

4. Particulars of Operation

F: Modulation Type

Pico Communications, Inc. plans to develop radios that emit signals according to the Bluetooth Specification version 1.1. The Specification calls for a frequency hopping signal in accordance with the requirements of Section 15.247 of FCC regulations. The hop channel center frequencies are $2402 + N$ MHz, where N ranges from 0 to 78. The nominal hopping rate is 1600 hops / second, and the hopping sequence is pseudo-random, such that on the average the signal spends an equal amount of time at each frequency. The maximum transmitted power level is +20 dBm peak.

Data modulation on the Bluetooth signal is binary FSK with Gaussian pulse shaping. The frequency deviation is ± 175 kHz maximum, and the on-air data rate is 1 Mbit/sec. Exclusive of hopping, the 20 dB bandwidth of this signal is less than 1 MHz.

G. Necessary Bandwidth

Necessary Bandwidth is computed as the bandwidth per hop channel times $N+1$, where N is the total number of hop channels. Then

$$B_n = (79 + 1) 1\text{MHz} = 79\text{MHz}.$$

10a. Program of Research and Experimentation

The proposed program has the purpose of developing radio hardware for commercial applications under the Bluetooth specification. Bluetooth is an industry standard for short-range 2-way communication using Frequency Hopped Spread Spectrum (FHSS) signals in the Industrial, Scientific and Medical band (2400 to 2483 MHz). The hardware to be developed is of two types. First, hardware will be developed for radio network base stations. The base station design will have maximum range and sensitivity, consistent with FCC regulations and the Bluetooth specification. Second, hardware will be developed for radio modules, easily integrated into various portable electronic devices. The module design will have low cost and moderate performance, consistent with FCC regulations and the Bluetooth specification.

The program of research anticipates development of base stations and modules in various physical formats. Base stations will normally be stand-alone, while modules might be in the form of PCMCIA cards, small surface-mount PC boards or Multi-Chip Modules (MCMs). The exact formats will be dictated by customer needs and requests.

Development Process

A typical product development program would proceed as follows. Following an initial product concept and definition phase, hardware prototypes are designed and produced. These are tested for basic functionality and for proof-of-concept of any new hardware features. Prototypes are used as development platforms for any system software which might be required. Approximate timing of the prototype phase is three to six months.

Following the prototypes, Alpha hardware is designed and built. Every attempt is made to make the Alpha hardware identical to the final product. Testing of the Alpha hardware typically includes testing for compliance with FCC regulations and with critical items of the Bluetooth specification. However the application for FCC approval is not submitted until the pilot phase, described below. Approximate timing of the Alpha phase is two to five months.

Following Alpha, Beta phase hardware is designed and built. Beta hardware incorporates any required changes determined during the Alpha phase or by any perceived changes in marketing requirements. The Beta hardware must have all the desired behavior of the final product. If not, iterations of the Beta design are performed until all the desired behavior is obtained. Beta testing typically includes testing for FCC compliance and testing for a large portion of Bluetooth requirements. Approximate timing of the Beta phase is four to six months.

Following Beta, minor changes for producibility are allowed in designing the production product. These changes are validated during a pilot production run. Pilot hardware undergoes FCC compliance testing and full testing for Bluetooth compliance. The FCC

testing is conducted at an FCC-approved facility. Following receipt of FCC approval and registration as a Bluetooth qualified product, the design enters full production and commercial sales.

Equipment

In each case the radio equipment will consist of a 3rd party chipset for Bluetooth radio, plus additions designed by Pico Communications. Figure 1 is a block diagram of the proposed base station radio architecture. The Bluetooth chipset in the figure consists of an RF IC, a baseband controller IC, and a baseband processor IC. The chipset provides the functions of frequency hopping, modulation and demodulation of the FSK data, data packet formatting and timing for half-duplex transmit and receive.

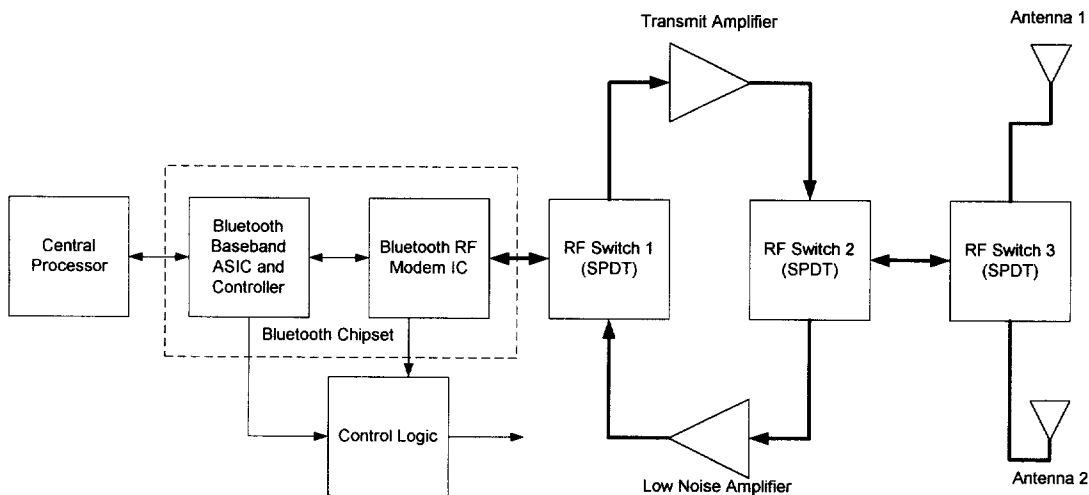


Figure 1: Block diagram of base station radio. Bold lines are RF signal paths.

External to the chipset are a low-noise amplifier IC for better receive sensitivity and a 100mW RF power amplifier IC for increased transmit power. RF switches 1 and 2 are used to multiplex these ICs onto the RF path for half-duplex communication. Signals from the Control ASIC coordinate the states of the switches and control the dc bias to the power amplifier and LNA ICs. The two antennas are used to provide spatial diversity. RF Switch 3 chooses between the antennas based on signals from the control logic.

Figure 2 is a block diagram of the proposed radio module. This is a simpler radio than the base station, consisting primarily of a 2-piece chipset. Logic external to the chipset creates the proper control signals for an LNA/PA/Switch combination similar to that of the base station. This allows users of the module an easy path to integration of higher performance, if desired.

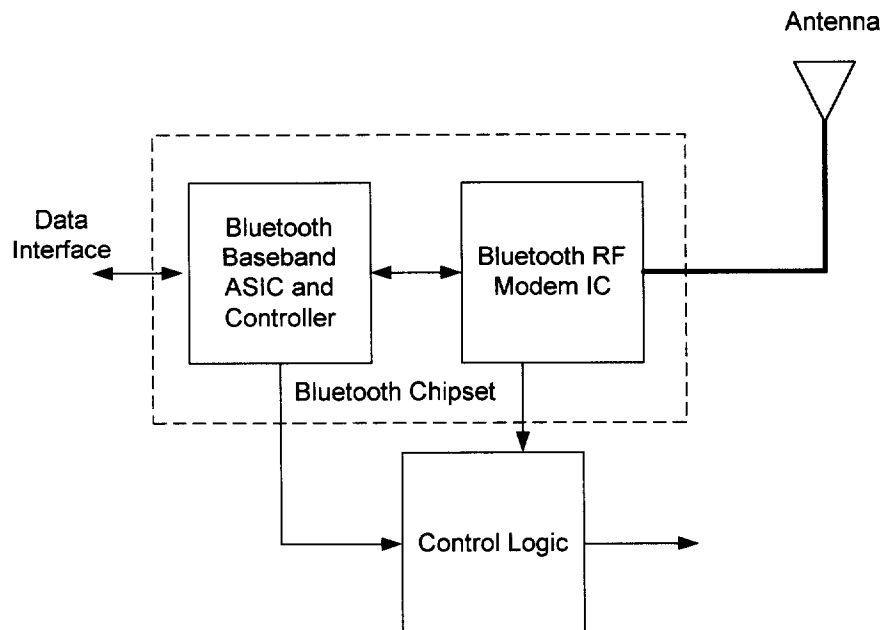


Figure 2: Block diagram of radio module.

Theory of Operation

The radio hardware to be developed will operate as short-range, half-duplex transceivers under the Bluetooth Specification. The Specification calls for frequency-hopped spread-spectrum in the ISM band (2400 to 2483 MHz). Bluetooth data modulation is binary Frequency Shift Keying (FSK).

Bluetooth Modem

In the proposed products, Bluetooth modem functionality is provided by the Bluetooth chipset. Bluetooth operation is based on the use of time slots with a duration of 625 microseconds. Data packets can have a duration of 1, 3 or 5 slots, and the on-air data rate is 1 Mbit/sec. In each Bluetooth link, one radio acts as master and one as slave. The master dictates time-division duplex timing and the hopping sequence. Packets transmitted from the master always begin in odd-numbered time slots, while slave transmissions always begin in even time slots. The master generates a pseudo-random hopping sequence, extending across 78 channels with 1 MHz channel spacing. Master and slave hop together, with a nominal rate of 1 hop per time slot (i.e. 1.6 kHz). A single master can control up to seven slaves, all hopping together and sharing the RF channel on the basis of Time Division Multiple Access.

Added Hardware

In the base station, hardware is added to the Bluetooth chipset in order to improve the RF performance. An external LNA reduces the receive noise figure, and an external power amplifier boosts the chipset's output power (nominally 0 dBm) to a maximum of +20 dBm. SPDT RF switches are used to multiplex between the LNA and the power amplifier.

In addition, the baseband design provides for spatial diversity of the signal path using two antennas. A third RF switch chooses between the antennas, independent of the transmit/receive multiplexing.

Other added hardware controls the DC bias for the power amplifier, the LNA and their associated RF switches. Because the system is half duplex, the bias states for the added hardware must synchronize with the transmit and receive states of the Bluetooth chipset. Synchronization is achieved by using signals from the internal interfaces of the chipset to drive the bias control circuitry.

The remainder of the base station hardware is a central processor assembly. This executes the higher layers of the Bluetooth protocol stack, as well as functions specific to Pico's product objectives. The assembly also includes circuitry for power supply, communication ports and memory for programs and data.

In the module, the Bluetooth chipset is integrated into a single assembly, but with no more added hardware than necessary. Depending on the application and the features of the chipset, the added hardware might include power conditioning, communication ports and logic to create appropriate signals for driving an external power amplifier/LNA/switch combination.

10b. Specific Objectives

The objective of this program is to develop certain commercial products for Bluetooth applications. The products will be radio base stations allowing connection to the Internet, or they will be Bluetooth radio modules facilitating easy integration of Bluetooth functionality into commercial electronic devices. Each product will meet all applicable requirements of the FCC regulations and the Bluetooth specification.

10c. Contribution to the Radio Art

These products will facilitate use of the radio spectrum in the 2.4 GHz Industrial, Scientific and Medical band for purposes benefitting businesses and consumers.