LOW-COST TELEMETRY USING FREQUENCY HOPPING AND THE TRF6900™ TRANSCEIVER

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ABSTRACT

The ISM bands have opened up new opportunities for telemetry using spread-spectrum communications. A low-cost frequency-hopping radio is described here for the 900 MHz ISM band that can be programmed with a wide range of hop and data rates. The ‘C6201 DSP from TI is used to control the frequency and data rate of the TI TRF6900 transceiver chip using a custom interface of the 6201 EVM board to the serial I/O on the 6900 evaluation board.

KEY WORDS

Frequency Hopping (FH) Telemetry, Mixed-Signal RF, Programmable DSP, and Software Defined Radio.

INTRODUCTION

The ISM bands (at 900 MHz, 2.4 GHz, and 5.7 GHz) have opened up new possibilities for unlicensed wireless communication, and specifically low-cost telemetry. However, existing ISM band protocols (e.g. 802.11x) are optimized for wireless LANs, and not necessarily telemetry. Here, a fully programmable frequency-hopping telemetry transceiver is proposed, that allows implementation of non-IP based protocols, such as ATM, as well as application-specific hopping and data rates. Unlike existing 802.11a/b networks, the programmable FH radio described here is not tied to any specific medium access controller (MAC). A user-defined MAC can be programmed in the ‘C6201 EVM board.

In order to develop new protocols we are constructing a test-bed using TI’s ‘C6201™ fixed-point DSP controlling the TRF6900 900 MHz FSK transceiver chip. The chips are interfaced with the DMA bus and the McBSP connectors that are provided for a daughterboard addition to the

1 This project was supported in part by The International Foundation for Telemetering.
C6201EVM. The TRF6900 is currently set up for a Frequency Hopping (FH) scheme using FSK, but with only two hopping frequencies (see Figure 1.) We are developing slow FH with continuous programming of the TRF6900 in the full duration of data transmission. FH is an excellent candidate for low-cost telemetry in that it has anti-multipath, anti-jamming, and multiple access capabilities. The software control of the TRF6900 chip allows for adaptive control of the MAC and transmission parameters in order to adjust for varying operating conditions.

An access point (AP) is also under construction that can communicate with the 6201/6900-based radios. The AP consists of a computer connected to a VME-cage with the 4291 quad processing board from Pentek. Connected to this board is the 6216 A/D and 6229 D/A from Pentek, and for the up- and down-conversion from IF to the ISM band we use the Analog Devices 6190 board (see Figure 2.)
RESEARCH APPLICATIONS

Direct-sequence and frequency-hopping are the two most common types of spread-spectrum modulation [6]. In FH the transmit center frequency is varied according to an assigned pseudorandom sequence and CDMA (Code Division Multiple Access) can be achieved by assigning individual codes to each user. Direct-sequence systems multiply a narrowband data stream by a wideband pseudo-noise binary sequence, and unlike FH, transmit using the entire frequency band instantaneously. However, DS systems have more demanding synchronization requirements than equivalent FH systems, and are in particular sensitive to the near-far effect [6]. Existing 802.11a/b radios do not take advantage of spreading but use orthogonal frequency-division multiplexing (OFDM) and (code complementary keying) CCK. For example, 802.11b systems use a one-sided bandwidth of 11 MHz and transmit at a data rate of 11 mbps, and thus do not employ any excess bandwidth. In order to avoid collisions, 802.11a/b systems must rely on CSMA (Carrier-Sense Multiple Access) /CA (Collision Avoidance) or RTS/CTS (request-to-send/clear-to-send) [4] which adds additional overhead to the data packets. In this respect FH might be more efficient in terms of minimizing latency and increasing throughput. This is a topic that will be investigated using the UCSB testbed.

TEST BED

The test bed consists of two wireless nodes and one base station. The nodes can transmit and receive data at a maximum rate of 115kbps [7] limited by the TRF6900 chip using a FSK/FH scheme. The base station A/D converter has a 30 MHz bandwidth, and hence can digitize and downconvert the entire 2.4 GHz ISM band.

MOBILE NODES

The wireless node consists of a TRF6900 FSK radio [1] that is controlled by a ‘C6201 DSP device. The TRF6900 allows programming of two hopping frequencies at any point in time, called Mode0 and Mode1. Switching between these two modes is easily done by toggling one of the control signals. There are four registers that hold information about the operating mode in the TRF6900. In order to do slow frequency hopping between more than two frequencies these control words must be programmed accordingly. The registers also control the frequency deviation for FSK and which components are activated in the RF chip.

![Intermediate PCB Diagram](image-url)

Figure 3
The interface between the ‘C6201EVM and the TRF6900EVK is done via respectively the two McBSP ports [9] and the 14 pin [8] connector. (See Fig. 3 and Table 1.) An intermediary PCB board with an 80 pin header is connected directly to the ‘C6201EVM from which a cable is connected to the 14 pin serial/control input on the TRF6900EVK. In the ‘C6201 chip any FH protocol can be programmed to control the operation of the TRF6900 and ultimately interfaced with an application running on the host computer. Communication between the host computer and the ‘C6201 is done using the RTDX™ (Real-Time Data Exchange) utility in Code Composer Studio™ and a OLE capable program [5] running on the host processor.

The following table shows the 14 pin layout on the TRF6900 and mapping to the ‘C6201 EVM McBSP interface.

<table>
<thead>
<tr>
<th>Pin on TRF6900</th>
<th>Pin on C6201</th>
<th>Description TRF6900</th>
<th>Description C6201</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>Vcc (Positive 3V) (out)</td>
<td>Not using</td>
</tr>
<tr>
<td>2</td>
<td>41</td>
<td>STROBE, serial programming (in)</td>
<td>XFSR1</td>
</tr>
<tr>
<td>3</td>
<td>39</td>
<td>CLK, serial programming (in)</td>
<td>XCLKR1</td>
</tr>
<tr>
<td>4</td>
<td>33</td>
<td>DATA, serial programming (in)</td>
<td>XCLKX1</td>
</tr>
<tr>
<td>5</td>
<td>35</td>
<td>MODE between mode 0 and 1 (in)</td>
<td>XFSX1</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>NC</td>
<td>Not using</td>
</tr>
<tr>
<td>7</td>
<td>36</td>
<td>STANDBY (in)</td>
<td>XDX1</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>NC</td>
<td>Not using</td>
</tr>
<tr>
<td>9</td>
<td>24</td>
<td>TX_DATA transmission data (in)</td>
<td>XDX0</td>
</tr>
<tr>
<td>10</td>
<td>42</td>
<td>LOCKDETECT (out)</td>
<td>XDR1</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>RSSI_OUT (analog out)</td>
<td>Not using</td>
</tr>
<tr>
<td>12</td>
<td>30</td>
<td>RX_DATA data slicer output (out)</td>
<td>XDR0</td>
</tr>
<tr>
<td>13</td>
<td></td>
<td>AMP_OUT post detection out amp out (analog out)</td>
<td>Not using</td>
</tr>
<tr>
<td>14</td>
<td>26</td>
<td>GND (in/out)</td>
<td>GND</td>
</tr>
</tbody>
</table>

THE BASE STATION

The base station consists of a VME-cage with the 4291 quad processing board from Pentek with four TI ‘C6701 DSP processors interconnected via BI-FIFOs. Connected to the board is the 6216 A/D and 6229 D/A from Pentek, and for the up- and down-conversion from IF to the ISM band we use the Analog Devices 6190 board (see Figure 2.) Once the data is captured on the 6216 A/D it is transmitted to the DSPs using the DMA bus, where the data is filtered and processed.

SYNCHRONIZATION AND PACKAGING ISSUES

In the MSP430-TRF6900EVK [3] synchronization is achieved by first transmitting a training sequence of alternating zeros and ones, a process that takes about 1ms, then the data packet of 32
bytes is sent, equivalent to a duration of about 7ms. The MSP430 continuously samples the output data signal from the TRF6900 and keeps track of the time between the pulse edges with a counter. When more than eight consecutive pulses have been detected the training sequence is considered detected and the MSP430 starts looking for the start bit. The start bit is three times the pulse width of the training sequence and at the end of the start bit the actual data transmission begins including CRC (Cyclic Redundancy Code) error correction code.

In the test bed described above alternative synchronization techniques can be tested and FH can be implemented by toggling the mode control signal or reprogramming the transmit frequency. Adaptive and continuous synchronization can be done in the full duration of the data transmission to account for varying noise and interference levels in the different frequency channels and while each data package is being sent. 53 byte ATM cells can be transmitted instead of the 32 byte packages in the MSP430-TRF6900EVK.

**CONCLUSION**

The test bed described here implements a general-purpose frequency-hopping based telemetry network. The mobile radios are programmable with arbitrary hopping and data rates, as well as custom MAC protocols. Applications such as wireless internet access and web-based telemetry can potentially be demonstrated using the 4291-based access point.

**REFERENCE**


