Use of ISM Band for University Satellites

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Executive Summary

Due to the availability of new equipment in the ISM band, the FHSS type radios offer significant advantages or use in university satellites. Using this radio on a university nanosatellite at 800km altitude meets all of the requirements of Part 15. We therefore, request an operating frequency range approval from FCC for university satellite use in the total ISM band. This would also require a power limit waiver for the ground parabolic antenna for which an experimental license must be applied for.

Introduction

This document is to outline the use of the ISM (Instrument, Science and Medicine) radio band for the university CubeSat program. Much of this information was compiled by Amit Ganguli, a Stanford graduate student working on the MAST program.

The ISM radio was chosen because the radio technology from Microhard Corporation in Canada solved many of the challenges in using the amateur radio bands at VHF and UHF for previous university satellites.

Background

Previous university satellite designs have been limited to using amateur radio communications. This was advantages at the time because it offered a wide range of radio equipment at costs much less than commercial equipment and the world wide AMSAT organization members provided assistance in initial communications after launch. This worked well for the microsatellite programs where the satellites would were in the 20kg and 8-10 watt average power range using VHF and UHF frequency ranges.

The amateur satellite communications uses a data encoding scheme call AX.25. This is a special protocol for digital amateur use since in contained the provisions for each packet containing the sending and receiving amateur radio license call sign.

To do AX.25 communications requires not only the radio for sending and receiving but a terminal node control (TNC) at both the sending and receiving stations. The TNC is in between the computer generating or receiving digital data and the radio. The TNC is generally a separate piece of hardware with a microcontroller that takes data on an RS-232 serial line, converts it into the digital packet and modulates this data onto the radio to be sent by RF transmission. When the packet is received at the receiving end, the radio demodulates the signal and sends it to the TNC. Part of the TNC's tasks is to add a check sum when sending data and check the checksum when data is received. If the checksum on the incoming data is calculated correct, indicating the data packet is error free, the TNC on the receiving end will send a packet to the sending end to send the next packet. If the data received has an incorrect checksum the receiving TNC will request a resend of the packet from the sending TNC.

With the development of the CubeSat at 1kg and an average power of 1-2watts, the conventional amateur radio equipment became a bigger challenge to use since the TNC took additional space and power as well as that required for the radio.

In addition to the TNC, the use of CubeSats began to require data rates higher than the standard amateur rates of 1200 and 9600 baud.

Selection of Another Radio for CubeSats

During the development of the NarcisSat CubeSat in 2002 Kyle Doerksen ,an under graduate student on the radio design team, found the Microhard MHX-2400 radio which solved many of the problems encountered with the amateur radios.

Microhard Corporation in Canada makes the MHX-2400 works in S-Band (2GHz – 4GHz) and a second radio MHX-900 which works in the 900MHz band. The advantage of these radio designs are that they do not require a TNC, they can be interfaced directly with a simple RS-232 serial input/control, have dynamically changeable frequency channels and power level; effective data rate for using in a satellite of through put of ~ 40k baud; forward error correction; and are small and light weight. The cost/radio is ~ $650 for one watt output, which is comparable to the cost of the TNC and amateur frequency radios. The radios operate on a frequency hopping basis which allows the several radios on different channels to operate simultaneously.

The MHX-2400 was selected because of the high frequency and shorter wavelength than the VHF and UHF bands allowed for the use of patch antennas which can produce directional antenna gain. This radio operates in the ISM radio band = 2.4 -2.4835 GHz. The uses of radios in this ISM band do not require an FCC license if they are operated within the power restrictions. This power restriction limits the use of external amplifiers and gain antennas the limits the EIRP (effective isotropic radiated power).

The challenges of using the MHX-2400 for CubeSats is the maintaining the communications link with the lower power output of 1 watt and the data rate transfer rate of 115k baud. The transmission rate is 115k baud, but the expected data through put is expected to be ~40kb with error correction. To maintain an adequate link margin, the operations scheme now includes at 6m parabolic antenna for the ground station. Using the ground station with a 1 watt MHX-2400 transmitter will exceed the EIRP required for the ISM band. The use of this ground antenna will require operation only above a 12 degree elevation angle and getting a power waiver from the FCC.

Use of ISM Band Radios on University Satellites

The use of the ISM band for university satellites has not been formally approved by the FCC for use by the university community. E-mail communications has been initiated with Robert Nelson (robert.nelson@fcc.gov) at the FCC regarding this use.

The operational range of the MHX-2400 Radio is 2.400-2.4835 GHz. Note below in Table 1. there are other uses within this radio band than for ISM. ISM use is only designated as Primary from 2.417GHz to 2.4385GHz. The amateur radio band 2.400-2.450 GHz is designated as primary use with ISM secondary.

Freq. (GHz)	Designated Use
2.400 – 2.402	No Primary, Amateur Use, ISM (Secondary)
2.402 – 2.417	Amateur Use (Primary), ISM (Secondary)
2.417 – 2.450	ISM (Primary), Amateur Use, Government Radiolocation (Secondary)
2.450 – 2.4835	ISM (Primary)

Figure 1. Designated Use of Frequencies in S-Band

The MHX-2400 Microhard radio hopping pattern is shown below.

F. Hopping Patterns

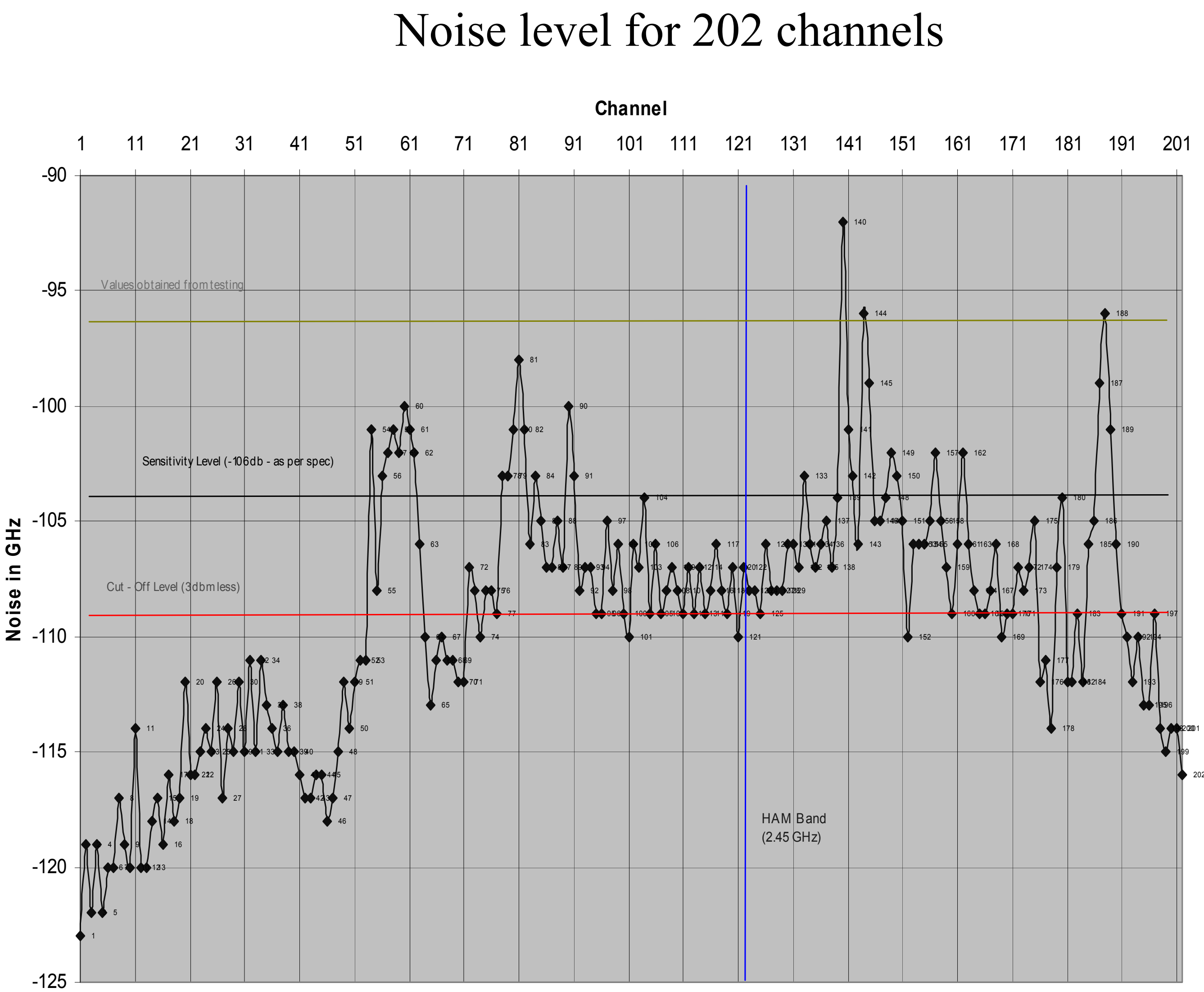
This Appendix provides a guide for selecting appropriate hopping patterns (S106,S206). There are 49 hopping patterns: Patterns have been designed to notch out certain segments of the ISM band.

Pattern Number	Spectrum Used
0 - 7	2.4012 - 2.4824 GHz
8 - 10	2.4012 - 2.4312 GHz
11 - 13	2.4052 - 2.4352 GHz
14 - 16	2.4092 - 2.4392 GHz
17 - 19	2.4132 - 2.4432 GHz
20 - 22	2.4172 - 2.4472 GHz
23 - 25	2.4212 - 2.4512 GHz
26 - 28	2.4252 - 2.4552 GHz
29 - 31	2.4292 - 2.4592 GHz
32 - 34	2.4332 - 2.4632 GHz
35 - 37	2.4372 - 2.4672 GHz
38 - 40	2.4412 - 2.4712 GHz
41 - 43	2.4452 - 2.4752 GHz
44 - 46	2.4492 - 2.4792 GHz
47 - 48	2.4520 - 2.4820 GHz

Patterns 44 to 48 may be manually edited by entering AT&H at the Command Line. Each pattern must use a channel only once, and must consist of exactly 76 channels. There are 202 channels available ranging from Channel 1 at 2.4016 GHz up to Channel 202 at 2.4820 GHz

Noise at Stanford in ISM Band

Noise measurements were taken with the 6m parabolic antenna at Stanford at one azimuth and elevation angles. This data shown below indicates that there the local noise is less at the lower channels that. Appropriate selection of operating patterns with channels will decrease the BER.



- Ideal channels over ISM: 1-53, 64-76, 191-202 (Limited to 4W EIRP)
- Ideal channels if restricted by HAM band – 1-53, 64-76, 100-122 (Limited to 1500W EIRP)

<u>University Licensing of MHX-2400 band for Student Satellites</u>

Request an operating frequency range approval from FCC for university satellite use in the total ISM band. This would also require a power limit waiver for the ground parabolic antenna.

Conclusions and Recommendations

The best possible licensing of the S-band frequency using the MHX-2400 radio is to get direct approval by the FCC for the full band.