On Amateur Radio Use of IEEE 802.11b Radio Local Area Networks

The following white paper on the use of IEEE 802.11b protocol has been published on the ARRL website. It is reprinted here courtesy of the authors.

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The 2400–2450 MHz band is not only an amateur allocation but also is used by other services. Primarily, it is an industrial, scientific, and medical (ISM) band with a center frequency of 2450 MHz. Other users of the band must accept any interference from ISM emitters. The amateur service has an allocation in this band that differs somewhat in various countries. In the United States, however, the amateur service has a secondary allocation in the 2400–2402 MHz segment, primary in 2402–2417 MHz, and secondary at 2417–2450 MHz. This band (actually a larger band of 2400–2483.5 MHz) is used by a number of unlicensed low-power devices, such as cordless telephones and radio local area networks (RLANs), which include IEEE 802.11b and Bluetooth. Quite often, the trade press mischaracterizes this band as "unlicensed spectrum," indicating perhaps that they are not aware of the amateur primary or secondary allocations. One other thing about amateur allocation status is that on petition from ARRL, the FCC has issued a Notice of Proposed Rule Making to upgrade the band 2400–2402 MHz to primary status.

This jumble of allocations and uses can be viewed as a glass half empty or half full. One view is that the FCC has loaded this band with so many applications as to make amateur operation very difficult. There are growing anecdotal stories that amateur systems, particularly amateur television repeaters operating in this band, are experiencing harmful interference from IEEE 802.11b devices. There is growing use of 802.11b in building and campus RLANs. The general experience is that RLANs inside buildings usually do not radiate much energy outside because of outer-wall attenuation. Even windows can attenuate the signal through application of sun-shielding film.

The Interference

The main interference from 802.11b to amateur systems seems to be the outside RLAN access points (APs). Most operate within the FCC Part 15 Rules, which may or may not be a problem to amateur systems, depending upon proximity, line-of-sight, and other factors. Those close by, perhaps with directional antennas bore-sighted toward an amateur station, are likely to be a problem. In addition, there are an increasing number of APs operating outside the Rules.

The FCC is aware of some of these high-power APs, and enforcement action is being considered. The ARRL has a program called Amateur Radio Interference Assessment (ARIA) that is trying to measure the noise level in the 2400–2450 MHz band (and others). However, this is a moving target and the situation could change dramatically in a year.

The Opportunity

IEEE 802.11b presents the amateur radio community with an opportunity to use the inexpensive RLAN cards for high-speed multimedia applications, including streaming television. While most prices presently hover around $100, some are available at about half that price. The APs, however, are more expensive by virtue of lower sales volumes, but they are available for several hundred dollars.

Frequencies

IEEE 802.11b channels are specified on center frequencies 5 MHz apart:

Channel	Center Freq. (MHz)	Comments
1	2412	These channels are
2	2417	used in the U.S. and
3	2422	other countries by
4	2427	802.11b devices.
5	2432	Their emissions fall
6	2437	within the 2400–2450 MHz amateur band
7	2442	These channels are
8	2447	used in the U.S. and
9	2452	other countries by
10	2457	802.11b devices, but
11	2462	cannot be used in the amateur service.
12	2467	Not used by 802.11
13	2472	in the U.S.
14	2484	Japan only.

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The existence of 14 channels does not mean that all are usable. In fact, the channel bandwidth is 22 MHz, or 11 MHz either side of the center frequency. Therefore, channel 1 occupies from 2401 to 2423 MHz. Furthermore, the receivers are such that there should be 25 MHz separation between channel centers, which are used in the same location. In practice, channels 1, 6, and 11 are the popular ones.

Channels 1 and 6 fall completely within the amateur band 2400–2450 MHz, and could be used by amateurs under Part 97 of the FCC Rules permitting spread-spectrum (SS) operation. In fact, amateurs are permitted up to 1 watt of transmitter power output without automatic power control (APC) and up to 100 watts if APC is used.

Band Plan

The existing (1991) ARRL band plan for the 13-cm band was not written with 802.11b in mind. Here are the existing band-plan segments:

2400–2403	Satellite
2403–2408	Satellite high-rate data
2408–2410	Satellite
2410–2413	FM repeaters (25 kHz spacing) output
2413–2418	High-rate data
2418–2430	Fast-scan TV
2430–2438	Satellite
2433–2438	Satellite high-rate data
2438–2450	Wideband FM, FSTV, FMTV, SS, experimental

It is not possible to pick an 802.11b channel within the 1 to 6 range without bumping into another use specified in the band plan. Bear in mind, however, that there may be some local variations. While operating within the applicable band plan is good practice, some flexibility exists. Generally, an amateur station operating in accordance with a band plan has some precedence over a station which is not operating according to the band plan. The main thing is to avoid harmful interference to users operating in accordance with the band plan. The ARRL Repeater Directory lists some, but not all, uses of the band. The local repeater coordinator should have additional information concerning who is doing what in order to avoid interference to existing users. Amateurs in Livingston County (MI) are in the process of planning what might be the first amateur 802.11b network. They are coordinating their experiments with the ARRL High Speed Multimedia Working Group (HSMM) and the Michigan Area Repeater Council (MARC).

Current plans call for using 802.11b channel 6 with a center frequency of 2437 MHz. This approach will place the 22 MHz spread-spectrum signal in what appears to be the most logical frequency for such testing. Approximately half the signal is in the experimental portion of the band (2438–2450 MHz) already designated for spread-spectrum use. The signal's other half is in the currently unused satellite sub-band (AMSAT-OSCAR 40 downlinks around 2401 MHz) and the 2.4 GHz fast-scan ATV sub-band.

If effective APC techniques can be developed, the experimenters plan to use RF output power in the range of 2–4 watts. With small dish antennas and helical beams, the experimenters hope to achieve throughputs in the range of 1–3 Mbit/s over a range of 10 miles or more.

Identification

An amateur station using 802.11b must identify periodically according to Part 97. Some have considered modification of the 802.11b protocol to map station callsigns into the frames in a manner similar to that used in AX.25.

At least for now, the simplest way is to identify in the text of the message so anyone with a normal 802.11b card can read the identities of the transmitting stations.

In the Livingston County amateur experimental high-speed network mentioned previously, identification will be callsigns typed in normal 802.11b text. Normal voice identification will use streaming audio. Normal ATV identification will be used for streaming video. If you would like more details on this experimental amateur high-speed multimedia network, please contact one of the authors.

Interoperation with Part 15 RLANs

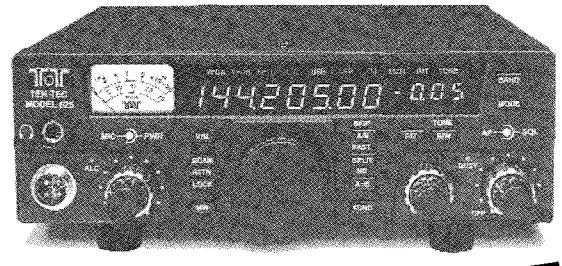
This is very sticky. Technically, an amateur station using 802.11b could interoperate with an RLAN operating under Part 15 rules. Communication, however, between FCC Parts is considered a "no-no." Nevertheless, it's possible for an amateur using the same 802.11b card to communicate with an RLAN under Part 15 of the Rules.

The problem is that a message received over a Part 15 link must be screened for permissible content before it can be introduced into a Part 97 link. However, a proper Part 97 message could be sent on a Part 15 link.

Confusing? The Rules were not written with any of this in mind.

Interference Issues

While the amateur services have primary and secondary allocations in the 2400–2450 MHz band, and while the Part 15 devices operating there without license must not interfere with



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Current FCC Regulations

FCC Part 97.311 Spread Spectrum Rules apply to 802.11b

97.311 SS emission types

(a) SS emission transmissions by an amateur station are authorized only for communications between points within areas where the amateur service is regulated by the FCC and between an area where the amateur service is regulated by the FCC and an amateur station in another country that permits such communications. SS emission transmissions must not be used for the purpose of obscuring the meaning of any communication.

(b) A station transmitting SS emissions must not cause harmful interference to stations employing other authorized emissions, and must accept all interference caused by stations employing other authorized modes.

(c) When deemed necessary by a District Director to assure compliance with this Part, a station licensee must:

(1) Cease SS emission transmissions;

(2) Restrict SS emission transmissions to the extent instructed; and

(3) Maintain a record, convertible to the original information (voice, test, image, etc.) of all spread spectrum communications transmitted.

(d) The transmitter power must not exceed 100 W under any circumstances.

If more than 1 W is used, automatic transmitter control shall limit output power to that which is required for the communication. This shall be determined by the use of the ratio, measured at the receiver, of the received energy per user data bit (Eb) to the sum of the received power spectral densities of noise (N0) and co-channel interference (I0). Average transmitter power over 1 W shall be automatically adjusted to maintain an Eb/(N0+I0) ratio of no more than 23 dB at the intended receiver.

or claim protection from licensed services, there is a problem.

The amateur licensee looks at the regulatory status and sees that there is no need to take Part 15 devices into account before transmitting. If interference from Part 15 devices is harmful, the amateur can report this to the FCC for enforcement action.

On the other hand, the Part 15 user just laid out $100 or so for the RLAN card and expects it to operate. He or she may not be happy that it doesn't work and may become convinced that the cause is interference from an amateur station.

Unfortunately, there are more of them than there are of us. A large number of complaints coming to Washington could be a problem and the outcome might not be what we want. Therefore, it pays to take this seriously and consider mitigation of interference to/from RLANs in any amateur network.

Best Practices

There is a need to develop a set of best practices in use of 802.11b in the amateur service. This paper touches on a number of considerations.

Recommended Additional Reading

Wireless LANs End to End, Bruce III, Walter R., and Gilster, Ron (Series Editor), Hungry Minds, Inc., 2002. ISBN: 0-7645-4888-3; <http://www.hungryminds.com/>.

Microwave Handbook, Volume 1, Components and Operating Techniques, Dixon, M.W., G3PFR (Editor), Radio Society of Great Britain, 1989. ISBN 0-900612-89-4; <http://www.arrl.org/>.

Also see: <http://www.qsl.net/kb9mwr/projects/wireless/plan.html>.

Corrections to EME Primer

by Bob Kocisko, K6PF

(Winter 2003 *CQ VHF*)

First, two minor corrections:

1. The FFTDSP display of S57TW's signal was labeled "(four 4-pol Yagis)" and should have read "(four x-pol Yagis)."

2. On page 22, it states that W5UN's TX/RX sequence sheet is included at the end of this article; it was inadvertently left out. Please go to W5UN's website <http://web.wt.net/~w5un/primer.htm#Seq> to download it.

The only major correction pertains to the examples I gave for using SKD 87 to set up skeds with I2FAK and W5UN during my moonrise, which starts on the bottom of page 20. The following is a correction to that text:

Let's look at an example of how K6PF, from his QTH, would use SKD 87 to determine when the best time would be to propose a sked with I2FAK, who uses 24 Yagis, and also with W5UN, who uses 32 Yagis. Assume, for the moment, that K6PF does not have elevation, and therefore is limited to operating only during his moonrise and moonset (say moon elevations between 0 and 12 degrees). Using any of the moon tracking programs mentioned, it is determined that conditions look very favorable on the weekdays of September 22 and 23, 2003, and that K6PF's moonrise on September 22 is at 0951 UTC and on September 23 it is at 1056 UTC. Be sure that your computer clock is set to UTC time when running these programs. These dates are chosen since degradation is very low (i.e., only 1.3 dB) and declination is reasonably high. Also, these dates are two to three days before new moon.

Since skeds usually start on either the hour or half-hour, SKD 87 shows us that a sked with I2FAK on September 22 at 1000 UTC will have good spatial polarity, and the moon's elevation during a 30-minute sked will be during K6PF's moonrise. SKD 87 also shows information about I2FAK, such as his sked frequency (144.061 MHz), his name, grid, equipment, e-mail address, etc. Similarly, a sked with W5UN on September 23 at 1100 UTC looks favorable on his sked frequency of 144.041 MHz.

Armed with this information, K6PF may then choose to e-mail both stations directly to propose a sked. For example, an e-mail to I2FAK might say:

Hello Franco. I'm just getting started on 2 meter EME and am running 180 watts to a single Yagi (12.5 dBd gain) with no elevation. I would like to propose a sked with you for September 22, 2003 during my moonrise starting at 1000 UTC and running for 30 minutes on 144.061. I2FAK to start with 2-minute sequences. Would you be available for this proposed sked?

73, Bob, K6PF

I hope this clarifies any confusion that may have occurred, and I hope that those of you who read the article found it informative.