1 Motivation

The motivation of the report is to demonstrate experiences gained by the group in designing the project. The report also serves as a mean to summarize unforeseen complications that the design team ran into and improvements that could be made to improve the project.

2 Experience Gained

Teamwork skills

One of the key objectives of the project was to improve team work skills of each member of the design team when working in conjunction with others on a complex problem. Through out the project, the team encountered various situations where members had differences in opinions. Each time, the team was able to resolve the difference in a logical and professional manner. Criticism from each member is also taken constructively.

Interpersonal skills

The team was able to increase its abilities to work with other parties involved in the design projects. These parties include groups that are interested in implementing the technology for future production, possible industry sponsors, department representatives and professors.

Research skills

Through out the project, the team had to constantly update its knowledge base in the area of wireless communications and RF. Apart from seeking information from classrooms the team also did extensive, addition research. Overall, the team improved its ability to analyze a problem logically and seek out resources that are relevant to the problem. This is an important skill because solutions to problems are not always presented clearly in the real world.

Planning / project management skills

Due to the size and the length of the project, the team had to implement a strict project time line to ensure the progress of each stages of the project. Overall, the major milestones of the project was met on time. Members of the team also constantly motivated each other to increase the efficiency of the team.

From the technology point of view, the team implemented a version control tool to back-up all progress of the project. This tool ensured the smooth operation of the team even when different members are working on the same part of the project while located in different geographical locations.

Technical skills

A major component of the design experience gained in this project relates to signal processing, specifically the design of the FSK modulator and demodulator. While fairly straightforward techniques were used for modulation, demodulation, and synchronization, actually implementing these algorithms in an efficient way for execution on a DSP is not as straightforward as simulating them in Matlab. The DSP supports only 16- and 32-bit fixed-point arithmetic in stead of the double-precision floating-point arithmetic used by Matlab. Numerical issues such as dynamic range and saturation or overflow conditions become important. Thus all signal processing routines were first developed in Matlab to create a working reference. The C version was then implemented, optimized, and tested against this working reference. Critical portions of the DSP code (particularly, discrete-time convolution) were implemented in assembly language for speed. Proceeding in this method greatly reduced bugs during system integration.

A second key aspect of the project was the partition of the design into independent layers with well-defined interfaces. The hardware components, device driver firmware, and modem firmware were all developed independently but in a chronologically overlapping fashion. By partitioning team member responsibilities along strict functional boundaries, a high degree of independence was possible. That is, blocks worked on by different team members were minimally coupled by design. This saved time and worked out well for everyone. This technique is scalable for use in both larger projects and larger teams.

3 Functional Requirement Change

There was only one minor change made in the original design specification that was used for the prototype's demonstration, namely the audio input/output signals' maximum amplitude level.

In the original design specification, it was stated that the audio output amplitude from the modem to the radio modules must be able to reach 0dBV, or $1V_{RMS}$. In the prototype testing checklist, the maximum audio output level was modified to -3dBV, or $0.70V_{RMS}$. The rationale behind this change was that excessive output voltage amplitude may cause audio signal distortion during radio transmission. As such, the team decided to decrease the maximum output amplitude from 0dBV to -3dBV.

Similar change was made on the input audio signal maximum amplitude, due to similar reasons. The original design specification stated that the modem must be able to tolerate a maximum of 0dBV input audio signal from the radio modules, whereas the prototype testing checklist stated that the modem needs to tolerate input level of -3dBV. Although the modem can well tolerate input level of over 0dBV by using an integrated voltage divider in the hardware or the programmable gain control in the audio codec IC, this change was made to ensure proper operation of the modem.

Since the above changes were made to correct an unreasonable specification that may affect the proper operation of the prototype, no further rectification was necessary.

4 Unforeseen Complications

Overall, there have been very few unforeseen complications due to careful research and planning. One problem encountered in the final stages of system integration of hardware and software was a lock-up of one of the serial ports after use for some time. Investigation and testing showed that it was due to how a certain hardware register was used and accessed by the firmware. Several hours were spent hunting for the problem as it only surfaced when both serial ports were active within a narrow time window of each other. The bug was narrowed down and fixed without further difficulty by creating test code that consistently reproduced the problem. This highlights the importance of *carefully* testing the assumptions that are implicit in the design of critical code for things like interrupt handlers and firmware drivers. Assuming design assumptions are correct without verification almost always yields more wasted time later.

5 Design Novelty

While the use of voice-band modems over radio links is definitely not new, the use of a fully self-contained software-defined modem for this application is less common. A very traditional modulation scheme was used for the initial design (4-FSK). However, much work could be done to improve this, choosing a scheme more optimal in a performance sense (but much more complex in an implementation sense). Voice-band modems have traditionally played a large role in the amateur radio community, and design has usually been limited to the simple, tried-and-true techniques. By taking a new approach with performance in view from the ground up, a truly unique modem could be built upon the platform that has been developed here.

6 Margin over Requirements

The two metrics set out in the project specification for measuring the modem performance were both exceeded. The requirements called for a net data rate of 100 bits/second and an error rate of no greater than 1 in 1000 with the ratio of bit energy to noise power density (Eb/No) at 15 dB. The final design delivered a net bit rate of 200 bits/second and an error performance within spec near an Eb/No of 8 dB or less. The performance metrics were purposely conservative due to the many unknowns (including radio performance) at the outset. It was decided that it was more important to make goals that could be achieved than to over promise and under deliver. The final report will contain a more complete analysis of the modem's performance.

7 Future Research and Development

The design team realizes that the technology chosen to implement the modem is not optimal in a performance sense. However, design decisions arrived after discussing trade-off between ease of implementation and the performance specifications. The team decided to use technologies that are well defined and documented and allow a pleasant learning experience. Future research to turn this prototype into a product includes: small board design (exclude all debugging hardware), faster modulating and demodulating scheme, packeting design, and more advanced error checking mechanism. A mobile, renewable power supply needs to be considered as well.

8 Possible Enhancements

If the project was redesigned, the team will aim to make a smaller, faster modem that is more reliable. These enhancements can be achieved by implementing more advanced modulating/demodulating schemes, as well as more sophisticated flow control mechanisms.