IEEE 802.11
Wireless Access Methods and Physical Layer Specifications

TITLE: RF Physical Layer Baseline Document for the Physical Media Dependent Sublayer of a Frequency Hopping Spread Spectrum PHY

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AUTHOR:
Tim Blaney
Apple Computer
One Infinite Loop
Cupertino, CA 95014
tblaney@applelink.apple.com

Ed Geiger
Apple Computer
One Infinite Loop
Cupertino, CA 95014
edg@goofy.apple.com

Introduction

The following document is submitted to the 802.11 Physical Layer Working Group with the intention that its contents be accepted as the Baseline Draft Standard for the Physical Media Dependent Layer of the Frequency Hopping Spread Spectrum PHY. This document is not intended to be a finalized version of the RF Physical Layer PMD, but is intended to be the basis for a working document for which future PHY Layer PMD submissions should reference.

1.0 Introduction

Figure 1 shows the Protocol Layer reference model which served as the basis for this document within the RF_PHY Layer. The RF physical layer is divided into two sublayers: the Data Transport Sublayer and the Physical Media Dependent Sublayer (RF_PMD). In addition to these sublayers, there also exists an RF Layer Management entity (RF_LM) which provides for the control and observation of each sublayer.

2.0 RF_PMD Functions

The following list describes the functions performed by the RF_PMD sublayer

- Transmit and Receive Data
- Transmit and Receive Frequency Generation
- Transmitter Power Level Generation
- Receiver Diversity
- Receiver Data Clock Recovery
- Carrier Sense and Channel Energy Detection

2.1 Transmit and Receive Data

This function is defined at the Data Transport Layer and the PMD Layer interface. It is the boundary at which data bits are passed from the PMD to the upper layers via the RXD line during reception of a packet, and which accepts data bits from the Data Transport Layer via the TXD line prior to transmission of a packet.

2.2 Transmit and Receive Frequency Generation

This function is used to place the transceiver onto the correct frequency or channel prior to reception or transmission of data. The PMD programs the frequency control circuitry with the proper frequency or channel assignment using information passed to it by both the Data Transport and the RF_LM sublayers.

2.3 Transmitter Power Level Generation

This function sets the transceiver to the appropriate power level prior to transmission of a data packet. The actual level is determined by the upper layers and passed down to the PMD Layer via the RF_LM interface. Selection of the correct power level is not determined by the PMD, but could be based on feedback from the PMD in the form of received signal strength and channel interference.

2.4 Receiver Diversity

This function is performed by the PMD Layer to select the appropriate antenna for reception of the next data packet. All timing requirements for selection of the correct antenna need to be adhered to by the PMD. The signal level information is obtained by sampling the energy level on each antenna port, comparing the sampled values and then passing the selected antenna onto the RF_LM Layer to inform the upper layers of the decision.

2.5 Receiver Clock and Data Recovery

This function performs clock and data recovery on the receive data stream. This is done after the diversity decision has been made to insure that the best signal level is being sampled. Clock and data recovery is used as one indicator to determine if the signal present at the input antenna of the receiver is valid data or noise. Recovered clock and data information is passed up to the Data Transport Layer for further analysis.

2.6 Carrier Sense and Channel Energy Detection

This function is used as one method of determining whether or not the medium is clear or has data/energy present on it. It is used in conjunction with the diversity decision to select the appropriate antenna, as well as, with the algorithm to determine whether the channel is clear to transmit a data packet. The information from this function is passed to the upper layers via the RF_LM and Data Transport Layer interfaces. The channel clear or busy decision is important to the upper layers to inform them of the status of the network.

3.0 RF_PMD Interface Primitives

The RF_PMD consists of two sets of interfaces. One interface is with the Data Transport Sublayer and the other interface is with the Layer Management entity (RF_LM). Figure 2 shows the signals which pass between the RF_PMD and these two protocol entities.

In the following sections, these signals or layer primitives will be described in detail.

4.0 Data Transport Layer Primitives

4.1 TXD

The TXD line is used to pass data to be transmitted over the RF media to the RF_PMD. Data is encoded in NRZ format over this line.

4.2 RXTX

This line controls whether the RF_PMD is in the transmit or receive mode. When this line is a logic "0", the RF_PMD is in the TRANSMIT mode and when this line is a logic "1", the RF_PMD is in the RECEIVE mode.

4.2 PAOFF

When the RF_PMD is in the TRANSMIT mode, as determined by the RXTX line, this signal is used to control the transceiver's power amplifier block. When this line is a logic "0", the power amplifier is OFF and when this line is a logic "1", the power amplifier is ON.

4.3 DIVSTRT

This line tells the RF_PMD to perform an energy level measurement on each antenna port to determine which antenna is receiving the strongest signal and to select that antenna for the current attempt of data reception. When the DIVSTRT line transitions from a logic "1" to a logic "0", the energy level measurement and antenna selection begins. When this line transitions from a logic "0" to a logic "1", the level sensing and antenna selection circuitry will be reset and become ready to perform another diversity measurement.

4.4 CHNL#

The CHNL# line is a set of three lines used to select one (1) of five (5) frequencies which programs the RF_PMD's frequency control circuitry. These five (5) frequencies are specified by the GROUP lines via the layer management entity (RF_LM).

4.5 RXD

The RF_PMD attempts to recover clock and data from the incoming media signal. When clock and data recovery is successful, the RXD line is used to pass recovered data from the RF_PMD to the Data Transport sublayer. The data is encoded using an NRZ format.

4.6 RXCLK

The RXCLK signal is used in conjunction with the RXD line to move recovered data from the RF_PMD to the Data Transport sublayer.

5.0 Layer Management Primitives

5.1 PWRMGMT

The PWRMGMT line is used by the layer management entity (RF_LM) to control the operating state of the RF_PMD. When this line is a logic "1", the RF_PMD will become fully operational and consume power required for normal operation. When this line is a logic "0", the RF_PMD will revert to a low power or standby state.

5.2 PWRLVL

This line is used to determine the power level the transmitter uses to transmit data. When this line is a logic "1", the power level is XX and when this line is a logic "0", the power level is YY. Additional levels can be implemented by increasing the number of control lines to this function.

5.3 GROUP1

The GROUP1 primitive is a set of five (5) channel numbers having a transceiver frequency associated with each channel number. When the Data Transport layer selects a specific channel number for transmitting or receiving data, that channel number specifies a frequency found in the GROUP1 primitive.

5.4 GROUP2

The GROUP2 primitive is a second set of five (5) channel numbers and their associated frequencies similar in function to the GROUP1 primitive. The purpose of two sets of GROUP primitives is to allow one set of GROUP primitives to be updated while the other is in use by the RF_PMD. The GROUPSEL line is used to determine which GROUP primitive is active.

5.5 GROUPSEL

The RF_PMD uses the GROUPSEL line to determine which GROUP primitive should be used to associate a CHNL# with a frequency. When this line is a logic "1", the GROUP2 primitive is the active set of frequencies. When this line is a logic "0", the GROUP1 primitive is the active set of frequencies.

5.6 DIVMAN

In some cases, it might be desirable to force the RF_PMD to select a specific antenna with which to receive data rather than using the diversity antenna selection mechanism. When this line is a logic "1", the antenna selection is done manually using the MANTSEL line. When this line is a logic "0", the antenna selection during receive mode is performed using the RF_PMD diversity logic.

5.7 MANTSEL

The MANTSEL line is only active when the DIVMAN line is set to a logic "1". When the MANTSEL line is a logic "0", the manual antenna selection logic will select antenna 0 as the antenna to use for data reception. When the MANTSEL line is a logic "1", antenna 1 will be selected.

5.8 RSSI

Received in-band energy level is provided by this analog line. The RSSI level will be monotonically increasing and proportional to the log of the incoming signal. The operational range of this input is defined to coincide with the dynamic range of the transceiver. It should provide information to the Data Transport and RF_LM entities about the conditions of the media over the range specified by the difference of the minimum input sensitivity level (-80 dBm @ 10^{-5} BER) and the maximum input signal level (-20 dBm), which is 60 dB. The corresponding voltage on this line should be proportional to the power level within this range. This function may also be implemented as a digital interface.

5.9 RXANT

The RXANT line is a status line from the RF_PMD diversity / antenna selection circuitry indicating which antenna is currently being used by the RF_PMD to receive data. This line is active regardless of whether the antenna selection is done manually or via the diversity logic. When this line is a logic "0", antenna 0 is the antenna used for data reception, and when this line is a logic "1', antenna 1 is used for data reception.

6.0 PMD Specifications

6.1 PMD General Specifications

	Parameter	Limit	Comments
1.	Transmit & Receive Frequency Range	2.402 - 2.482 GHz 2.471 - 2.497 GHz All channel centers in 1.0 MHz steps	For U.S.A/Europe For Japan
2.	Minimum number of Transmit & Receive Channels	75 20 10	For U.S.A. band For Europe band For Japan band
3.	Minimum number of Transmit and Receive Hops per second	2.5	
4.	Transmit and Receive Occupied 20 dB Bandwidth	± 500 kHz	
5.	Channel Data Rate	1.0 Mbps	
6.	Transmit and Receive Antenna Port Impedance	50 ohms	
7.	Transmit and Receive Channel Availability	99.5 %	

6.2 PMD Transmit Specifications

	Parameter	Limit	Comments
1.	Maximum Transmitted Power Levels [mW]	1000 100 10	For U.S.A. band For Europe band For Japan band
2.	Optional Transmitted Power Levels [mW]	1.0 / 10 / 100	For U.S.A./Europe
3.	Transmitter Maximum Radiated E.I.R.P.	Per FCC 15.247 Per ETSI RES 02-09 TBD in Japan	Total radiated power including antenna gain. (For reference only)
4.	Transmitter Modulation Frequency Deviation	ÆF$_{min}$ = 160 kHz	
5.	Modulation	GFSK with BT = 0.5	
6.	Transmit Occupied Channel Bandwidth	20 dBc @ÆF = ± 0.5 MHz 45 dBc @ÆF = ± 2.0 MHz 60 dBc @ÆF = ± 3.0 MHz	Defines transmitted spectrum mask. Allows coexistence of multiple networks.
7.	Transmitter Center Frequency Tolerance	± 20 ppm	Refer to document IEEE P802.11-93/83r1
8.	Transmitter Spurious Emissions @ÆF > 4.0 MHz from F$_c$ (carrier)	-64 dBc	For spurii within the designated band
9.	Transmitter Spurious Emissions outside of the designated band	Per FCC 15.247, 15.205 & 15.209 Per ETSI RES 02-09	For U.S.A. For Europe

6.3 PMD Receive Specifications

	Parameter	Limit	Comments
1.	Receiver Sensitivity	-80 dBm @ 10^{-5} BER	
2.	Receiver maximum Input Level	-20 dBm	
3.	Receiver Alternate Channel Interference Tolerance	45 dB @ 10^{-5} BER as measured by the method outlined in DOC IEEE P802.11-93/83r1	Facilitates interoperability
4.	Receiver Center Frequency Acceptance Range	± 25 ppm	For interoperability purposes
5.	Receiver BER for a Given E_b/N_o	At E_b/N_o = 16 dB, the BER 10^{-5}	

7.0 PMD Timing Requirements

7.1 Receive-to-Transmit Switching Requirement

Time to change from Receive mode to Transmit mode (on the same frequency):

$T_{rx\text{-}tx}$ _ 5.0 µseconds.

This stringent timing requirement is necessary to reduce the uncertainty period between a "channel clear sense" condition during scanning and its corresponding transmit mode in a system using a CSMA protocol variant. This time is defined as the time required for the transceiver to physically change from the receive state to the transmit state, and for the power amplifier to be fully powered "ON" and ready to transmit the first bit of data. This can be depicted as follows:

$T_{rx\text{-}tx} = T_{sw} + TPA_{on}$ = 1.0 µsec. + 4.0 µsecs. = 5.0 µsecs. (max.)

The times listed above are reflective of the physical switching time to change from receive mode to transmit mode (T_{sw}), and the time required for the power amplifier (TPA_{on}) to ramp up to full power. It is assumed that these timing events are serial.

7.2 Transmit-to-Receive Switching Requirement

Time to change from Transmit mode to Receive mode (on the same frequency):

$T_{tx\text{-}rx}$ _ 5.0 µseconds.

This stringent timing requirement is necessary to reduce the turnaround period between transmission of successive bursts of data on each of the five channels because the transceiver changes states ($T_{tx\text{-}rx}$) prior to hopping to the next logical channel. This time is defined as the time required for the transceiver to physically change from the transmit state to the receive state, and for the power amplifier to be fully powered "OFF". This can be depicted as follows:

$T_{tx\text{-}rx}$ = TPAoff + T_{sw} = 4.0 µsecs. + 1.0 µsec. = 5.0 µsecs. (max.)

The times listed above are reflective of the time required for the power amplifier (TPAoff) to decay in amplitude to a minimum detectable signal level, and the physical switching time to change from transmit mode to receive mode (T_{SW}). It is assumed that these timing events are serial.

7.3 Channel Switching Requirement

Time to change from one channel frequency to another, once provided with the channel information from the Data Transport Layer. This is defined such that the desired final frequency has settled to within ± 40 kHz of the center frequency (F_c) and the RSSI output line has had ample time to build up with energy and can produce a valid measurement:

Thop _ 80.0 µseconds.

In addition to having energy valid at the output of the RSSI line within the prescribed 80.0 µsecond hop period, the transceiver must have stable data, that meets the jitter tolerance specification TBD at the output of the RXD line 10.0 µseconds following the end of the 80.0 µsecond hop period. So, after 90.0 µseconds from the time that the transceiver changes from one frequency channel to another, it must be capable of supplying data to the Data Transport Layer on the RXD line to the limits specified by the jitter tolerance.

7.4 Channel Energy Sense Requirement

Time required for a valid data bit to appear on the RXD line at the Data Transport Layer interface. This can be measured as the time delay from a signal entering either antenna port of the receiver until it is recovered at the output of the RXD line.

TRxd_D _ 4.0 µseconds.

The detection logic may sense any signal within the channel bandwidth. This signal may or may not have the same modulation characteristics as a desired signal, but the delay time through the receiver should be equal under all channel conditions. The time required for energy to build-up in the transceiver is an important parameter when making the diversity decision.

All of the above timing requirements have a direct effect on the network dead time and the overall network throughput and performance. Therefore, it is critical that these numbers be kept to a minimum.

7.5 Diversity Selection Requirement

The time required for the RF_PMD to perform the diversity decision and select the appropriate antenna for reception of the next data packet is related to the choice of the preamble length and the response time of the transceiver to changes in energy levels. This time is specified as follows:

TDiv _ 16.0 µseconds.

This time includes the energy build periods, sampling periods, switching periods, conversion periods, and comparison period associated with performing a diversity measurement. This time needs to be minimized to reduce the latency between selection of a receive path (i.e. antenna) and the time when data and clock recovery begins. This will have a direct effect on the preamble length and synchronization time.