

Case Study

Digital Signal Processing

Reliable identification and location of stolen vehicles by radio has long been the dream of the Police services.

This has now become a reality thanks to Plextek's novel application of Digital Signal Processing to radio.



The TRACKER™ unit in operation with the UK's Police force.

When TRACKER™ Networks launched its VHF radio based stolen vehicle tracking system in the UK, Plextek were contracted to design the vehicular unit, and subsequently to create an additional uplink facility and design the necessary base-station demodulator.

This radio system is unusual in one significant respect: instead of being mounted for best visibility, the vehicular unit and its antenna are covertly mounted in unspecified positions within the vehicle's bodywork! This significantly degrades both the transmit and receive performance of the vehicular unit and makes it necessary to design the vehicular and base-station receivers to operate on very low level signals which suffer significant distortion from ever-present thermal noise and electrical interference.

Both the vehicular and the base-station receivers employ digital signal processing to provide repeatable high performance at low cost.

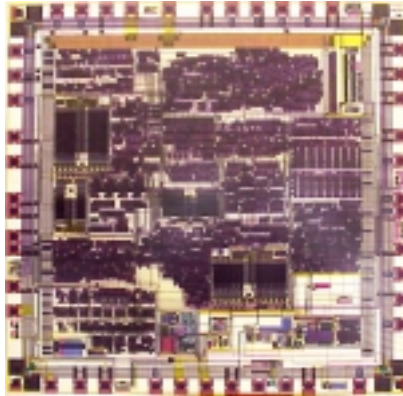
The vehicular unit employs a custom integrated circuit containing both analogue and digital circuitry. The digital processing functions used in the received signal chain are:

- A linear phase digital filter to maximise the signal to noise ratio.
- A digital oscillator phase-locked to the modulation zero-crossing points to provide a precise sampling clock.
- Dynamically adjusted histogram processing of samples across the symbol period to estimate symbol presence and timing.
- Correlation against orthonormal reference waveforms to give optimal detection of symbols and generate soft outputs.
- Viterbi processing to maximise the probability of correct demodulator decisions when decoding a poor quality signal.

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Custom ASIC for vehicular TRACKER unit

All of these processes, including models of the radio link, were simulated in depth prior to chip design, in order to optimise algorithm parameters and minimise the hardware complexity without compromising the required performance. Within the ASIC, some processes (like the channel filter) were implemented in dedicated logic circuitry and others (like Viterbi) were implemented using application-specific processors.

The novel and patented uplink was provided within the original downlink spectrum allocation by the use of proprietary low bit-rate frequency shift keying (FSK).

This is treated by a receiver as a pair of antiphase pulsed-carrier signals, each of which occupies a very narrow bandwidth and can therefore potentially be detected at low level. The vehicular units

use, by necessity, low-cost reference oscillators whose tolerance and drift cover a range several times this bandwidth. Rather than being a disadvantage, this adds a form of diversity and allows the transmissions from several vehicles to coexist without conflict. This is achieved by:

- Diversity enhancement by the addition of controlled, random, digital frequency offset.
- Using a low final IF to enable the use of a very linear analog-to-digital converter. Linearity is essential for extracting signals from high levels of noise.
- Using an FFT to create several hundred simultaneous narrow-band channels, each with its own detector. This gives coverage of the whole 12.5kHz band but with the improved noise rejection necessary to detect low-level vehicular signals.
- Using pattern matching algorithms in each detector to improve the reliability of signal detection and accurately measure each signal's carrier frequency and symbol timing.
- Allocating dedicated very narrow band demodulators, equipped with error correction and detection capabilities, to detected signals.

These processes were all implemented within a single 33MHz SHARC DSP device, coded in assembly language for optimal performance. The complete demodulator fits onto a single half-size PC card containing the DSP device, an audio analogue-to-digital converter (ADC), a program memory and a few interface devices. The card receives an analogue IF signal from the radio receiver and passes on decoded messages and system information to the host PC.

In trials, uplink ranges of 70 miles were achieved. The system is installed in over 200,000 vehicles and is in everyday use with Police forces across the UK.

This spectacular success is in great measure due to the application of appropriate DSP to what would otherwise have been very difficult radio links.



SHARC-based demodulator fitted in half-sized PC card

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