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Pentek, Inc.
One Park Way, Upper Saddle River, NJ 07458
Tel: (201) 818-5900 • Fax: (201) 818-5904
email: pipeline@pentek.com
http://www.pentek.com

AT&T Labs-Research Conducts More Studies in Cellular Communications

The previous issue of The Pentek Pipeline presented the results of some experimental work at AT&T Labs aimed at improving cellular communications in an indoor environment. We discussed how preselection diversity* improved the reception in an environment which is susceptible to slow fading. Measured improvements in signal level amounted to 9 dB, which closely agrees with the theoretically predicted improvement of 10 dB.

In this issue we will cover the results of further experimental studies using an indoor digital communications system designed as an extension of IS-136, the North American standard for cellular communications. The current IS-136 standard provides wide-area wireless access with 8 kbits/sec end user data rate. The system provides good speech quality due to the advanced speech coding employed.

With indoor wireless systems, there is a demand for even higher speech quality and more robust communications, comparable to the present wired systems, while still adhering to cost, size and power consumption constraints. To address these considerations, a system was designed to achieve twice the effective bit rate of IS-136 for transmission of high-quality coded speech and various antenna diversity options were investigated.

IS-136 Standard

IS-136 uses a 6-slot TDMA (Time Division Multiple Access) protocol with 40 msec frames as shown in Figure 1. During each frame, a user is allocated two evenly spaced uplink and downlink slots. Each slot contains 162 symbols: 130 of these are for user data and the remainder for synchronization, signaling and control. IS-136 uses π/4-DQPSK (Differential Quadrature Phase Shift Keying) modulation. As a result, every 20 msec 260 channel bits or 13 kbits/sec are available for user data. Channel coding reduces this number considerably, so the IS-136 coder provides about 8 kbits/sec end user rate.

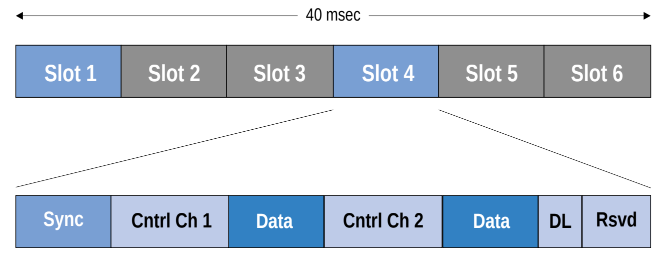

Figure 1. IS-136 Downlink Frame Structure

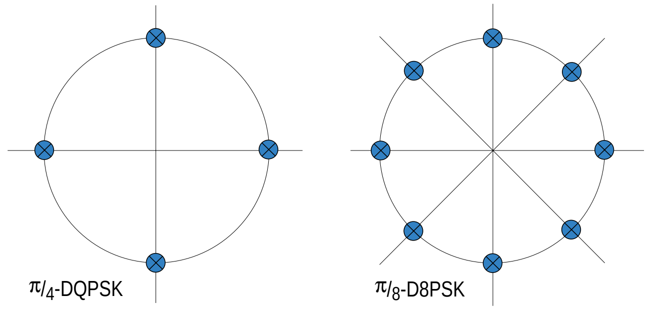

Figure 2. Constellation Diagrams (after demodulation)

Enhanced IS-136 System

The enhanced AT&T Labs system uses π/8-D8PSK (Differential Eight Phase Shift Keying) for the data symbols, while the overhead symbols are transmitted in the original format. This scheme provides 390 channel bits per slot for an uncoded capacity of 19.5 kbits/sec. A forward error correction speech coder reduces this to 16 kbits/sec end user rate. Figure 2 shows phasor diagrams of the two modulation schemes, also known as constellation diagrams.

Size, power and cost constraints for the handset are the most demanding characteristics of the system design. The choice of π/8-D8PSK modulation reduced link margin by several dB. To make up the difference, various antenna diversity options were investigated. The preselection diversity scheme that was used in the previous Pipeline article was employed again. For the uplink, where size, power and cost constraints are not as stringent, other signal enhancement methods were subsequently investigated.

Signal Processing

The downlink portion of the enhanced IS-136 system is implemented with the general-purpose VME-based signal processing platform shown in the block diagram of Figure 3. The major hardware components include:

- 900 MHz transceiver
- Custom interface circuitry
- A/D converters and 'C40 DSP processors from Pentek

A modified handset with two antennas was used for preselection diversity. Major system components were partitioned into the separate DSPs of the Pentek 4270 Quad DSP processor and

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* Preselection diversity improves reception quality by utilizing two or more antennas at the receiver.

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the Pentek 4257 Dual ’C40 coprocessor for ease of implementation and flexibility. Functions allocated to different DSPs include:

- Speech coding
- Transmit channel coding, modulation and filtering
- Receive filtering, synchronization and demodulation
- Receive channel decoding
- Speech decoding

In addition, system control and monitoring, (e.g. constellation display and user interface to control system parameters) are performed by a separate DSP. This modularity allows for the easy investigation of different speech coding algorithms and channel coding techniques.

The custom interface circuitry provides most of the functions needed in a product implementation of the enhanced IS-136 system. Additional functions needed to measure the performance of the experimental system are also included. These functions include:

- Audio and baseband I/Q signal anti-aliasing and reconstruction filtering
- Transmitter modulation, upconversion, RF filtering and power amplification
- Receiver RF filtering, amplification, downconversion and demodulation to I/Q signals

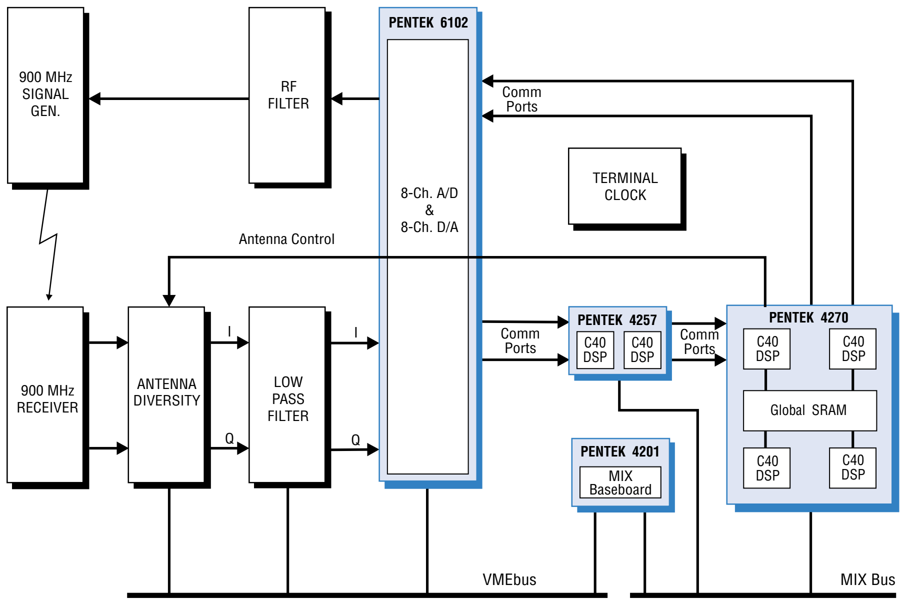

Figure 3. Signal Processing Downlink System Block Diagram

- Antenna control for diversity experiments
- Clock generation and control

The downlink design dominated system development. Once it was fully operational, implementation of the uplink system was fairly straightforward.

“Having made the choice of a signal processing platform, we looked into the development tools available for use on that platform. Experience on a prior project showed that we could expect very good performance from a C compiler optimized for the instruction set of the DSP,” said Bruce McNair, Principal Technical Staff Member of the Wireless Systems Research Department at AT&T Labs in Red Bank, NJ. “Breaking down the different project functions, such as filtering, speech and channel coding, and assigning them to individual DSPs, allowed us to address each one separately and optimize performance without reprogramming other parts of the system,” he added.

Results

Over-the-air demonstrations are the most effective way to show the performance of a wireless communications system. While they were used extensively in the course of this project, it was difficult to quantify results or to compare systems with different parameters. Precise SNRs, fading rates and other channel conditions cannot be reliably replicated. For this reason, all the performance evaluations and measurements were conducted over simulated RF channels using a RF impairment simulator and a commercial frequency synthesizer as the LO.

As shown in Figure 4, the fader provides two independently fading

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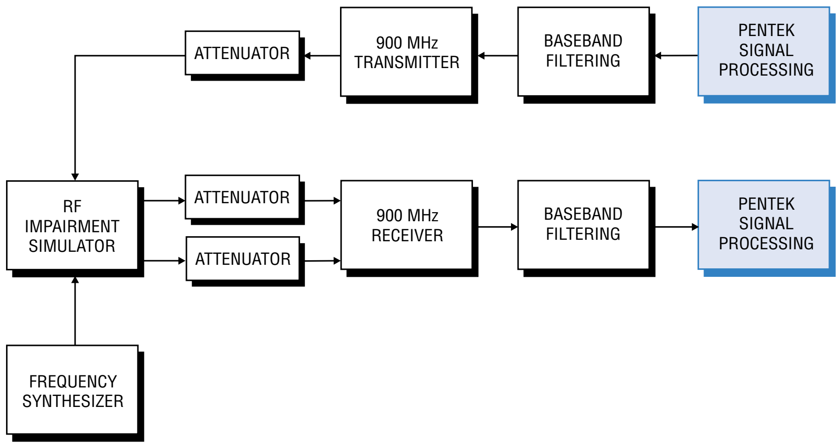


Figure 4. Hardware Configuration for Measurements

Wideband Digital Receiver and Parallel Digital I/O

[Continued from page 4]

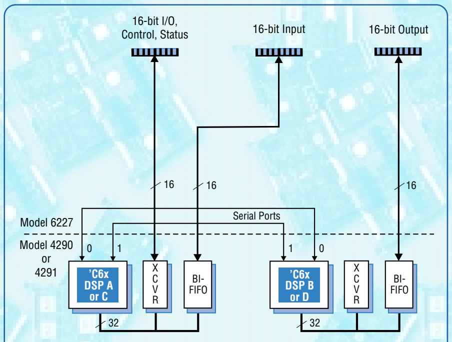
The output section delivers direct I and Q complex outputs to the mezzanine FIFO of the ’C6x DSP board.

The **Model 6227** Parallel Digital I/O VIM-2 Module serves as a general purpose digital interface for the Texas Instruments TMS320C6x processors, providing two high-speed parallel data ports plus a third control/status port. This flexible module is ideal for connecting to a wide range of digital peripherals.

Two Model 6227s may be attached to the quad processor board, nesting in the same VMEbus slot. Alternately, the Model 6227 may be combined with any other VIM-2 module to provide additional I/O functions.

The two high-speed streaming input data ports are 16-bit parallel data buses using single-ended TTL lines. One port is dedicated as an input and the second as an output. Maximum clock rates for both streaming ports are 5 MHz, supporting 16-bit transfers of 100 MB/sec.

For more information on these or any other Pentek products call us at 201-818-5900 ext. 609 or visit our website at **www.pentek.com.** ❑



Model 6227 Block Diagram

Editor’s Note

It was exactly seven years ago, in the summer of 1992, when the first Pentek Pipeline was published.

This issue marks the beginning of a new era. Starting with this issue, the Pipeline will provide you with the same great technical depth and application articles with a brand new “colorful” look. Hope you’ll like this new style.

More Prize Winners

Ralf Rose of Fraunhofer EADQ in Dresden is our second winner of a $400 Hewlett Packard digital camera. Ralf got lucky by just visiting our web site **www.pentek.com** and registering while there. We wish Ralf good luck and many hours of fun with his new hobby.

You too can participate in a future drawing by visiting our web site. ❑

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channels that can be used to alter the 900 MHz RF signals generated by the transmitter. The downlink receiver selects between these two channels.

Using the setup of Figure 4, it was found that coding improves results by 5 dB, while diversity gives a 10 dB improvement. When these two are used together, i.e. coding plus diversity, a 14 dB improvement can be expected. In order to maintain a frame error rate (FER) of 1%, a SNR of 34 dB is required in an environment with fading at the rate of 1 Hz without coding or diversity. When coding and diversity are used together, a FER of 1% can be maintained with a SNR of only 20 dB.

Figure 5 is a photograph of part of the system in action at AT&T Labs. Pictured are the VME components and two X-Y displays showing the transmitter and receiver constellations.

Epilogue

In order to address operation in outdoor cellular environments, the scope of this project was subsequently expanded by adding a complete uplink to the enhanced downlink IS-136 system.

In addition to preselection diversity, other signal enhancement methods, such as coherent detection, were investigated. Some of the results indicate that preselection diversity provides comparable improvements, while coherent detection only offers an improvement of 2 dB.

Again, the same signal processing system from Pentek was used. The system, chosen five years ago, will now be used in upcoming smart antenna and high-speed wireless data networks studies. ’C6x boards from Pentek provide a growth path for future work. ❑

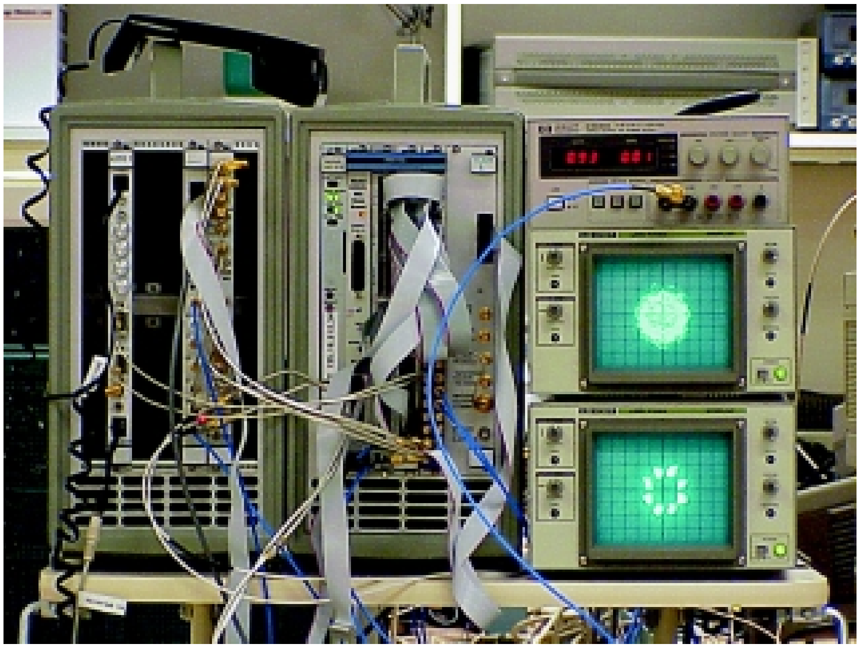

Figure 5. Signal Processing System (Courtesy of AT&T Labs)

The Pentek Pipeline

Product Focus

Models 6216, 6227

Wideband Digital Receiver and Parallel Digital I/O

New Additions to VIM Lineup Join Pentek's 'C6x I/O Peripherals Line

The **Model 6216** is a dual amplifier, A/D converter and wideband digital receiver VIM-2 module which attaches directly to the Pentek Models 4290 and 4291 Quad 'C6x DSP boards. It features two complete channels of signal processing and is ideally suited to HF software radio applications.

Each channel includes a wideband input amplifier followed by a programmable gain amplifier for HF analog inputs with bandwidths up to 30 MHz. Analog inputs are accepted through front panel SMA connectors.

An anti-aliasing filter removes out-of-band frequency components and can be tailored for specific signal types. The standard filter has a cutoff frequency of 25 MHz.

Each channel employs a 12-bit A/D converter capable of operating at up to 65 MHz sampling. The A/D sample clock is derived either from an external reference supplied to a front panel SMA connector or an internal 64 MHz crystal oscillator. The converters are Analog Devices type AD6640.

Both A/D converters operate synchronously from the same sampling clock to support multichannel applications, such as in direction finding, where phase between channels must be maintained.

The digitized output of each A/D converter feeds the Graychip GC1012 programmable downconverter. This device is designed for wideband output operation with decimation values ranging from 2 to 64 for output bandwidths as high as 25 MHz.

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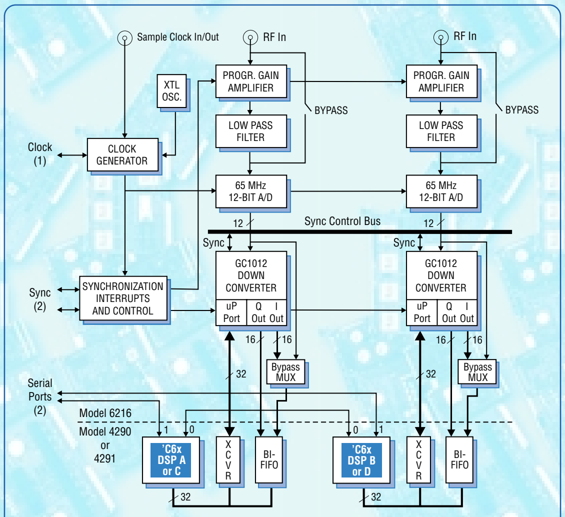

Model 6216 Block Diagram

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