 can be found in the header file **vector128.h**.

9.1 Data type

Vector1 defines vector data type which contains an array of elements. An element can be of various types, from integer, float, to complex values. The element type is typedef-ed as elem_type in the vector type, for example vb::elem_type is defined as "Signed Byte". Table 6 summarizes the vector types supported in the Vector1 library. It also summarizes the size of each element and the number of elements in one vector type. For example, a **vb** variable contains a vector of sixteen 8-bit long integers (a byte) and a **vub** presents a vector contains sixteen unsigned bytes. Note that a vector type should be 16-byte aligned.

Vector Type	Element Type	Element Size	No. of Elements
vb/vub	Signed /Unsigned Byte	8b	16
vs/vus	Signed /Unsigned Short	16b	8
vi/vui	Signed /Unsigned Integer	32b	4
vq/vuq	Signed/Unsigned Quad Word	64b	2
vf	Float	32b	4
vcb/vcub	Complex Signed / Unsigned Byte	16b	8
vcs/vcus	Complex Signed / Unsigned Short	32b	4
vci/vcui	Complex Signed / Unsigned Integer	64b	2

vcq/vcuq	Complex Signed / Unsigned Quad Word	128b	1
vcf	Complex Float	64b	2

Table 6. Vector1 Data Types.

9.2 Basic Operations

The Vector1 library defines many operations on the vector types. The most common operations are arithmetic operations on vector types, including **abs, abs0, add, conj, conj0, conj_mul, conj_mul_shift, conjre, mul_high, mul_j, mul_low, mul_shift, pairwise_muladd, hadd4, saturated_hadd4, hadd, saturated_hadd, saturated_add, saturated_pack, saturated_sub,** and **sign.** For example, you can perform an "**add**" operation on two variables of the same vector type. Each element in the resulting vector is the sum of the corresponding elements from two vectors. Figure 35 shows sample code to remove the DC component from incoming samples using Vector1.

```
Void RemoveDC (SignalBlock & block, vcs &dc) {
       For (int i=0; i<7; i++) {
         block[i] = sub(block[i], dc);
       }
}
```

Figure 35 Removing the DC component with Vector1.

There are also logic operations, including **and, andnot, or**, comparison operations, including **hmax, hmin, is_great, is_less,** and **smax,** shift operations, like **shift_left, shift_right,** and element data manipulation, including **comprise, extract, flip, interleave_high, interleave_low, pack, permutate, permutate_high, permutate_low.**

One can also use **set_all, set_all_bits, set_zero** or **assignment operator** to initialize a vector.

9.3 *Rep* utility

Vector1 further supports longer vector operations through the *Rep utility*. Using the *Rep utility,* one can perform SIMD operations on an array of vector data and optimized for exectution speed. The operations are defined as static member functions in the template class "**rep**", including

vmemcpy, **vsqrnorm**, **vshift_right**, **vshift_left**, **vsum**. An integer template argument of the class specialize the size of arrays. For example, the code snippet below copies consequent 11 vector data from a memory buffer (pointed by “pSpreadSig”) to another location (indicated by “pbuf”).

```
rep<11>::vmemcpy(pbuf, pSpreadSig );
```

Figure 36 Removing the DC component with Vector1.

9.4 Vector1 References

The following sections explain each operation defined in current Vector1 Library. For the sake of simplicity, we use the following format:

- In the **Vector type** line, we define the list of vector types. We use **T** to refer any vector type in the list.
- In the **prototype** line, we define the prototype of the operation. The symbol **T** may refer to any vector type defined in the **Vector type** line.

For example, we define **abs** operations as follows:

Vector type: T = vb/s/i/q

Prototype: T abs (const **T** & a);

This means **abs** operation can be applied to a **vb**, **vs**, **vi**, or **vq** type. The prototype will take a constant reference to a variable of any of above vector type, and return a same vector type as the parameter.

9.4.1 abs

Vector type: T = vb/s/i/q

Prototype: T abs (const **T** & a);

Description: approximately compute the element-wise absolute value of a vector, based on “xor” operation.

9.4.2 abs0

Vector type: T = vb/s/i/q

Prototype: T abs0 (const **T** & a);

Description: compute the actual element-wise absolute value of a vector.

9.4.3 add

Vector type: T = vb/s/i/q/f/ub/us/ui/uq/cb/cs/ci/cq/cf/cub/cus/cui/cuq

Prototype: T add(const **T** & a, const **T** & b);

Description: compute the sum of two vectors

9.4.4 and

Vector type: T = vb/s/i/f/ub/us/ui/cb/cs/ci/cf/cub/cus/cui

Prototype: T and(const **T** & a, const **T** & b);

Description: compute the logic bit-wise and of two vectors

9.4.5 andnot

Vector type: T = vb/s/i/f/ub/us/ui/cb/cs/ci/cf/cub/cus/cui

Prototype: T andnot(const **T** & a, const **T** & b);

Description: compute the logic bit-wise and of the logic not of vector **a** and vector **b. andnot (a,b) = (not(a) and b).**

9.4.6 average

Vector type: T = vub/us/cub/cus

Prototype: T average(const T & a, const T &b);

Description: Element-wise average of two operand vectors.

9.4.7 comprise

Prototype: void **comprise**(vci & r1, vci& r2, const vi& re, const vi& im);

Description: Make two complex vectors from two real number vectors. One real number vector defines the real part and the other defines the imaginary part. The resulted complex vector r1 contains the first two complex numbers, and r2 gets the second two complex numbers.

9.4.8 conj

Prototype: vcs **conj**(const vcs & a);

Description: compute an approximate conjugate of each complex number in a vector, using the "xor" operator for sign reversion. It is not accurate but has better performance.

9.4.9 conj0

Prototype: vcs **conj0**(const vcs & a);

Description: Compute the accurate conjugate of each complex number in a vector.

9.4.10 conj_mul

Prototype: void **conj_mul**(vi& re, vi& im, const vcs& a, const vcs& b);

Description: Multiply the first source vector by the conjugate of the second source vector. re gets all real parts of the product, and im gets all imaginary parts.

9.4.11 conj_mul_shift

Prototype: vcs **conj_mul_shift**(const vcs& a, const vcs& b, int nbits_right);

Description: Multiply the first operand by the conjugate of the second source, right shift the results by **nbits_right** bits, and keep the low 16-bit of the results.

9.4.12 conjre

Prototype: vcs **conjre**(const vcs& a);

Description: Invert the sign of the real part of each complex numbers.

9.4.13 extract

Vector type: T = vb/s/i/q/ub/us/ui/uq

Prototype: typename **T**::elem_type **extract**(const **T**& a);

Description: Extract element from a vector type, similar to the index operator. The index is 0-based and starts from the lowest address.

9.4.14 Flip

Vector type: T = vcs/vcus

Prototype: T **flip**(const T& a);

Description: Swap the real and imaginary parts of each complex number

9.4.15 hadd

Vecotr type: T = vcs/vi/vui

Prototype: T hadd (const T&a);

Description: hadd returns a vector, each element of which contains the sum of all elements in the input parameter.

9.4.16 hmax

Vector type: T = vb/s/ub/us

Prototype: T hmax(const **T**& a);

Description: Copy the largest element in the source vector to all elements of a vector128 type

9.4.17 hmin

Vector type: T = vb/s/ub/us

Prototype: T hmin(const **T**& a);

Description: Copy the smallest element in the source vector to all elements of a vector128 type

9.4.18 insert

Vector type: T = vs/cs

Prototype: template<int ndx> **T insert**(const **T**& a**, T**::elem_type b)

Description: Inserts an element into a vector at the index position "ndx".

This can be expressed with the following equations:

r0 := (ndx == 0) ? b : a0

r1 := (ndx == 1) ? b : a1

...

r0... and a0... are the sequentially ordered elements of return value r and parameter a. r0 and a0 are the least significant bits.

9.4.19 interleave_high

Vector type: T = vb/s/i/q/ub/us/ui/uq/cb/cs/ci/cub/cus/cui

Prototype: T interleave_high(const **T**& a, const **T**& b);

Description: Interleave the elements in the higher half of the 2 source vectors to a resulting vector. The first source operand will be interleaved to the even indices, and the second source to the odd indices.

9.4.20 interleave_low

Vector type: T = vb/s/i/q/ub/us/ui/uq/cb/cs/ci/cub/cus/cui

Prototype: T interleave_low(const **T**& a, const **T**& b);

Description: Interleave the elements in the lower half of the 2 source vectors to a resulting vector. The first source operand will be interleaved to the even indices, and the second source to the odd indices.

9.4.21 is_great

Vector type: T = vb/s/i/f

Prototype: T is_great(const **T**& a, const **T**& b);

Description: Element-wise greater than (>) test for two vectors. The result is a vector of the same type, with all-1 element for true test and all-0 for false test.

9.4.22 is_less

Vector type: T = vb/s/i/f

Prototype: T **is_less**(const T& a, const T& b);

Description: Element-wise less than (<) test for two vectors. The result is a vector of the same type, with all-1 element for true test and all-0 for false test.

9.4.23 load

Vector type: T = vb/s/i/q/ub/us/ui/uq/cb/cs/ci/cq/cub/cus/cui/cuq

Prototype: void **load**(**T**& r, void* p);

Description: Load 128-bit vector from the address p, which is not necessarily 16-byte aligned

9.4.24 move_mask

Vector type: T=vb/vs/vi

Prototype: int move_mask (const T& a);

int move_mask (const vs&a, const vs&b);

int move_mask (const vi&a, const vi&b);

int move_mask (const vi&a, const vi&b, const vi&c, const vi&d);

Description: Creates a K-bit mask from the most significant bits of each element in the vector parameters. K is the number of the elements in the parameter list. The following table shows the value of K in different settings.

	T = vb	T = vs	T = vi
int move_mask (const T& a)	16	8	4
int move_mask (const T&a, const T&b)	N/A	16	8
int move_mask (const T&a, const T&b, const T&c, const T&d)	N/A	N/A	16

9.4.25 mul_high

Prototype: vs **mul_high**(const vs& a, const vs& b);

Description: Element-wise multiplication, keeping only the higher half of the product.

9.4.26 mul_j

Prototype: vcs **mul_j**(const vcs& a);

Description: Multiply a complex vector by the imaginary unit.

9.4.27 mul_low

Vector type: T = vs/i

Prototype: T mul_low(const **T**& a, const **T**& b);

Description: Element-wise multiplication, keeping only the lower half of the product

9.4.28 mul_shift

Prototype: vcs **mul_shift**(const vcs& a, const vcs& b, int nbits_right);

Description: Multiply and keep the low part product after right-shifting, i.e., return a * b >> nbits_right

9.4.29 or

Vector type: T = vb/s/i/q/ub/us/ui/uq/cb/cs/ci/cq/cub/cus/cui/cuq

Prototype: T or(const **T**& a, const **T**& b);

Description: Bitwise OR

9.4.30 pack

Prototype: vs **pack**(const vi& a, const vi& b);

Description: Pack elements in the two operand vectors into returned vector, keeping only the low 16-bit for each element.

9.4.31 pairwise_muladd

Prototype: vi **pairwise_muladd**(const vs& a, const vs& b);

Description: Add the element-wise multiplication product pair-wise. i.e.,

result[0] := (a[0] * b[0]) + (a[1] * b[1])

result [1] := (a[2] * b[2]) + (a[3] * b[3])

result [2] := (a[4] * b[4]) + (a[5] * b[5])

result [3] := (a[6] * b[6]) + (a[7] * b[7])

9.4.32 permutate

Vector type: T = vcs/i/ui

Prototype: template<int a0, int a1, int a2, int a3> T **permutate**(const **T**& a);

template<int n> **T permutate**(const **T**& a);

Description: Permute four elements in a vector.

Template parameter n: each 2-bit field (from LSB) selects the content of one element location (from low address) in the destination operand. i.e.,

r[0] := a[n(1:0)]

r[1] := a[n(3:2)]

r[2] := a[n(5:4)]

r[3] := a[n(7:6)]

Template parameter a0 ~ a3: selects the contents of one element location in the destination operand. ie.

r[0] := a[a0]

r[1] := a[a1]

r[2] := a[a2]

r[3] := a[a3]

9.4.33 permutate16

Vector type: T = vb/ub

Prototype: T **permutate**(const **T**& a, const **T**& mask);

Description: Permutate 16 byte-element in a 128-bit vector.

The return value can be expressed by the following equations:

r0 = (mask0 & 0x80) ? 0 : SELECT(a, mask0 & 0x0f)

r1 = (mask1 & 0x80) ? 0 : SELECT(a, mask1 & 0x0f)

...

r15 = (mask15 & 0x80) ? 0 : SELECT(a, mask15 & 0x0f)

r0-r15 and mask0-mask15 are the sequentially ordered 8-bit components of return value r and parameter mask. r0 and mask0 are the least significant 8 bits.

SELECT(a, n) extracts the nth 8-bit parameter from a. The 0th 8-bit parameter is the least significant 8-bits.

mask provides the mapping of bytes from parameter a to bytes in the result. If the byte in mask has its highest bit set, the corresponding byte in the result will be set to zero.

9.4.34 permutate_high

Vector type: T = vs/cs/us/ucs

Prototype: template<int a0, int a1, int a2, int a3> **T permutate_high**(const T& a);

template<int n> **T permutate_high**(const **T**& a);

Description: Permute 4 elements in the higher half vector.

The definitions of the template parameters are similar to permutate_low.

9.4.35 permutate_low

Vector type: T = vs/cs/us/ucs

Prototype: template<int a0, int a1, int a2, int a3> T **permutate_low**(const T& a);

template<int n> **T permutate_low**(const T& a);

Description: Permutate 4 elements in the lower half vector.

The definitions of template parameters are similar to permutate_low.

9.4.36 hadd4

Vector type: T = vcs/i

Prototype: T hadd4(const **T**& a0, const **T**& a1, const **T**& a2, const **T**& a3);

Description: Take for vector operands and perform horizontal addition to each vector. The return vector contains the result for each operand vector.

Input: {$A0_0$, $A0_1$, $A0_2$, $A0_3$}, {$A1_0$, $A1_1$, $A1_2$, $A1_3$}, {$A2_0$, $A2_1$, $A2_2$, $A2_3$}, {$A3_0$, $A3_1$, $A3_2$, $A3_3$}

Output: {R_0, R_1, R_2, R_3},

$R_0 = A0_0+A0_1+ A0_2+ A0_3$

$R_1= A1_0+A1_1+A1_2+A1_3$

$R_2= A2_0+A2_1+A2_2+A2_3$

$R_3= A3_0+A3_1+A3_2+A3_3$

9.4.37 saturated_hadd4

Prototype: vcs **saturated_hadd4**(const vcs& a0, const vcs& a1, const vcs& a2, const vcs& a3);

Description: Take for vector operands and perform saturated horizontal addition to each vector. The return vector contains the result for each operand vector.

Input: {$A0_0$, $A0_1$, $A0_2$, $A0_3$}, {$A1_0$, $A1_1$, $A1_2$, $A1_3$}, {$A2_0$, $A2_1$, $A2_2$, $A2_3$}, {$A3_0$, $A3_1$, $A3_2$, $A3_3$}

Output: {R_0, R_1, R_2, R_3},

R_0 =saturated_add ($A0_0$, $A0_1$, $A0_2$, $A0_3$)

R_1= saturated_add ($A1_0$, $A1_1$, $A1_2$, $A1_3$)

R_2= saturated_add ($A2_0$, $A2_1$, $A2_2$, $A2_3$)

R_3= saturated_add($A3_0$, $A3_1$, $A3_2$, $A3_3$)

9.4.38 hadd

Vector type: T = vcs/i/ui

Prototype: T hadd(const **T**& a);

Description: Peform a horizontal addition of all elements in the operand vector.

Obsoleted. Please use hadd instead.

9.4.39 saturated_hadd

Prototype: T saturated_hadd (const vcs& a);

Description: Perform a saturated horizontal addition of all elements in the operand vector.

Obsoleted. Please use saturated_hadd instead.

9.4.40 saturated_add

Vector type: T = vb/s/ub/us/cb/cs/cub/cus

Prototype: T saturated_add(const **T**& a, const **T**& b);

Description: Element-wise saturated add

9.4.41 saturated_pack

Vector type: T = vs/i/cs

Prototype: T saturated_pack(const **T**& a, const **T**& b);

Description: Saturated packs the 2 source vectors into one. The elements in the resulting vector have half the length of the source elements.

9.4.42 saturated_sub

Vector type: T = vb/s/ub/us/cb/cs/cub/cus

Prototype: T saturated_sub(const **T**& a, const **T**& b);

Description: Element-wise saturated subtract

9.4.43 set_all

Vector type: T = vb/s/i/cs/q/f

Prototype: void **set_all**(T& x, typename T::elem_type a);

Description: Assign the same value to all elements in a vector

9.4.44 set_all_bits

Vector type: T = vb/s/i/q/f/ub/us/ui/uq/cb/cs/ci/cq/cf/cub/cus/cui/cuq

Prototype: void **set_all_bits**(**T**& a);

Description: Set all bits in a vector

9.4.45 set_zero

Vector type: T = vb/s/i/q/f/ub/us/ui/uq/cb/cs/ci/cq/cf/cub/cus/cui/cuq

Prototype: void **set_zero**(**T**& a);

Description: Clear all bits in a vector

9.4.46 shift_element_left

Vector type: T = vs/i/q/cs/ci/cq/us/ui/uq/cus/cui/cuq

Prototype: T shift_left(const T& a, int nbits);

Description: Shift the whole vector left by specified elements

9.4.47 shift_element_right

Vector type: T = vs/i/q/cs/ci/cq/us/ui/uq/cus/cui/cuq

Prototype: T shift_left(const T& a, int nbits);

Description: Shift the whole vector right by specified elements while shifting in zeros

9.4.48 shift_left

Vector type: T = vs/i/q/cs/ci/cq/us/ui/uq/cus/cui/cuq

Prototype: T shift_left(const T& a, int nbits);

Description: Element-wise arithmetic left shift

9.4.49 shift_right

Vector type: T = vs/i/cs/ci/us/ui/cus/cui/ub

Prototype: T shift_right(const **T**& a, int nbits);

Description: Element-wise arithmetic right shift

9.4.50 sign

Vector type: T = vb/s/i/q/cs

Prototype: T sign(const **T**& a, const **T**& b);

Description: Element-wise polarization on the first operand based on the second operand, ie.

r[n] := (b[n] < 0) ? -a[n] : ((b[n] == 0) ? 0 : a[n])

9.4.51 smax

Vector type: T = vs/cs/ub/cub/b/cb/us/cus

Prototype: T smax(const **T**& a, const **T**& b);

Description: Compute element-wise maximum

9.4.52 smin

Vector type: T = vs/cs/ub/cub/b/cb/us/cus

Prototype: T smin(const **T**& a, const **T**& b);

Description: Compute element-wise minimum

9.4.53 SquaredNorm

Prototype: vi SquaredNorm(const vcs&a)

Description: Compute the squared norm of a complex vector

9.4.54 store

Vector type: T = vb/s/i/q/ub/us/ui/uq/cb/cs/ci/cq/cub/cus/cui/cuq

Prototype: void **store**(void *p, const **T**& a);

Description: Store 128-bit vector to the address p, which is not necessarily 16-byte aligned

9.4.55 store_nt

Vector type: T = vb/s/i/q/ub/us/ui/uq/cb/cs/ci/cq/cub/cus/cui/cuq

Prototype: void **store_nt**(T *p, const T& a);

Description: Store 128-bit vector to the address p without polluting the caches

9.4.56 sub

Vector type: T = vb/s/i/q/f/ub/us/ui/uq/cb/cs/ci/cq/cf/cub/cus/cui/cuq

Prototype: T sub(const **T** & a, const **T** & b);

Description: Element-wise Subtract

9.4.57 unpack

Vector type: T = vb/s/i/ub/us/ui

Vector type: T = vs/i/q/us/ui/uq

Prototype: void **unpack**(**TO**& r1, **TO**& r2, const **T**& a);

Description: Unpack elements in source vector to 2 destination vectors. Each element will be unpacked to a double-length field; r1 gets the unpacked elements in the lower half of the source vector, r2 get elements in the higher half.

9.4.58 xor

Vector type: T = vb/s/i/q/ub/us/ui/uq/cb/cs/ci/cq/cub/cus/cui/cuq

Prototype: T xor(const **T** & a, const **T** & b);

Description: Bitwise XOR

9.4.59 rep<N>:: vmemcpy

Vector type: T = vb/s/i/q/ub/us/ui/uq/cb/cs/ci/cq/cub/cus/cui/cuq

Prototype: template<int N> void rep<N>::**vmemcpy(T** * pdst, **T** * psrc);

Description: Copy consequent N elements in psrc buffer to pdst buffer.

9.4.60 rep<N>:: vshift_left

Vector type: T = vb/s/i/q/ub/us/ui/uq/cb/cs/ci/cq/cub/cus/cui/cuq

Prototype: template<int N> void rep<N>::**vshift_left (T** * psrc, int nbits);

Description: Shift consequent N elements in psrc buffer to the left by “nbits” bits, and store to original buffer separately.

9.4.61 rep<N>::vshift_right

Vector type: T = vb/s/i/q/ub/us/ui/uq/cb/cs/ci/cq/cub/cus/cui/cuq

Prototype: template<int N> void rep<N>::**vshift_right (T** * psrc, int nbits);

Description: Shift consequent N elements in psrc buffer to the right by “nbits” bits, and store to original buffer separately.

9.4.62 rep<N>:: vsqrnorm

Prototype: template<int N> void rep<N>::**vsqrnorm (**vi * pdst, vi * psrc);

Description: Compute the squared norm of consequent N elements in psrc buffer, and store to pdst buffer separately.

9.4.63 rep<N>:: vsum

Vector type: T = vb/s/i/q/ub/us/ui/uq/cb/cs/ci/cq/cub/cus/cui/cuq

Prototype: template<int N> void rep<N>::**vsum (T&** r, **T** * psrc);

Description: Compute the sum of consequent N elements in psrc buffer, and store to the variable r.

Chapter 10.
The Sample SoftWiFi Driver

Since version 1.1, Sora SDK package includes the SoftWiFi sample SDR driver. SoftWiFi implements the IEEE 802.11a/b/g standards. The driver follows the Windows NDIS 5 framework and exposes a virtual Ethernet interface to the operating system. All applications can run on SoftWiFi without modification.

The SoftWiFi driver can be found in folder **%SORA_ROOT%\src\driver**. The files in sub-folder **SDRMiniport** implements the NDIS driver framework as well as the device I/O control to the driver. Sub-folder **ll** contains the link layer implementation, whose main function is frame format converting, i.e. from Ethernet to 802.11, and vice versa. Folder **mac** contains the implementation of the MAC state machine; while folder **phy** contains the implementation of the physical layer. It calls the baseband signal processing routines defined in folder **%SORA_ROOT%\src\bb**.

The architecture of the SoftWiFi driver is shown in Figure 37. The Link Layer receives frames from NDIS and converts them to 802.11 frames (see **sdr_ll_send.c**). The converted frames are stored in a frame queue. A sending thread monitors the queue and calls PHY functions to modulate the frame into waveform (see **sdr_mac_send.c**), which is then transferred to the RCB. The MAC state machine implemented in this sample driver is shown in Chapter 4, Figure 19. The state machine is initialized to the carrier sense state. It continuously calls the PHY function **FnPHY_Cs** to read incoming samples and computes the energy. If it senses a frame, the state machine goes to the RX state. Otherwise, it will continuously sense the channel. Carrier sense is implemented in **sdr_mac_cs.c** and **sdr_phy_cs.c**. In the RX state, MAC calls the PHY function **FnPHY_Rx** to demodulate the received signal. The RX functions are implemented in **sdr_mac_rx.c** and **sdr_phy_rx.c**. For 802.11a/g, an additional thread is created for Viterbi decoding, whose implementation is in **arx_bg1.c**. The demodulated/decoded frame is put into a receiving queue. Another thread monitors this receiving queue, and indicates the correctly received frames to NDIS.

The initialization routines of the link layer, MAC and PHY are in **sdr_ll_main.c**, **sdr_mac_main.c,** and **sdr_phy_main.c**.

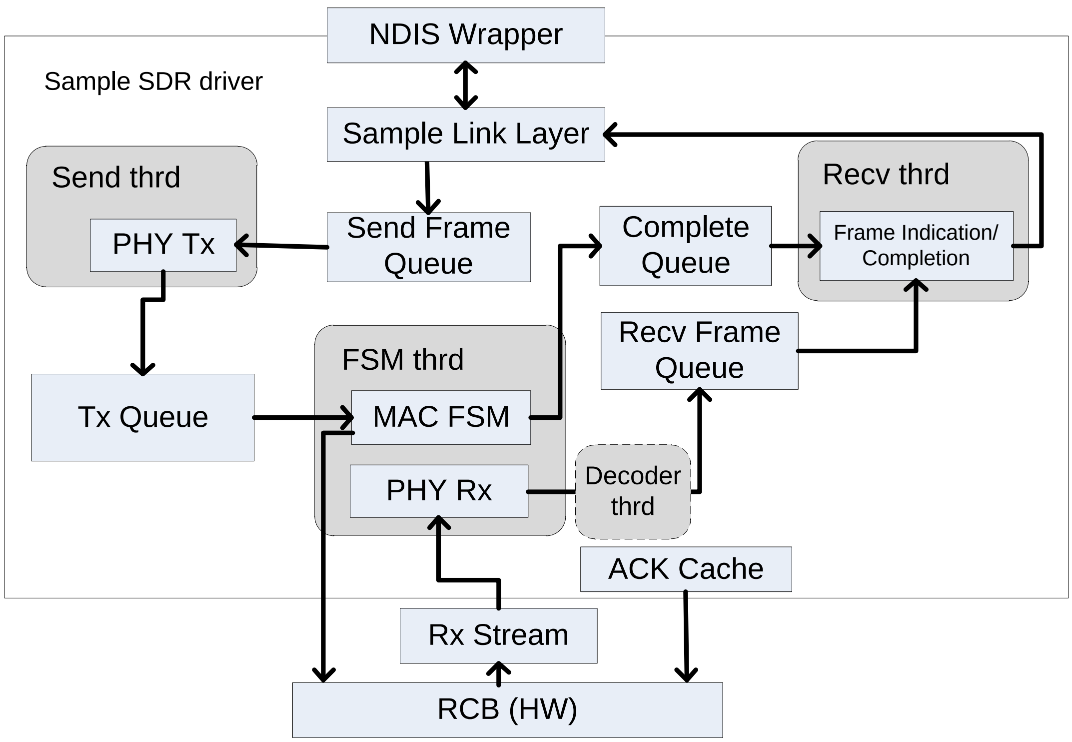


Figure 37. Software Architecture of SoftWiFi.

A novice is encouraged to learn the NDIS programming model before working on the SoftWiFi sample driver and you can find much information about NDIS at MSDN web site (http://msdn.microsoft.com).

10.1 Configuring the SoftWiFi driver

You can use the **dot11config.exe** tool to configure the SoftWiFi driver. The table below shows a summary of command line parameters for **dot11config.exe**.

-r | --datarate [Kbps]	Transmission data rate, i.e., 1000 for 1Mbps, 5500 for 5.5Mbps, 6000 for 6Mbps, etc.

-c | --channel [channel NO.]	Channel 1:2412MHz, 2:2417MHz, 3:2422MHz ..., 15: 2482MHz, 36:5180MHz, 40:5200MHz ...
-f | --freqoffset [Hz]	Set frequency offset, can be negative. Real central frequency is channel frequency plus this frequency offset value.
-a | --setmacaddr	Set MAC address for SDR miniport driver.
-p | --preamble [0/1]	0/1 for long/short preamble for 11b
-s | --spdmax [blocks]	set 802.11b power detection block timeout
-t | --spdthd [energy]	set energy threshold for 802.11b power detection
--spdthd_lh [energy]	set energy threshold for 802.11b power detection
--spdthd_hl [energy]	set energy threshold for 802.11b power detection
--rxgain_preset0 [gain value]	Set radio RX gain preset0 to gain value in 1/256 db, i.e., 0x1000
--rxgain_preset1 [gain value]	Set radio RX gain preset1 to gain value in 1/256 db, i.e., 0x2400
-R | --rxgain [gain value]	Set radio RX gain to gain value in 1/256 db, i.e., 0x1000
--rxpa [power level]	Set radio RX PA. This value is RF front-end dependent. For USRP XCVR2450 receives only values of 0, 0x1000, 0x2000, 0x3000. 0, 0x1000 – 0dB; 0x2000 – 16dB; 0x3000 – 32dB. * Note that it is preferred to use high RxPa instead of high RxGain.
-T | --txgain [gain value]	Set radio TX gain to gain value in 1/256 db, i.e., 0x1000
-S | --shift [bits]	set shift bits after downsampling (for 11b only)
-d | --dump	Dump RX signals into file which will be saved at c:\. The dump file name is automatically generated based on the timestamp.
-i | --info	Show 802.11 adapter running status
-g | --regs	Display Debug registers (reserved)

10.2 Offline Wrapper

Sora SDK ver 1.5 also provides an offline wrapper for SoftWiFi baseband library. The source code of the wrapper application, named **demode11**, is located at **%SORA_ROOT%\src\bb\exe**. It is very handy to use demode11 to read from a dump file to debug or test your modifications to baseband algorithms. The usage of the **demod11** tool is summarized below.

-a | --802.11a	specify 802.11a mode
-b | --802.11b	specify 802.11b mode
-m | --mod	To modulate
-c | --conv	specify converting mode
-d | --demod	specify demodulation
-k | --ack	specify ack test mode
-f | --file [file name]	specify signal file
-o | --out [file name]	specify output file(mod/conv only)
-t | --spdthd [energy]	set energy threshold for 802.11b power detection(802.11b demod only)
--spdthd_lh [energy]	set energy threshold for 802.11b power detection(802.11b demod only)
--spdthd_hl [energy]	set energy threshold for 802.11b power detection(802.11b demod only)
-S | --shiftright [bits]	set shift bits after downsampling(802.11b demod only)
-s	start processing from startDescCount(802.11b demod only)
-r | --bitrate [bit rate]	bit rate in unit of Kbps for modulation
-p | --samplerate [sampling rate]	Specify the sampling rate at RAB (40/44MHz)

Example command lines:

1. Modulate an input file and store the generated waveform

   demod11.exe –a –m –f d:\frame.bin –o d:\frame.tx

2. Convert a Tx signal file to a Rx signal file

   demod11.exe –a –c –f d:\frame.tx –o d:\frame.dmp

3. Read a Rx signal file (dump file) and decode the frames

   demod11.exe –a –d –f d:\frame.dmp

Chapter 11.
Tools and Utilities

11.1 dut tool

11.1.1 Using dut to configure the HwTest driver

dut is the configuration tool for the HwTest driver. The command **dut start** will enable the driver as well as the UMX library. You can use dut to configure radio parameters. For example, run

dut txgain --value 0x1000

to set the transmission gain. Or, you can set the receiving gain with

dut rxgain --value 0x1000.

Or you can set the central frequency of the radio with

dut centralfreq --value 2414.

You can also use "**dut dump"** to take a snapshot of the channel and store the dump file at root of disk C. You can use the software oscilloscope to load the dump file and check the signal.

11.1.2 Using dut to transmit a signal

To transmit a signal, you can first prepare the waveform in a Tx signal file. The Tx signal file is simply an array of I/Q samples (each I or Q component is of 8-bit). The total file size should be less than 2MB. The following command line transfers the signal to the RCB memory,

dut transfer –-file d:\frame.tx.

You can use "**dut info"** to check the id of all signals stored on RCB and run "**dut tx –-sid 0x01**" to transfer the cached waveform (assuming the id of the frame.tx returned is 0x01). You may optionally specify a repeat number for the tx command. For example,

dut tx --sid 0x01 --value 100

tells the hwtest driver to transmit the signal 0x01 for 100 times. You can use "**dut stoptx**" to cancel a repeating transmission. When transmission is complete, you can remove the signal from the RCB memory using

dut txdone --sid 0x01.

11.1.3 Dut usage summary

start	Enable the radio hardware.
stop	Disable the radio hardware.
tx	Transmit a signal
txdone	Remove a stored signal from the RCB memory
dump	Dump the radio Rx channel
txgain	Set Tx Gain
rxgain	Set Rx Gain
rxpa	Set RX PA. With USRP XCVR2450 can only be 0, 0x1000, 0x2000, 0x3000
info	Get driver and RCB information
transfer	Transfer a signal to the RCB memory
centralfreq	Set the radio central frequency (in MHz)
freqoffset	Set the radio frequency compensation (in Hz), i.e, -5Hz
stoptx	Stop Tx
samplerate	Change sample rate. No effective to USRP XCVR2450 or WARP RF daughter board
fwver	Display the firmware version
--value	Specify a number value to the command
--sid	Specify a signal ID
--file	Specify a file name

11.2 Oscilloscope

Sora SDK ver 1.5 releases software oscilloscope applications for both 802.11b DSSS and 802.11a/g OFDM signals. You can find them, **sdscope-11b** and **sdscope-11a** at %SORA-ROOT%\bin. Figure 38 and Figure 39 show the graphic interface and the annotation of each view on the windows. The following table summarizes the basic operations for the scope applications.

You can press “o” to open a dump file and start/stop the processing with the space key. You can also set a “processing point” by clicking on the overview panel.

Sdscope-11a also allows you to specify the sampling rate of the dump file with command line, sdscope-11a –s[40|44].

Key	Function
o/O	Open a dump file
Space	Start or Pause the processing
s/S	Rotate the sampling rate (sdscope-11a only)
Left Arrow/Right Arrow	Speedup or Slow down
Up Arrow/Down Arrow	Scale up/down of amplitude

11.3 SrView

SrView is a simple but handly GUI tool to view a Sora dump file. It can cut a portion of dumped signal and store it to a separate file for further analysis. You can use Menu item File/open to load a dump file. The window displays the energy of each recorded samples. You can use “up-arrow” and “down-arrow” to zoom-out and zoom-in, or use the scroll-bar at the bottom of window to view the different portion of the signal. You may select a portion of the signal – you click on the window to set a start marker and shift-click to set an end marker. You can save the selection into a separate file for later processing. Figure 38 shows a snapshot of Srview.

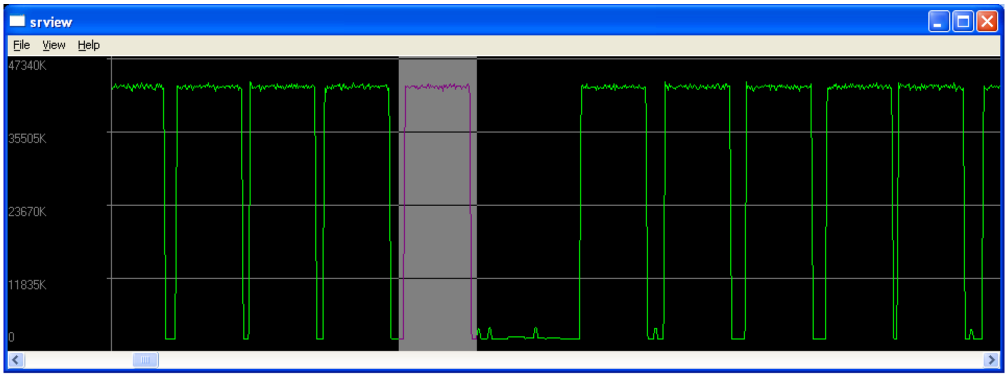


Figure 38. The main window of SrView.

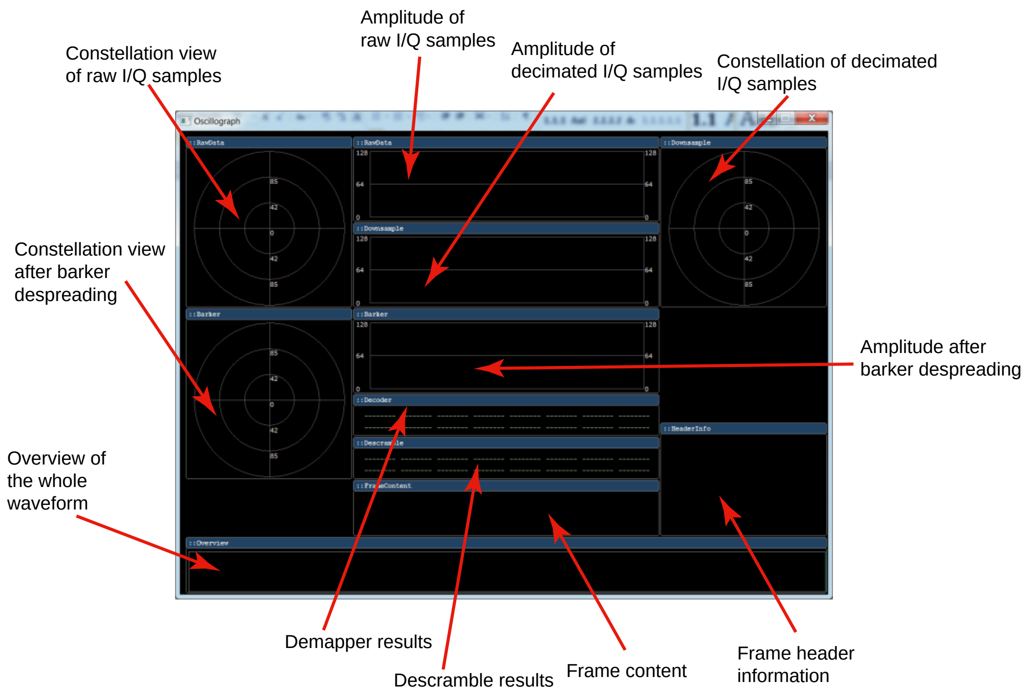


Figure 39. The main window of sdscope-11b.

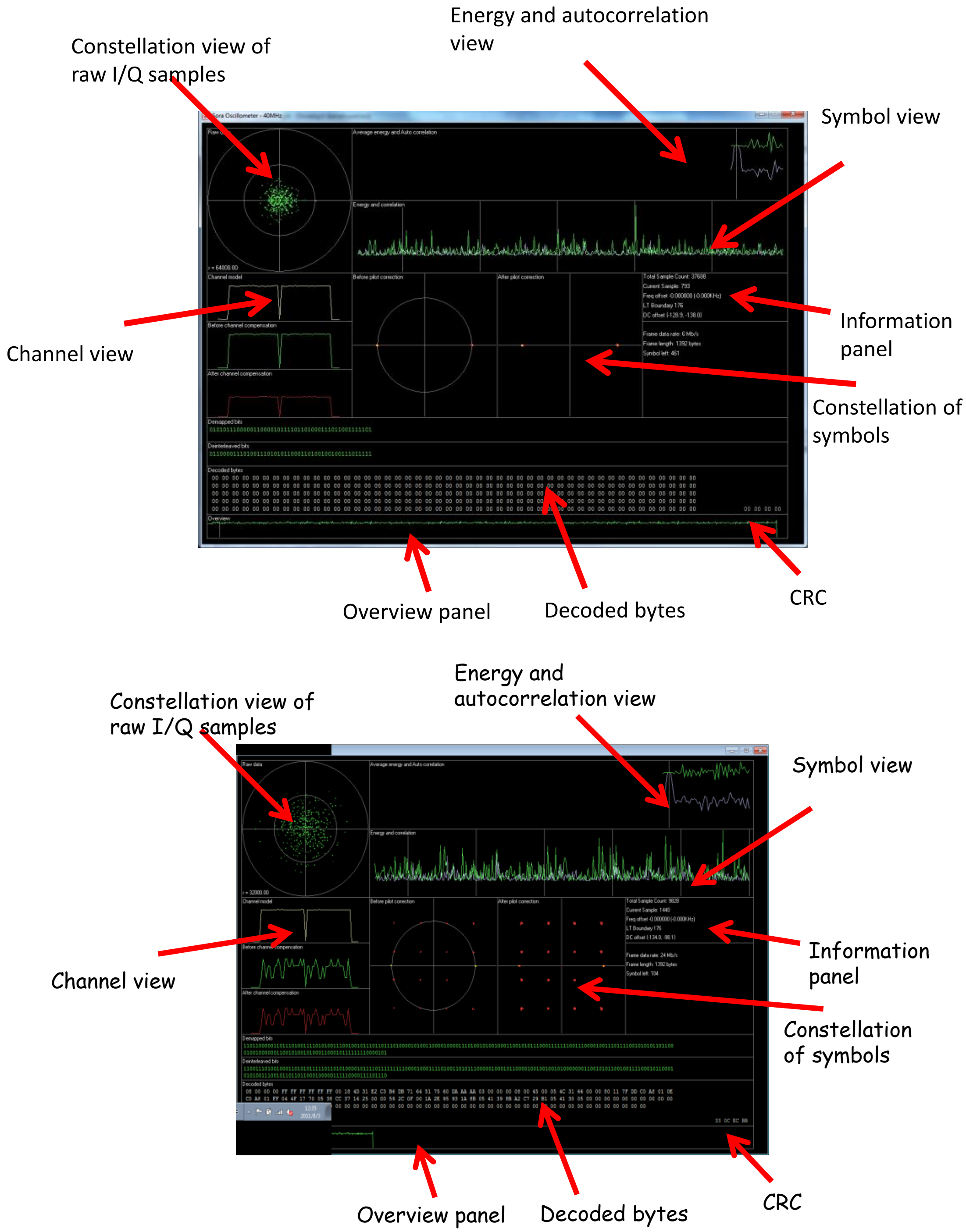


Figure 40. The main window of sdscope-11a.

11.4 Hardware Verification Tool

The Hardware Verification Tool (HVT) is a helpful tool to test and configure Sora hardware components. HVT supports two types of tests: the sine test (single tone test) and the SNR test (wide-band test). To use HVT, you need two Sora boxes: one works as sender and the other is a receiver.

In the sine test, the sender transmits a 1MHz sine signal; the receiver captures and analyzes the received signal. Based on this simple test, HVT can compute many useful radio related parameters, such as frequency offset between the two machines, I/Q imbalance, the direct current (DC) value and the best receiver gain setting.

In the SNR test, the sender transmits a wide-band 16QAM-modulated OFDM signal. The receiver can demodulate the signal and compute the wide-band signal-to-noise ratio (SNR). The SNR value is one key parameter to assess channel quality.

Figure 2 (at page 22) shows the main window of HVT. A summary of all elements on the window can also be found in

Table 2 (at page 18). HVT is based on UMX APIs. Please make sure the RCB driver and the HwTest driver are properly installed.

11.4.1 The Sine Wave Test

a) Start the test.

- Set up two Sora boxes. Place the two antennas about one meter apart.
- Select **sine test** on both boxes.
- Choose one box as the sender (select **send**) and the other as the receiver (select **receive**).
- Click **start button (b)** at the sender. You will see the sender's **status bar (j)** showing "Sending 1MHz sine wave". If a failure occurs, the error message will be shown in the **log window (k)**.
- Select a proper Tx **gain (t)** setting at the sender (for example 15dB).
- Choose the same **sampling rate (r)** as your RAB at the receiver.
- Click **start button (b)** at the receiver to capture the signal. You will see the waveform displayed on two popup windows, as shown in the first row of Table 7. If failures occur, the error messages will be shown in the **log window (k)**.
- By default, the receiver gain is automatically adjusted (The **AGC box (p)** is checked). But the user can disable the AGC and adjust the receiver gain manually by unchecking the box.
- The user can also start a central frequency offset (CFO) calibration by clicking the **auto calibration button (e)**. The tool will automatically compute the frequency offset between the sender and receiver and adjust the receiver's frequency setting to match the sender's. The calibration result will be shown in the **log window (k)**.
- The calibration results (parameters) can be stored in a file and the user can late configure the RF front-end based on these values. Figure 41 shows a sample configuration file.

```
[Parameter]
freqOffset=8064
txgain=0xb80
rxgain=0x1800
rxpa=0x1000
centralFreq=2422
sampleRate=40
```

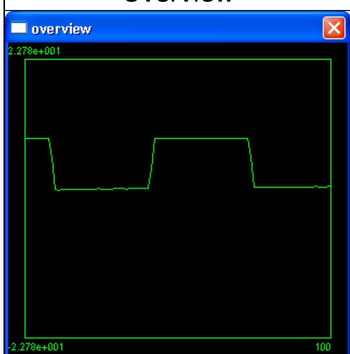
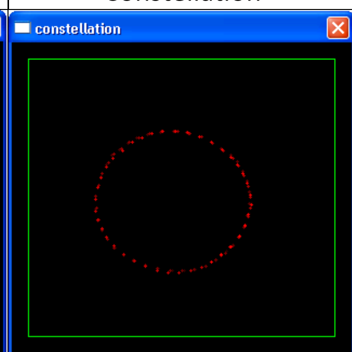
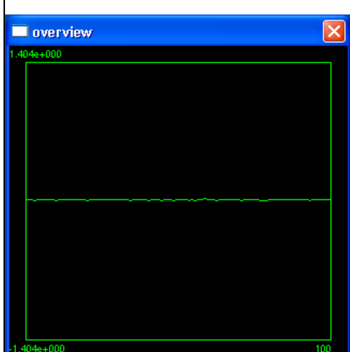
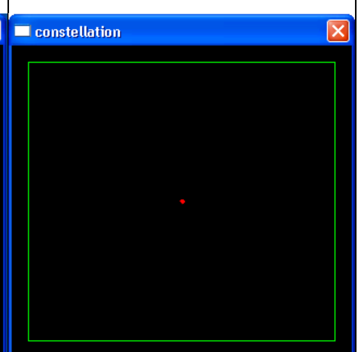
```
[Calibration]
freqOffsetLineSlope=-0.894473
freqOffsetLineIntercept=121178
```

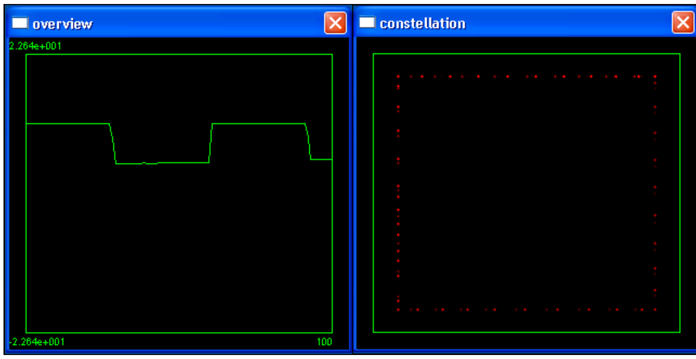
Figure 41. A sample configuration file after calibration.

b) Diagnosis

The user can use the sine test to pin-point several hardware related issues. Table 7 summarizes some typical graphs and their explanations. This table can be displayed anytime when the user clicks the **suggestion button (d)** at the receiver.

Table 7. Typical graphs shown in the sine test and their descriptions.

Overview	Constellation	Description
		Normal signal. The overview window displays the energy level of the received signal. Since the sine wave is sent in burst, the overview window will show this on-off pattern. The constellation view of the sine wave is a circle.
		No signal received. The receiver receives no signal. Please try the following actions to solve this problem: 1. Check if the hardware are connected properly; 2. Check if the drivers are installed properly; 3. Move the antennas closer; 4. Increase txgain at the sender side; 5. Increase rxgain and rxpa, or enable AGC at the receiver side; 6. Try to reset the hardware and disable/enable drivers.

	Saturated signal. The received signal has been saturated. Please try the following actions: 1. Decrease the rxpa and rxgain or enable AGC at the receiver; 2. Decrease the txgain at the sender side; 3. Move the antennas further away.

11.4.2 The SNR Test

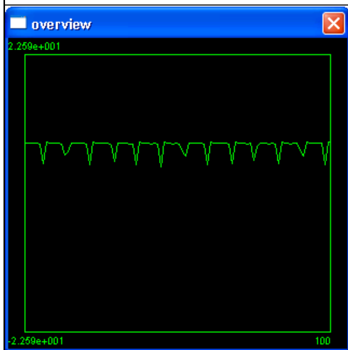
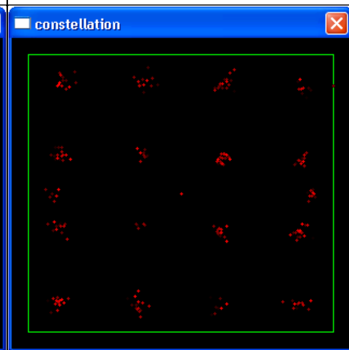
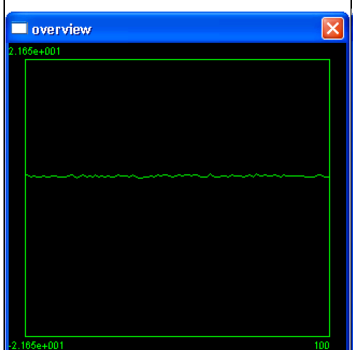
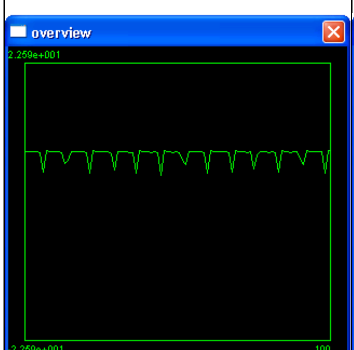
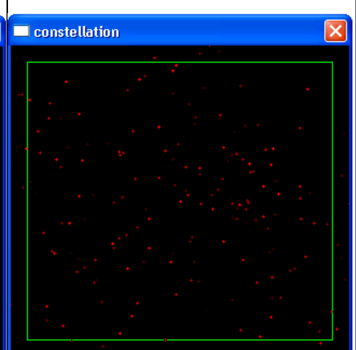
a) Start a test

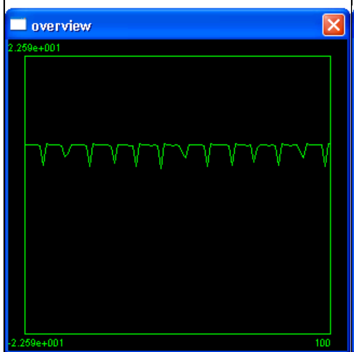
- Set up two Sora boxes. Place the two antennas about one meter apart.
- Select **snr test** on both boxes.
- Choose one box as the sender (select **send**) and the other as the receiver (select **receive**).
- Click **start button (b)** at the sender. You will see the sender's **status bar (j)** showing "Sending 16QAM wave". If a failure occurs, the error message will be shown in the **log window (k)**.
- Select a proper Tx **gain (t)** setting at the sender (for example 15dB).
- Choose the same sampling rate (r) as your RAB at the receiver.
- Click **start button (b)** at the receiver to capture the signal. You will see the waveform displayed on two popup windows, as shown in the first row of Table 8. If failures occur, the error messages will be shown in the **log window (k)**.
- The SNR value, DC, as well as the frequency offset are computed and displayed on the corresponding fields in the window.

b) Diagnosis

The user can use the SNR test to pin-point several hardware related issues. Table 8 summarizes some typical graphs and their explanations. This table can be displayed anytime when the user clicks the **suggestion button (d)** at the receiver.

Table 8. Typical graphs shown in the SNR test and their descriptions.

Overview	Constellation	Description
		Channel quality is high. The 16QAM constellation graph is clearly displayed.
		No signal. The receiver receives no signal. Please try the following actions to solve this problem: 1. Check if the hardware are connected properly; 2. Check if the drivers are installed properly; 3. Move the antennas closer; 4. Increase txgain at the sender side; 5. Increase rxgain and rxpa or enable AGC at the receiver side; 6. Try to reset the hardware and disable/enable drivers.
		Channel quality is poor. The 16QAM constellation graph can hardly be observed. Please try the following actions to solve this problem: 1. Adjust the radio parameters, e.g. adjusting frequency offset, gain. You can find proper values using the sine test; 2. Reset hardware and disable/enable the drivers; 3. Use better antennas or use a cable connection.

		No frame detected. The receiver receives signals but no valid frame is detected. Please try the following actions to solve this problem: 1. Make sure no other interfering sources exist; 2. Increase txgain at the sender side; 3. Increase rxpa and rxgain or enable AGC at the receiver side; 4. Move the antennas closer; 5. Adjust frequency offset. You can find proper values using the sine test; 6. Reset hardware and disable/enable the drivers.

11.4.3 Misc functions

a) Save/Load calibrated parameters

Click **save button (n)** in the parameters group to save calibrated parameters in a file. A saved file can be loaded by clicking the **load button (o)** in the parameters group. In **log window (k)**, the loaded parameters are displayed.

b) Save/Clear logs

Click **save button (l)** to save the messages in the log window to a file. Click **clear button (m)** to clear the messages in the log window.

c) Dump

HVT can also save a snapshot of received signal in a dump file for further analysis. To make a dump, HVT must run in the receiving mode. Clicking **dump button (c)** will save the signal to a file.

11.5 DbgPlot

DbgPlot is a versatile tools that allows programs to dynamic generate graphics in real-time. It is a powerful tool for real-time monitoring and debugging DSP programs. Please refer to the separated *debug plot manual* for complete information (http://research.microsoft.com/apps/pubs/?id=160801).

Chapter 12. Reference

12.1 Kernel Mode API

1) SoraAllocateRadioFromRCBDevice

```
HRESULT
SoraAllocateRadioFromRCBDevice(
    IN OUT PLIST_ENTRY    pRadiosHead,
    IN ULONG              nRadio,
    IN PCWSTR             UserName
);
```

Parameters

pRadiosHead

Pointer to a list head the returned radio objects are linked to.

nRadio

Number of the radios to allocate.

UserName

Pointer to a Unicode string specifying a tag for the allocated radios. Each allocation code path should use an identical tag to help system to identify the code path.

Return Value

SoraAllocateRadioFromRCBDevice returns E_DEVICE_NOT_FOUND if the RCB device cannot be found; it returns E_NOT_ENOUGH_FREE_RADIOS if there are not enough available radios to allocate. Otherwise, it returns S_OK and the allocated radios are linked to pRadiosHead.

Comments

SoraAllocateRadioFromRCBDevice allocates one or more radios from the RCB device.

The allocated radios are linked to the list specified by pRadiosHead. Otherwise, pRadiosHead will point to an empty list.

The allocated radios should be released using **SoraReleaseRadios**.

Requirements

IRQL: PASSIVE_LEVEL

Headers: Include sora.h

See Also

SoraReleaseRadios, **SoraRadioInitialize**, **SoraStartRadio**.

2) SoraReleaseRadios

```
VOID
SoraReleaseRadios(
    IN LIST_ENTRY   *pRadiosHead
);
```

Parameters

pRadiosHead

Pointer to the radio list.

Return Value

None

Comments

SoraReleaseRadios releases radio objects allocated by **SoraAllocateRadioFromRCBDevice**.

Requirements

IRQL: PASSIVE_LEVEL

Headers: Include sora.h

See Also

SoraAllocateRadioFromRCBDevice, **SoraRadioInitialize**, **SoraRadioStart**.

3) SoraRadioInitialize

```
HRESULT
SoraRadioInitialize(
    IN OUT PSORA_RADIO    pRadio,
    IN PVOID              pReserved,
    IN ULONG              nTxSampleBufSize,
    IN ULONG              nRxSampleBufSize
);
```

Parameters

pRadio

Pointer to a radio object.

pReserved

Reserved.

nTxSampleBufSize

The size of the buffer that holds the transmission digital samples. Each radio object is assigned to a unique Tx sample buffer.

nRxSampleBufSize

The size of the buffer that holds the received digital samples. The RCB will fill the Rx sample buffer with latest received samples. The size must be a multiple of 4K.

Return Value

SoraRadioInitialize returns E_NOT_ENOUGH_CONTINUOUS_PHY_MEM if not enough memory is available. It returns S_OK if succeeds.

Comments

SoraRadioInitialize initializes a radio object and allocates the Tx and Rx sample buffers. Any allocated radio object should be first initialized before use.

Requirements

IRQL: PASSIVE_LEVEL

Headers: Include Sora.h

See also

SoraRadioStart

4) SoraRadioStart

```
HRESULT
SoraRadioStart (
        IN OUT PSORA_RADIO      pRadio,
        ULONG                   RxGain,
        ULONG                   TxGain,
        PSORA_RADIO_CONFIG      pConfig
);
```

Parameters

pRadio

Pointer to the radio object to be enabled.

RxGain

Reception gain in units of 1/256 dB, e.g. a value of 0x200 means 2dB.

TxGain

Transmission gain in units of 1/256 dB, e.g. a value of 0x200 means 2dB.

pConfig

Pointer to a reserved configuration structure.

Return Value

SoraRadioStart returns S_OK if the radio hardware is enabled successfully. It returns E_RADIO_NOT_CONFIGURED if the radio object is not properly initialized and E_REG_WRITE_FAIL if hardware fails.

Comments

SoraRadioStart enables the RF front-end and sets the gain control parameters.

The SDR driver may change the gain setting later using **SoraHwSetTXVGA1** and **SoraHwSetRXVGA1**. The SDR driver can get the current gain setting using **SORA_RADIO _GET_RX_GAIN** and **SORA_RADIO_ GET_TX_GAIN**.

Requirements

IRQL: PASSIVE_LEVEL

Headers: Include Sora.h

See also

SoraHwSetTXVGA1, SoraHwSetRXVGA1, SoraHwSetCentralFreq.

5) SoraRadioGetRxStream

```
__inline
PSORA_RADIO_RX_STREAM
SoraRadioGetRxStream (
    PSORA_RADIO pRadio
);
```

Parameters

pRadio

Pointer to a radio object.

Return Value

SoraRadioGetRxStream returns the pointer of RX_STREAM associated with the radio object.

Comments

When a radio object is initialized, an RX_STREAM object is also created and associated to the radio object. A SDR driver should use the RX_STREAM object to read the radio's Rx sample buffer.

Requirements

IRQL: <= DISPATCH_LEVEL

Headers: Include Sora.h

See Also

SoraRadioReadRxStream

6) SoraRadioReadRxStream

```
HRESULT
SoraRadioReadRxStream (
        PSORA_RADIO_RX_STREAM pRxStream,
        FLAG *                pbTouched,
        SignalBlock&          block
);
```

Parameters

pRxStream

Pointer of the RX_STREAM object.

pbTouched

Pointer to a flag that receives the indication of the emptiness of the RX channel.

block

Signal block just read.

Return Value

The return value is S_OK if a signal block is succeeded read. Otherwise, the return value is E_FETCH_SIGNAL_HW_TIMEOUT if no new signal blocks are available in a timeout period. This may indicate an error in hardware.

Comments

This function gets a new signal block from the RX_STREAM object. pbTouched points to a flag variable that receives the indication whether or not the returned signal block is the last one in the RX channel. If the flag is set, the RX channel of the radio is empty.

This function can also be called in user-mode.

Requirements

Headers: Include soradsp.h

See Also

SoraRadioGetRxStream

7) SoraRadioGetRxStreamPos

```
PRX_BLOCK
SoraRadioGetRxStreamPos (
    PSORA_RADIO_RX_STREAM pRxStream
);
```

Parameters

pRxStream

Pointer of RX_STREAM object.

Return Value

The current position of the RX_STREAM object.

Comments

This function returns the current position of the RX_STREAM.

This function can also be called in user-mode.

Requirements

Headers: Include _rx_stream.h

See Also

SoraRadioReadRxStream

8) SoraInitSignalCache

```
HRESULT
SoraInitSignalCache(
    OUT PSIGNAL_CACHE    pCache,
    IN PSORA_RADIO       pRadio,
    IN ULONG             uSize,
    IN ULONG             uMaxEntryNum
);
```

Parameters

pCache

Pointer to a signal cache object to be initalized.

pRadio

Pointer to the radio object that allocates the signal cache.

uSize

The size, in bytes, of each entry in the signal cache. The size must be a multiple of 128byte.

uMaxEntryNum

The maximum number of entries in the signal cache.

Return Value

SoraInitSignalCache returns S_OK if succeeded. It returns E_NO_FREE_TX_SLOT if there is not enough onboard memory associated to the radio object. It returns E_INVALID_SIGNAL_SIZE if the specified size is not a multiple of 128.

Comments

A signal cache allocates a portion of RCB onboard memory to store pre-computed signals.

These cached signals can be transmitted for multiple times later using **SORA_HW_FAST_TX.**

Requirements

IRQL: If the cache object is non-paged, **SoraInitSignalCache** can be called at IRQL <= DISPATCH_LEVEL; Otherwise it must be called at PASSIVE_LEVEL.

Headers: Include sora.h

See Also

SoraCleanSignalCache, SoraGetSignal, SoraInsertSignal.

9) SoraInsertSignal

```
HRESULT
SoraInsertSignal(
    IN PSIGNAL_CACHE        pCache,
    IN PCOMPLEX8            pSampleBuffer,
    IN PHYSICAL_ADDRESS *pSampleBufferPa,
    IN ULONG                uSampleSize,
    IN CACHE_KEY            Key
);
```

Parameters

pCache

Pointer to the signal cache object.

pSampleBuffer

Pointer to a buffer containing the signal samples to be inserted.

pSampleBufferPa

Pointer to the physical address structure of the sample buffer.

uSampleSize

The size, in bytes, of the signal to be inserted. It must be a multiple of 128 bytes.

Key

An 8-byte key associated to the signal.

Return Value

SoraInsertSignal returns E_SIGNAL_EXISTS if a same key is already in the cache. [Kun: what happens next? The signal is overwrote or not?] It returns E_NOT_ENOUGH_RESOURCE if there is no free entries in the cache.

SoraInsertSignal returns E_INVALID_SIGNAL_SIZE if uSampleSize is not a multiple of 128.

Comments

The size of the signal should be less than the buffer size of a cache entry; Otherwise it will cause a fatal error.

Requirements

IRQL : <= DPC_LEVEL

Headers: sora.h

See Also

SoraGetSignal, SORA_HW_FAST_TX.

10) SoraGetSignal

```
PTX_DESC
SORAAPI
SoraGetSignal (
    IN PSIGNAL_CACHE pCache,
    IN CACHE_KEY     Key
);
```

Parameters

pCache

Pointer to the signal cache object from which to retrieve a signal.

Key

The 8-byte key associated to a cache entry.

Return Value

SoraGetSignal returns a TX descriptor of the stored signal; otherwise, it returns NULL if the key cannot be found in the cache.

Requirements

IRQL: <= DISPATCH_LEVEL

Headers: Include sora.h

See Also

SoraInsertSignal

11) SoraCleanSignalCache

```
void
SoraCleanSignalCache (
    IN PSIGNAL_CACHE pCache
);
```

Parameters

pCache

Pointer to the signal cache to be cleaned.

Return Value

None.

Comments

The SDR application should call **SoraCleanSignalCache** to free the RCB onboard memory.

12) SoraHwSetSampleClock

```
VOID
SoraHwSetSampleClock (
    PSORA_RADIO   pRadio,
    ULONG         Hz
);
```

Parameters

pRadio

Pointer to the radio object to be configured.

Hz

The desired sampling rate, in unit of Hz.

Return Value

None.

Comments

The sampling clock depends on the implementation of the RF front-end board. This function only provides a hint to the hardware and can be silently ignored by the hardware component.

13) SoraHwSetCentralFreq

```
VOID
SoraHwSetCentralFreq (
    PSORA_RADIO pRadio,
    ULONG kHzCoarse,
    LONG    HzFine
);
```

Parameters

pRadio

Pointer to the radio object to be configured.

kHzCoarse

The coarse part (KHz) of the desired central frequency.

HzFine

The fine part (Hz) of the desired central frequency.

Return Value

None.

Comments

SoraHwSetCentralFreq sets the central frequency of the RF front-end. The desired central frequency is split into the coarse part (kHz) and the fine part (Hz), and

Central freq = kHzCoarse * 1000 + HzFine.

14) SoraHwSetFreqCompensation

```
VOID
SoraHwSetFreqCompensation (
    PSORA_RADIO pRadio,
    LONG            lFreq
);
```

Parameters

pRadio

Pointer to the radio object to be configured.

lFreq

The frequency, in Hz, to be compensated.

Return Value

None

Comments

SoraHwSetFreqCompensation sets the central frequency compensation. The true frequency that the RF front-end works on is the sum of the frequency sets by **SoraHwSetCentralFreq** and the compensation value specified by **SoraHwSetFreqCompensation**.

SoraHwSetFreqCompensation provides a convenient way to synchronize the central frequency between the sender and the receiver.

15) SoraHwSetTXVGA1

```
VOID
```

```
SoraHwSetTXVGA1 (
    PSORA_RADIO pRadio,
    ULONG uGain
);
```

Parameters

pRadio

Pointer to the radio object to be configured.

uGain

The value, in unit of 1/256 dB, to be set to transmission Variable Gain Amplifier (VGA) of the RF front-end.

Return Value

None

Comments

SoraHwSetTXVGA1 sets the transmission variable gain amplifier of the RF front-end. The gain control is specified in unit of 1/256 dB. However, the true precision of VGA depends on the implementation of the RF front-end.

16) SoraHwSetRXPA

```
VOID
SoraHwSetRXPA (
    PSORA_RADIO pRadio,
    ULONG uGain
);
```

Parameters

pRadio

Pointer to the radio object to be configured.

uGain

The gain value sent to the RF front-end to configure the receiving Low Noise Amplifier (LNA).

Return Value

None

Comments

SoraHwSetRXPA writes a value to the virtual control register of the RF front-end to provide a hint to configure LNA on the reception path. The value depends on the implementation of the RF front-end board. For USRP XCVR2450 board, there can be three effective configurations: 0 (or 0x1000) means 0dB, 0x2000 means 16dB, and 0x3000 means 32dB.

SoraHwSetRXVGA1

```
VOID
SoraHwSetRXVGA1(
    PSORA_RADIO pRadio,
    ULONG uGain
);
```

Parameters

pRadio

Pointer to the radio object to be configured.

uGain

The value, in unit of 1/256 dB, to be set to the reception Variable Gain Amplifier (VGA) of the RF front-end.

Return Value

None

Comments

SoraHwSetRXVGA1 sets the reception variable gain amplifier of the RF front-end. The gain control is specified in unit of 1/256 dB. However, the true precision of VGA depends on the implementation of the RF front-end.

17) SORA_HW_TX_TRANSFER

```
HRESULT
SORA_HW_TX_TRANSFER (
    IN PSORA_RADIO  pRadio,
    IN PPACKET_BASE pPacket
);
```

Parameters

pRadio

Pointer to the radio object that the modulated signal of a frame is transferred to.

pPacket

Pointer to the packet base object.

Return Value

SORA_HW_TX_TRANSFER returns S_OK on success.

Comments

SORA_HW_TX_TRANSFER downloads the modulated signals of a frame from the shared TX sample buffer to the memory location on RCB as indicated in the packet base object.

18) SORA_HW _TX

```
HRESULT
SORA_HW _TX (
    PSORA_RADIO   pRadio,
    PPACKET_BASE pPacket
);
```

Parameters

pRadio

Pointer to the radio object to send the signal.

pPacket

Pointer to the packet base object.

Return Value

SORA_HW _TX returns S_OK on success.

Comments

SORA_HW _TX indicates the hardware to send out the signal at the memory location on the RCB as indicated in the packet base object. The function will be blocked until the signal has been transmitted out. The signal should be previously transferred onto the RCB memory using **SORA_HW_TX_TRANSFER**.

19) SORA_HW_FAST_TX

```
HRESULT
SORA_HW_FAST_TX (
    PSORA_RADIO pRadio,
    PTX_DESC pTxDesc
);
```

Parameters

pRadio

Pointer to the radio object to send the signal.

pTxDesc

Pointer to the TX descriptor.

Return Value

SORA_HW_FAST_TX returns S_OK on success.

Comments

SORA_HW_FAST_TX indicates the hardware to send out the signal at the memory location on the RCB as indicated in the Tx Descriptor. A Tx Descriptor is normally obtained after querying an entry of a signal cache.

20) SORA_HW_ENABLE_RX

```
VOID
SORA_HW_ENABLE_RX (
    PSORA_RADIO pRadio
);
```

Parameters

pRadio

Pointer to the radio object whose RX channel is to be enabled.

Return Value

None.

Comments

SORA_HW_ENABLE_RX enables the RX channel of a radio object. Once the RX channel is enabled, the hardware starts to fill the RX sample buffer via DMA operations.

21) SORA_HW_STOP_RX

```
VOID
SORA_HW_STOP_RX (
    PSORA_RADIO pRadio
);
```

Parameters

pRadio

Pointer to the radio object whose RX channel is to be disabled.

Return Value

None.

Comments

SORA_HW_STOP_RX disables the RX channel of a radio object. Once the RX channel is disabled, the DMA operations are stopped.

22) SoraPacketGetTxSampleBuffer

```
VOID
SORAAPI
SoraPacketGetTxSampleBuffer(
   IN PPACKET_BASE   pPacket,
   OUT PTXSAMPLE    *ppBuf,
   OUT PULONG          pBufSize
);
```

Parameters

pPacket

Pointer to the packet base object.

ppBuf

Pointer to a sample buffer pointer.

pBufSize

Pointer to an unsigned variable that receives the sample buffer size.

Return Value

None.

Comments

SoraPacketGetTxSampleBuffer obtains and locks the shared TX sample buffer from the radio that is associated to the packet object. After calling this function, the SDR driver can fill the TX sample buffer with the modulated signal samples.

23) SoraPacketSetSignalLength

```
VOID
SORAAPI
SoraPacketSetSignalLength (
              IN OUT PPACKET_BASE pPacket,
              IN ULONG                      uLen
);
```

Parameters

pPacket

Pointer to the packet base object.

uLen

The length, in bytes, of the modulated signal.

Return Value

None.

Comments

SoraPacketSetSignalLength specifies the actual bytes that have been occupied by the modulated signal of a data frame. The SDR driver should call this function right after it stores the modulated waveform in the TX sample buffer.

24) SoraPacketSetTXDone

```
__inline
void
SoraPacketSetTXDone (
    IN OUT PPACKET_BASE pPacket
);
```

Parameters

pPacket

Pointer to the packet base object.

Return Value

None.

Comments

SoraPacketSetTXDone sets the status of a packet base object to PACKET_TX_DONE. The function also frees the RCB memory that the signal has previously been transferred.

25) SoraThreadAlloc

```
HANDLE
SoraThreadAlloc ();
```

Parameters

None.

Return Value

SoraThreadAlloc returns NULL if an error occurred; otherwise it returns the handle of a Sora thread.

Comments

SoraThreadAlloc allocates a Sora exclusive thread object. A Sora exclusive thread cannot be preempted by any other thread and should be only used for real-time tasks on a multi-core system. After allocation, the SDR application should call **SoraThreadStart** to start an exclusive thread.

Requirements

IRQL: <= DISPATCH_LEVEL

Headers: Include thread_if.h

See Also

SoraThreadFree

26) SoraThreadFree

```
VOID
SoraThreadFree (
    IN HANDLE hThread
);
```

Parameters

hThread

Handle to the Sora thread object.

Return Value

None.

Comments

SoraThreadFree release the Sora thread object that is previously allocated by **SoraThreadAlloc**.

Requirements

IRQL: PASSIVE_LEVEL

Headers: Include thread_if.h

See Also

SoraThreadAlloc

27) SoraThreadStart

```
BOOLEAN
SoraThreadStart (
```

```
    IN HANDLE hThread,
    IN PSORA_UTHREAD_PROC pUserRoutine,
    IN PVOID                  pParameter
);
```

Parameters

hThread

Handle to the Sora thread object.

pUserRoutine

Address of a routine that the Sora thread calls periodically.

pParameter

Parameter provided to the user routine.

Return Value

SoraThreadStart returns TRUE if success; otherwise it returns FALSE.

Comments

SoraThreadStart starts a Sora exclusive thread that will call the user specified routine periodically. The user routine should have the follow prototype

BOOLEAN (*PSORA_UTHREAD_PROC) (PVOID pParameter) ;

The user routine should not contain long processing loops. Large processing tasks should be divided into several small pieces and the user routine should return when one piece of work has finished. If the user routine returns a value of TRUE, it will be immediately called again to continue the rest processing work. A return value of FALSE indicates the thread should be stopped. Alternatively, other thread can call **SoraThreadStop** to terminate this Sora thread.

Caution: Never call **SoraThreadStop** to terminate a Sora thread from its user routine. It will cause a dead-lock.

Requirements

IRQL: PASSIVE_LEVEL

Headers: Include thread_if.h

See Also

SoraThreadStop

28) SoraThreadStop

```
VOID
SoraThreadStop(
    IN HANDLE hThread
);
```

Parameters

hThread

Handle of the Sora thread object.

Return Value

None.

Comments

SoraThreadStop stops the running Sora thread.

Caution: Never call **SoraThreadStop** to terminate a Sora thread from its user routine. It will cause a dead-lock.

Requirements

IRQL: PASSIVE_LEVEL

Headers: Include thread_if.h

See Also

SoraThreadStart

12.2 UMX API

29) SoraUInitUserExtension

```
BOOLEAN
SoraUInitUserExtension (
      const char * szDevName
);
```

Parameters

szDevName

Pointer to the name of device supporting UMX API.

Return Value

SoraUInitUserExtension returns true if the initialization succeeds; otherwise, it returns false.

Comments

SoraUInitUserExtension initializes the user-mode extension. The device name should be "\\.\HWTest".

30) SoraUCleanUserExtension

```
VOID
SoraUCleanUserExtension ();
```

Parameters

None.

Return Value

None.

Comments

SoraUCleanUserExtension cleans the resources allocated when initialing the user-mode extension.

31) SoraURadioStart

```
HRESULT
SoraRadioStart (
          IN ULONG      uRadioID
);
```

Parameters

uRadioID

The ID referring to the radio object.

Return Value

SoraURadioStart returns S_OK if the radio hardware is enabled successfully.

Comments

SoraURadioStart enables the RF front-end and initializes the gain control parameters.

32) SoraURadioSetSampleRate

```
HRESULT
SoraURadioSetSampleRate(
    IN ULONG    uRadioID,
    IN ULONG    MHz
);
```

Parameters

uRadioID

The ID referring to the radio object.

MHz

The desired sampling rate, in unit of MHz.

Return Value

SoraURadioSetSampleRate returns S_OK if the sample rate is successfully set.

Comments

The sampling clock depends on the implementation of the RF front-end board. This function only provides a hint to the hardware and can be silently ignored by the hardware component.

33) SoraURadioSetCentralFreq

```
HRESULT
SoraURadioSetCentralFreq (
    ULONG  uRadioID,
    ULONG  KHz
);
```

Parameters

uRadioID

The ID referring to the radio object.

KHz

The KHz of the desired central frequency.

Return Value

SoraURadioSetCentralFreq returns S_OK if the central frequency is successfully set.

Comments

SoraURadioSetCentralFreq sets the central frequency of the RF front-end.

34) SoraURadioSetFreqOffset

```
HRESULT
SoraURadioSetFreqOffset(
    ULONG uRadioID,
    LONG    lFreq
);
```

Parameters

uRadioID

The ID referring to the radio object.

lFreq

The frequency offset, in Hz, to be set.

Return Value

SoraURadioSetFreqOffset returns S_OK if the frequency offset is successfully set.

Comments

SoraURadioSetFreqOffset sets the frequency offset. The true frequency that the RF front-end works on is the sum of the frequency sets by **SoraURadioSetCentralFreq** and the offset value specified by **SoraURadioSetFreqOffset**.

SoraURadioSetFreqOffset provides a convenient way to synchronize the central frequency between the sender and the receiver.

35) SoraURadioSetTxGain

```
HRESULT
SoraURadioSetTxGain (
    ULONG  uRadioID,
    ULONG  uGain
);
```

Parameters

uRadioID

The ID referring to the radio object.

uGain

The value, in unit of 1/256 dB, to be set to transmission Variable Gain Amplifier (VGA) of the RF front-end.

Return Value

SoraURadioSetTxGain returns S_OK if the Tx Gain is successfully set.

Comments

SoraURadioSetTxGain sets the transmission variable gain amplifier of the RF front-end. The gain control is specified in unit of 1/256 dB. However, the true precision of VGA depends on the implementation of the RF front-end.

36) SoraURadioSetRxPA

```
HRESULT
SoraURadioSetRxPA (
    ULONG uRadioID,
    ULONG RxPa
);
```

Parameters

uRadioID

The ID referring to the radio object.

RxPa

The gain value sent to the RF front-end to configure the receiving Low Noise Amplifier (LNA).

Return Value

SoraURadioSetRxPA returns S_OK if the Rx PA is successfully set.

Comments

SoraURadioSetRxPA writes a value to the virtual control register of the RF front-end to provide a hint to configure LNA on the reception path. The value depends on the implementation of the RF front-end board. For USRP XCVR2450 board, there can be three effective configurations: 0 (or 0x1000) means 0dB, 0x2000 means 16dB, and 0x3000 means 32dB.

37) SoraURadioSetRxGain

```
HRESULT
SoraURadioSetRxGain (
      ULONG  uRadioID,
      ULONG  uGain
);
```

Parameters

uRadioID

The ID referring to the radio object.

uGain

The value, in unit of 1/256 dB, to be set to the reception Variable Gain Amplifier (VGA) of the RF front-end.

Return Value

SoraURadioSetRxGain returns S_OK if the Rx Gain is successfully set.

Comments

SoraURadioSetRxGain sets the reception variable gain amplifier of the RF front-end. The gain control is specified in unit of 1/256 dB. However, the true precision of VGA depends on the implementation of the RF front-end.

38) SoraURadioMapTxSampleBuf

```
HRESULT
SoraURadioMapTxSampleBuf (
           IN ULONG       uRadioID,
           OUT PVOID    *ppBuf,
           OUT PULONG puSize
);
```

Parameters

uRadioID

The ID referring to the radio object.

ppBuf

Address of a pointer variable that receives the pointer to the mapped TX sample buffer of the radio.

puSize

Address of an unsigned long variable that receives the size of the mapped TX sample buffer.

Return Value

SoraURadioMapTxSampleBuf returns S_OK if success.

Comments

SoraURadioMapTxSampleBuf maps the TX sample buffer of the radio object into the user-mode space. The radio object is specified by RadioID. The function needs to be called only once during the initialization phase of a SDR application. The SDR application then can directly output digital samples to the TX sample buffer via this mapped address.

39) SoraURadioTransfer

```
HRESULT
SoraURadioTransfer (
    IN ULONG uRadioID,
    IN ULONG uSignalLen,
    OUT PULONG pTxID
);
```

Parameters

uRadioID

The ID referring to the radio object.

uSignalLen

The signal length stored in Tx sample buffer.

pTxID

Address of an ULONG variable that receives the TxID of transferred signal.

Return Value

SoraURadioTransfer returns S_OK if success.

Comments

SoraURadioTransfer allocates a block of RCB memory and transfers the modulated signal in the TX sample buffer to that memory block. The returned TxID can be later used in **SoraURadioTx** to transfer the signal or used in **SoraURadioTxFree** to remove the signal from RCB memory.

40) SoraURadioTx

```
HRESULT
SoraURadioTx (
      IN ULONG uRadioID,
      IN ULONG TxID
);
```

Parameters

uRadioID

The ID referring to the radio object.

TxID

TX ID of a signal to be transmitted.

Return Value

SoraURadioTx returns S_OK if success.

Comments

SoraURadioTx instructs the hardware to send out the signal indicated by the TX ID. The signal should have been transferred to the RCB memory using **SoraURadioTransfer**.

41) SoraURadioTxFree

```
HRESULT
SoraURadioTxFree (
      IN ULONG uRadioID,
      IN ULONG TxID
);
```

Parameters

uRadioID

The ID referring to the radio object.

TxID

TX ID of a signal to be freed.

Return Value

SoraURadioTxFree returns S_OK if success.

Comments

SoraURadioTxFree frees the memory block on RCB that holds the signal indicated by the TxID. After **SoraURadioTxFree**, the TX ID is no longer valid.

42) SoraURadioUnmapTxSampleBuf

```
HRESULT
SoraURadioUnmapTxSampleBuf (
      IN ULONG uRadioID,
      IN PVOID  pMappedBuf
);
```

Parameters

uRadioID

The ID referring to the radio object.

pMappedBuf

Pointer to the mapped TX sample buffer.

Return Value

SoraURadioUnmapTxSampleBuf returns S_OK if success.

Comments

SoraURadioUnmapTxSampleBuf releases the mapped TX sample buffer. The user-mode address, as pointed by pMappedBuf, is no longer valid. pMappedBuf should contain a valid address that is returned by **SoraURadioMapTxSampleBuf**.

43) SoraURadioMapRxSampleBuf

```
HRESULT
SoraURadioMapRxSampleBuf (
      ULONG           uRadioID,
      OUT PVOID       *ppBuf,
      OUT PULONG      puSize
);
```

Parameters

uRadioID

The ID referring to the radio object.

ppBuf

Address of a pointer variable that receives the pointer to the mapped RX sample buffer of the radio.

puSize

Address of an unsigned long variable that receives the size of the mapped RX sample buffer.

Return Value

SoraURadioMapRxSampleBuf returns S_OK if success.

Comments

SoraURadioMapRxSampleBuf maps the RX sample buffer of the radio object into the user-mode space. The radio object is specified by *uRadioID*. **SoraURadioMapRxSampleBuf** needs to be called only once during the initialization phase of a SDR application. The SDR application then can directly read digital samples from the RX sample buffer via this mapped address.

44) SoraURadioUnmapRxSampleBuf

```
HRESULT
SoraURadioUnmapRxSampleBuf (
    ULONG           uRadioID,
    OUT PVOID       pMappedBuf,
);
```

Parameters

uRadioID

The ID referring to the radio object.

pMappedBuf

Pointer to the mapped RX sample buffer.

Return Value

SoraURadioUnmapRxSampleBuf returns S_OK if success.

Comments

SoraURadioUnmapRxSampleBuf releases the mapped RX sample buffer. The user-mode address, as pointed by pMappedBuf, is no longer valid. pMappedBuf should contain a valid address that is returned by **SoraURadioMapRxSampleBuf**.

45) SoraURadioAllocRxStream

```
HRESULT
SORAAPI
SoraURadioAllocRxStream (
    OUT PSORA_RADIO_RX_STREAM   pRxStream,
    IN ULONG                    uRadioID,
    IN PUCHAR                   pMappedRxBuf,
    IN ULONG                    uSize
);
```

Parameters

pRxStream

Pointer to a RX_STREAM object.

uRadioID

The ID referring to the radio object.

pMappedRxBuf

Pointer to the mapped RX sample buffer.

uSize

Size, in bytes, of the mapped RX sample buffer.

Return Value

SoraURadioAllocRxStream returns S_OK if success. It returns E_RADIO_NOT_CONFIGURED if the radio object is not properly initialized. It returns E_FAIL if the radio object cannot allocate a new RX_STREAM object.

Comments

SoraURadioAllocRxStream retrieves a RX_STREAM object from the mapped RX sample buffer of the radio object. A SDR application should use SoraRadioReadRxStream with the RX_STREAM object to read received digital samples, instead of directly accessing the RX sample buffer of a radio. pMappedRxBuf should contain a valid address that is returned by **SoraURadioMapRxSampleBuf**.

46) SoraRadioReadRxStream

```
HRESULT
SoraRadioReadRxStream (
        PSORA_RADIO_RX_STREAM pRxStream,
        FLAG *                pbTouched,
        SignalBlock&          block
);
```

Parameters

pRxStream

Pointer of the RX_STREAM object.

pbTouched

Pointer to a flag that receives the indication of the emptiness of the RX channel.

block

Signal block just read.

Return Value

The return value is S_OK if a signal block is succeeded read. Otherwise, the return value is E_FETCH_SIGNAL_HW_TIMEOUT if no new signal blocks are available in a timeout period. This may indicate an error in hardware.

Comments

This function gets a new signal block from the RX_STREAM object. pbTouched points to a flag variable that receives the indication whether or not the returned signal block is the last one in the RX channel. If the flag is set, the RX channel of the radio is empty.

This function can also be called in kernal-mode.

Requirements

Headers: Include soradsp.h

47) SoraRadioGetRxStreamPos

```
PRX_BLOCK
SoraRadioGetRxStreamPos (
    PSORA_RADIO_RX_STREAM pRxStream
);
```

Parameters

pRxStream

Pointer of RX_STREAM object.

Return Value

The current position of the RX_STREAM object.

Comments

This function returns the current position of the RX_STREAM.

This function can also be called in user-mode.

Requirements

Headers: Include _rx_stream.h

See Also

SoraRadioReadRxStream

48) SoraURadioReleaseRxStream

```
VOID
SORAAPI
SoraURadioReleaseRxStream (
    IN PSORA_RADIO_RX_STREAM   pRxStream,
    IN ULONG                   uRadioID,
);
```

Parameters

pRxStream

Pointer to a RX_STREAM object.

uRadioID

The ID referring to the radio object.

Return Value

None.

Comments

SoraURadioReleaseRxStream releases the RX_STREAM object that allocated from **SoraURadioAllocRxStream**. Once **SoraURadioReleaseRxStream** is called, the RX_STREAM is not valid anymore.

49) SoraUAcquireTxBufLock

```
HRESULT
SoraUAcquireTxBufLock (
    ULONG uRadioID
);
```

Parameters

uRadioID

ID of the radio object whose TX buffer is to be locked.

Return Value

SoraUAcquireTxBufLock returns S_OK is success.

Comments

SoraUAcquireTxBufLock acquires the shared TX buffer lock of the radio object. After acquiring the lock, the application has exclusive access to the TX sample buffer of the radio. A SDR application should release the lock after it has transferred the modulated signal to the RCB memory, so that other SDR applications can use the TX buffer to output and transfer their signals.

50) SoraUReleaseTxBufLock.

```
VOID
SoraUReleaseTxBufLock (
      ULONG uRadioID
);
```

Parameters

uRadioID

ID of the radio object whose TX buffer lock is to be released.

Return Value

None.

Comments

SoraUReleaseTxBufLock releases the shared TX buffer lock of the radio object. The SDR application should previously obtain the TX buffer lock by **SoraUAcquireTxBufLock**.

51) SoraUWriteRadioRegister

```
HRESULT
SoraUWriteRadioRegister (
    IN ULONG uRadioID,
    IN ULONG uAddr,
    IN ULONG uValue
);
```

Parameters

uRadioID

ID of the radio object to be configured.

uAddr

Address of the register on the RF front-end board.

uValue

Value to be written to the radio register.

Return Value

SoraUWriteRadioRegister returns S_OK if success.

Comments

SoraUWriteRadioRegister writes to a value to a virtual register on the RF front-end board. The definition of the register and the value depends on the RF front-end implementation. This function allows the SDR application to access the extended registers of a RF front-end board.

52) SoraUReadRadioRegister

```
HRESULT
SoraUReadRadioRegister (
    IN ULONG uRadioID,
    IN ULONG uAddr,
    IN ULONG * puVal
);
```

Parameters

uRadioID

ID of the radio object to be configured.

uAddr

Address of the register on the RF front-end board.

uValue

Address of an unsigned long variable that receives the register value.

Return Value

SoraUReadRadioRegister returns S_OK if success.

Comments

SoraUReadRadioRegister reads the value in a virtual register on the RF front-end board. The definition of the register and the value depends on the RF front-end implementation. This function allows the SDR application to access the extended registers of a RF front-end board.

53) SoraUIndicateRxPacket

```
HRESULT
SoraUIndicateRxPacket (
    IN UCHAR* pPktBuf,
    IN ULONG  uPktLength
);
```

Parameters

pPktBuf

Pointer to the buffer containing a data packet.

uPktLength

Size of the data packet, in bytes.

Return Value

SoraUIndicateRxPacket returns S_OK if success.

Comments

SoraUIndicateRxPacket indicates a demodulated packet to the HwTest driver, which then indicates the packet to the upper layers, i.e. TCP/IP, for further processing. **SoraUIndicateRxPacket** enables the seamless integration of the SDR application with Windows network stack.

54) SoraUThreadAlloc

```
HANDLE
SoraUThreadAlloc ();
```

Parameters

None

Return Value

SoraUThreadAlloc returns NULL if an error occurred; otherwise it returns the handle of a Sora thread.

Comments

SoraUThreadAlloc allocates a Sora exclusive thread object. A Sora exclusive thread cannot be preempted by any other thread and should be only used for real-time tasks on a multi-core system. After allocation, the SDR application should call **SoraUThreadStart** to start an exclusive thread.

55) SoraUThreadFree

```
VOID
SoraUThreadFree (
    IN HANDLE hThread
);
```

Parameters

hThread

Handle to the Sora thread object.

Return Value

None.

Comments

SoraUThreadFree release the Sora thread object that is previously allocated by **SoraUThreadAlloc**.

56) SoraUThreadStart

```
BOOLEAN
SoraUThreadStart (
    IN HANDLE hThread,
    IN PSORA_UTHREAD_PROC pUserRoutine,
    IN PVOID              pParameter
);
```

Parameters

hThread

Handle to the Sora thread object.

pUserRoutine

Address of a routine that the Sora thread calls periodically.

pParameter

Parameter provided to the user routine.

Return Value

SoraUThreadStart returns TRUE if success; otherwise it returns FALSE.

Comments

SoraUThreadStart starts a Sora exclusive thread that will call the user specified routine periodically. The user routine should have the follow prototype

BOOLEAN (*PSORA_UTHREAD_PROC) (PVOID pParameter) ;

The user routine should not contain long processing loops. Large processing tasks should be divided into several small pieces and the user routine should return when one piece of work has finished. If the user routine returns a value of TRUE, it will be immediately called again to continue the rest processing work. A return value of FALSE indicates the thread should be stopped. Alternatively, other thread can call **SoraUThreadStop** to terminate this Sora thread.

Caution: Never call **SoraUThreadStop** to terminate a Sora thread from its user routine. It will cause a dead-lock.

57) SoraUThreadStop

```
VOID
SoraUThreadStop(
      IN HANDLE hThread
);
```

Parameters

hThread

Handle of the Sora thread object.

Return Value

None.

Comments

SoraUThreadStop stops the running Sora thread.

Caution: Never call **SoraUThreadStop** to terminate a Sora thread from its user routine. It will cause a dead-lock.

58) SoraUGetTxPacket

```
HRESULT
SoraUGetTxPacket(
      OUT PACKET_HANDLE * phPacket,
      OUT VOID  **    ppAddr,
      OUT UINT   *     puLength,
      IN DWORD       dwTimeout
);
```

Parameters

phPacket

Address of a pointer variable that receives the TX data packet handle.

ppAddr

Address of a pointer variable that receives the start address of a TX data packet.

puLength

Address of an unsigned integer that receives the length, in bytes, of the TX data packet.

dwTimeout

The timeout interval, in milliseconds, or INFINITE.

Return Value

SoraUGetTxPacket returns S_OK if a TX data packet is successfully obtained.

It returns ERROR_CANCELLED if **SoraUEnableGetTxPacket** is not called or

SoraUDisableGetTxPacket is called to disable the SDR application to obtain a data packet from hwtest driver. **SoraUGetTxPacket** returns ERROR_INVALID_HANDLE if the UMX is not initialized.

SoraUGetTxPacket returns ERROR_TIMEOUT if the timeout interval has elapsed without getting a data packet.

Comments

SoraUGetTxPacket allows the SDR application to retrieve an Ethernet packet from the **HWTest** driver, which has received these data packets from upper layers, e.g. TCP/IP, in the Windows network stack. The SDR application can convert the packet format, modulate signal, and finally transmit the signal through RCB and RF front-end boards.

59) SoraUCompleteTxPacket

```
HRESULT
SoraUCompleteTxPacket (
   IN PACKET_HANDLE   hPacket,
   IN HRESULT hResult
);
```

Parameters

hPacket

Handle to a data packet obtained using **SoraUGetTxPacket**.

hResult

The resulting status of the packet.

Return Value

SoraUCompleteTxPacket returns S_OK if success.

Comments

SoraUCompleteTxPacket indicates the hwtest driver (then all upper layers in the network stack) the completion of the data packet transmission. hResult is set to S_OK if the packet has been successfully handled. Otherwise, a S_FAIL should be set. The SDR application should eventually call **SoraUCompleteTxPacket** to release the resource associated to the data packet along the network stack.

60) SoraUEnableGetTxPacket

```
HRESULT
SoraUEnableGetTxPacket ();
```

Parameters

None

Return Value

SoraUEnableGetTxPacket returns S_OK if success.

Comments

SoraUEnableGetTxPacket should be called before calling **SoraUGetTxPacket**.

61) SoraUDisableGetTxPacket

```
HRESULT
SoraUDisableGetTxPacket ();
```

Parameters

None

Return Value

SoraUDisableGetTxPacket returns S_OK if the function succeeds.

Comments

SoraUDisableGetTxPacket releases all blocking calls to **SoraUGetTxPacket** and disables its function. Subsequent calls to **SoraUGetTxPacket** will return ERROR_CANCELLED.

62) SoraUAllocBuffer

```
PVOID
SoraUAllocBuffer (
    IN ULONG Size
);
```

Parameters

Size

The size of buffer required.

Return Value

This function returns the address of buffer if succeeded.

Otherwise, NULL is returned.

Comments

SoraUAllocBuffer allocates the required kernel buffer and is usually used for modulation. User is able to store the modulated signal in the address returned by **SoraUAllocBuffer** and invoke **SoraURadioTransferEx** subsequently to transfer it. Kernel buffer is a limited rare resource. Once the buffer is obtained, hold and reuse it unless you don't need it anymore. Frequent allocation and release is not recommended and might fail.

63) SoraUReleaseBuffer

```
VOID
SoraUReleaseBuffer (
    IN PVOID Buff
);
```

Parameters

Buff

Specify the buffer address to release, which is always returned by previous **SoraUAllocBuffer**.

Return Value

None

Comments

SoraUReleaseBuffer releases the kernel buffer allocated by **SoraUAllocBuffer**.

64) SoraURadioTransferEx

```
VOID
SoraURadioTransferEx (
    IN ULONG RadioNo,
    IN PVOID SampleBuffer,
    IN ULONG SampleSize,
    OUT PULONG TxID
);
```

Parameters

RadioNo

The ID referring to the radio object.

SampleBuffer

The buffer address that stores the signal for transferring.

SampleSize

The signal length stored in SampleBuffer.

pTxID

Address of an ULONG variable that receives the TxID of transferred signal.

Return Value

SoraURadioTransfer returns S_OK if success.

Comments

SoraURadioTransferEx allocates a block of RCB memory and transfers the modulated signal to that memory block. The returned TxID can be later used in **SoraURadioTx** to transfer the signal or used in **SoraURadioTxFree** to remove the signal from RCB memory. The main difference between **SoraURadioTransfer** and **SoraURadioTransferEx** is the parameter buffer address. **SoraURadioTransferEx** provides more flexibilities and programmers are now able to modulate more that one singal concurrently, store to different modulation buffer allocated from **SoraUAllocBuffer** and finally transfer the modulation buffer to RCB by **SoraURadioTransferEx**.

12.3 Sora Time API

65) ExistTSC

```
bool
ExistTSC();
```

Parameters

None

Return value

true if suporting, false otherwise

Comments

Determine whether current CPU support Time Stamp Counter (TSC) instructions

66) SoraSetTimestampMethod

```
int
SoraSetTimestampMethod (PTIMESTAMPINFO pInfo, int use_tsc );
```

Parameters

pInfo

pointer to the TIMESTAMPINFO object

use_tsc

true means use TSC, false means not

Return value

original method of TIMESTAMPINFO object

Comments

Set the method of TIMESTAMPINFO object to specified method

67) InitializeTimestampInfo

```
void
InitializeTimestampInfo ( PTIMESTAMPINFO pInfo, bool use_tsc = true );
```

Parameters

pInfo

pointer to the TIMESTAMPINFO object

use_tsc

true means use TSC, false means not

Return value

none

Comments

Intialize TIMESTAMPINFO object

68) SoraGetCPUTimestamp

```
ULONGLONG
SoraGetCPUTimestamp (PTIMESTAMPINFO pTSInfo);
```

Parameters

pTSInfo

pointer to the TIMESTAMPINFO object

Return value

current timestamp

Comments

Get current timestamp by the method specified by TIMESTAMPINFO object

69) SoraGetTimeofDay

```
ULONGLONG
SoraGetTimeofDay (PTIMESTAMPINFO pTSInfo);
```

Parameters

pTSInfo

pointer to the TIMESTAMPINFO object

Return value

the number of us has passed since last reboot

Comments

Get the number of us has passed since last reboot

70) SoraParseTime

```
bool
SoraParseTime ( PSORATIMEOFDAYINFO info, ULONGLONG us );
```

Parameters

info

pointer to the SORATIMEOFDAYINFO object

us

the microseond value

Return value

true

Comments

Parse the microseond value into hh:mm:ss.us format stored in SORATIMEOFDAYINFO object

71) SoraTimeElapsed

```
ULONGLONG
SoraTimeElapsed ( ULONGLONG ts, PTIMESTAMPINFO tsinfo )
```

Parameters

info

pointer to the SORATIMEOFDAYINFO object

us

the microseonds value

Return value

nanoseconds value

Comments

Convert ticks value to nanoseconds. Ticks value is difference between two timestamp returned by SoraGetCPUTimestamp functions

72) SoraStallWait

```
void
SoraStallWait ( PTIMESTAMPINFO pTSInfo, ULONGLONG waitns )
```

Parameters

pTSInfo

pointer to the TIMESTAMPINFO object

waitns

the nanoseconds value

Return value

none

Comments

Spinlock specified nanoseconds