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Building Wireless Communications & Broadcast Systems with the HERON Range

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Introduction

Wireless communications is being revolutionised by new high performance signal processing systems. Many system building blocks can now be built using digital technology, bringing new levels of manufacturability, reliability and performance – usually at reduced cost. Using technologies like the TMS320C6000 range from Texas Instruments, the Xilinx reconfigurable devices, or the current state of the art in ADC and DAC converters allows designers to view their system in a whole new way.

The HERON modular DSP range offers the developer quick and easy access to these new technologies. Using HERON, it is possible to build and deploy a system very rapidly – usually without hardware development. Of course, a HERON system, based on standard buses like PCI, is not ideal for deployment inside miniaturised mobile equipment like handsets – but it is very suitable for concept demonstration. For many other systems it is also ideal for deployment – in fields such as infrastructure testing, electronic surveillance / intelligence, satellite communications and many more.

In this document we look at the possibilities of these new technologies, and see how these systems can be implemented using HERON.

The Basics

All wireless communications systems have one thing in common – they are built to carry a signal from one place to another. This signal may be analog, as in the case of an FM radio station; or it may be digital, in the case of computer-computer applications, such as wireless LAN or Bluetooth. In the middle are digital systems carrying analog signals – such as the mobile phone networks. In these cases, the audio signal is digitized before transmission. It is often also compressed (in a vocoder), reducing the amount of data that must be sent.

The signal cannot be transmitted directly – it must be modulated onto some sort of carrier. This modulation typically shifts the frequency of the signal upwards – for example, a typical FM radio station has a signal bandwidth of a few KHz, while it is probably transmitted at 90-100MHz. A GSM mobile phone has an audio signal bandwidth of around 3KHz, while it is usually transmitted at 900MHz.

The modulation is performed by changing some aspect of the carrier – typically phase, frequency or amplitude. In many cases a quadrature carrier is used – for example, in QAM, or Quadrature Amplitude Modulation, the two phases of a quadrature carrier are amplitude modulated.

Many systems support only simplex communication – as in broadcast, where there is no ability for a listener to transmit data back to a radio station. Full duplex communication is usually achieved by replicating the transmitter and receiver of the simplex system on different frequencies – giving a forward and reverse channel, each with its own transmitter and receiver. Of course, half-duplex allows the same spectrum to be re-used for the forward and reverse channels.

Multiple access systems create additional problems, where many transmitters try to use the same bandwidth. This is typical of the mobile phone world. Most mobile phone systems use multiple carrier frequencies, and allow handsets to transmit for only short bursts at a time – allowing the carrier to be allocated to another user. Of these, CDMA is perhaps the most complex – using a semi-random carrier to transmit signals over a wide frequency band.

Air Interfaces

Many air interfaces operate in the region of 1 - 3GHz – for example, GSM is classically at 900MHz, while 3G is 2.4GHz. Today, it is not possible to generate or receive these very high frequencies digitally. Instead, we tend to use an Intermediate Frequency, or IF.

IF signals are much slower – a 70MHz IF is common. At these levels, it is possible to digitise the signals directly. Techniques like bandpass sampling are often used – using a sample rate lower than the IF. Care is needed in doing this

– the sampling rate must be 2x the bandwidth of the signal you are trying to extract, and good anti-aliasing filters are required – but it allows high IF signals to be digitised with much slower ADCs or DACs. The high speed HERON-IO and GDIO modules are ideal for this.
In a receiver, this stage is typically followed by a Digital Down Converter (DDC). This performs further frequency shifting to move the signal to baseband, and will often translate the signal to the complex domain – if this wasn't performed in analog before the ADC! They are simple to implement in HERON-FPGA modules, or even in the FPGAs on some I/O modules.

For the transmitter, the DAC output is often generated by upsampling or interpolating filters and pulse shapers – again best implemented in FPGA.

Modulation & Demodulation

Once the signal has been shifted to baseband, a receiver can demodulate the data. In many cases, the modulation system is simple – for example, QPSK or QAM. In these cases, the demodulation can be performed synchronously, and the demodulator an provide steering information back to the DDC block – allowing the frequency shifter to more accurately estimate the carrier. This can be implemented in either FPGA, or in a DSP processor.

In the case of CDMA however, demodulation involves matching a pseudo-random carrier sequence to the received data at a very high rate. This typically involves high-rate matched filters, operating at sample rates of several MHz. These matched filters are best implemented in HERON-FPGA modules.

A similar story exists for the transmitter; modulation can be performed by a DSP processor module, or by a HERON-FPGA module.

Encoding, Decoding

The data transmitted over a wireless link is usually “scrambled” by some sort of encoder. Typically, the goals of this encoder are to ease the job of the receiver (through making it easier to track the carrier for example) and to allow correction of errors – although security of the data is also a consideration!

This encoding typically results in an increase in the amount of data transmitted as extra bits are added to ensure error detection/correction. These functions are typically best implemented in hardware, on something like a HERON-FPGA module.

Vocoders, MPEG etc

Many applications transmit compressed audio or video data that must be decompressed for playback. In a communications system this is performed by a vocoder (voice coder). As an example, the GSM-6.10 vocoder takes 64Kbps speech from the telecoms network and compresses it to 13Kbps for transmission.

Many broadcast systems use asymmetric communication –the same video is broadcast to many users, as in the case of digital TV (or indeed movie clips on CD-ROM). This makes it attractive to design a system where the compression is more computationally intensive, while decode is simpler and therefore cheaper to implement. This is the case with MPEG, making it ideal for broadcast of both audio and video.

In all cases, a HERON-DSP processor module is a good choice to implement the audio/video compression or decompression. These are often relatively complex algorithms implemented in software – a task a DSP processor is optimised for. It may be attractive to supplement the DSP processor with an FPGA, but this will greatly extend the development time – unless a suitable core can be licensed!

Summary

We've given a quick snapshot of some of the key blocks in a communications system, along with a few pointers as to how they might be implemented. However, real systems may vary greatly from what we've described – and technology is moving onwards. What today is best implemented in FPGA may be better in a DSP processor in a couple of years time. Of course, with the flexibility of the HERON system, you can stay up to date with the latest technologies, and always use the optimal implementation!

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