1. INTRODUCTION

Driver assistance systems use a combination of warnings and some degree of active intervention to help steer the driver away from trouble. Although the accent is on giving assistance to the driver rather than take control away, motorists are still wary about cars that supposedly drive themselves. While active intervention clearly holds many possibilities, it is also fraught with difficulty. A number of manufacturers are pursuing the aim of reducing the frequency and severity of accidents by developing active and passive driving assistance systems. Driver assistance systems aim to make the vehicle capable of perceiving its surroundings, interpret them, identify critical situations, and assist the driver in performing driving maneuvers. The object is, at best, to prevent accidents completely and, at worst, to minimize the consequences of an accident for those concerned. Consequently, these systems are increasingly being incorporated in cars across the board, from luxury vehicles to small city cars. Indeed, many of these systems are being fitted as standard equipment.

Driver assistance systems have become more popular with the introduction of 24GHz radar systems for passenger cars. The car manufactures are now focusing their interest on fusion-based multi-sensor systems, enabling the car to monitor the whole environment. One of the requirements resulting from this system set-up is a new distribution of signal processing blocks between sensor(s) and a central Engine Control Unit(ECU). As this fusion-ECU becomes responsible for data validation, object recognition, object tracing and communication with the car network, the sensor itself becomes a simple data acquisition unit. Ideally it would transfer all data to the central ECU for processing. Assuming a typical cycle time of 30-40ms this could result in data rates up to 2.9Mbit/s per sensor. This bandwidth isn’t available with today’s car networks; therefore some data pre-processing and data reduction has to be performed in the sensor. One approach is to implement the required signal processing in an FPGA. With their internal multipliers and RAM blocks, they offer an unbeatable DSP performance at a moderate frequency. Their architecture is suitable for the whole algorithm including offset correction, FFT and digital beam forming. Even tasks like threshold calculation and spectral peak detection can be performed within the FPGA.
2. RADAR

Radar is an object-detection system that uses electromagnetic waves - specifically radio waves - to identify the range, altitude, direction, or speed of both moving and fixed objects such as aircraft, ships, spacecraft, mountain ranges, radio and TV towers, guided missiles, motor vehicles, weather formations, and terrain. The radar dish, or antenna, transmits pulses of radio waves or microwaves which bounce off any object in their path. The object returns a tiny part of the wave's energy to a dish or antenna which is usually located at the same site as the transmitter.

The term RADAR was coined in 1940 by electronics engineers working for the U.S. Navy as an acronym for Radio Detection And Ranging. The uses of radar include air traffic control, radar astronomy, air-defense systems, antimissile systems; nautical radars to locate landmarks and other ships; aircraft anticollision systems, ocean-surveillance systems, outer-space surveillance and rendezvous systems; meteorological precipitations, radar altimeters, earth-skimming flight-control systems, guided-missile target-locating systems, and ground-penetrating radars.

RADAR transmits radio signals at distant objects and analyzes the reflections. Data gathered can include the position and movement of the object, also radar can identify the object through its "signature" - the distinct reflection it generates. There are many forms of RADAR - such as continuous, CW, Doppler, ground penetrating or synthetic aperture; and they're used in many applications, from air traffic control to weather prediction. In the modern Radar systems digital signal processing (DSP) is used extensively. At the transmitter end, it generates and shapes the transmission pulses, controls the antenna beam pattern while at the receiver, DSP performs many complex tasks, including STAP (space time adaptive processing) - the removal of clutter, and beamforming (electronic guidance of direction). The front end of the receiver for RADAR is still often analog due the high frequencies Involved. With fast ADC convertors- often multiple channel, complex IF signals are digitized. However, digital technology is coming closer to the antenna. We may also require fast digital interfaces to detect antenna position, or control other hardware.
2.1. PRINCIPLE OF OPERATION

A Radar system has a transmitter that emits radio waves called radar signals in predetermined directions. When these come into contact with an object they are usually reflected and/or scattered in many directions. Radar signals are reflected especially well by materials of considerable electrical conductivity - especially by most metals, by seawater, by wet land, and by wetlands. Some of these make the use of radar altimeters possible. The radar signals that are reflected back towards the transmitter are the desirable ones that make radar work. If the object is moving either closer or farther away, there is a slight change in the thus frequency of the radio waves, due to the Doppler effect. Radar receivers are usually, but not always, in the same location as the transmitter. Although the reflected radar signals captured by the receiving antenna is usually very weak, these signal can be strengthened by the electronic amplifiers that all radar sets contain. More sophisticated methods of signal processing are also nearly always used in order to recover useful radar signals.

The small absorption of radio waves by the medium through which it passes is what enables radar sets to detect objects at relatively-long ranges - ranges at which other electromagnetic wavelengths, such visible light, infrared light, and ultraviolet light are too strongly attenuated. In particular, there are weather conditions under which radar works well regardless of the weather. Such things as fog, clouds, rain, falling snow, and sleet that block visible light are usually transparent to radio waves. Certain, special values of radio frequencies are absorbed or scattered by water vapor, raindrops, or atmospheric gases (especially oxygen) are avoided in designing radars except when detection of these are intended. Finally, radar relies on its own transmissions, rather than light from the Sun or the Moon, or from electromagnetic waves emitted by the objects themselves, such as infrared wavelengths (heat). This process of directing artificial radio waves towards objects is called illumination, regardless of the fact that radio waves are completely invisible to the human eye or cameras.
2.2. BLOCK DIAGRAM OF A RADAR SYSTEM

2.2.1. Antenna and scan pattern generator:

This determines the shape and direction of TX/RX beam. The antenna can be either a mechanically rotating reflector or a phased array electronically steered in azimuth and elevation. The antenna allows transmitted energy to be propagated into space and then collects the echo energy on receive. It is almost always a directive antenna, one that directs the radiated energy into narrow beam to concentrate the power as well as to allow the determination of direction to the target. An Antenna that produces a narrow directive beam on transit usually has a large area on receive to allow the collection of weak echo signals from the target. The antenna not only concentrate energy on transmit and collect the echo energy on receive, but it also act as a spatial filter to provide angle resolution and other capabilities.

2.2.2. Transmitter:

It is generally a tube generating a coherent pulse train with high peak power and possibly a wide band; alternatively, mini TWT or solid state amplifiers can be used in active phased-array radar.
2.2.3. Waveform generator:

It tailors the waveform to the environment and to the particular operating mode actually used. The waveforms can be wide pulse with frequency or phase code modulation for improved range resolution and clutter discrimination.

2.2.4. Duplexer:

This is an RF switch which conveys all the energy from the transmitter to the antenna in the transmitting phase while all the energy gathered by the antenna in the receiving phase is sent directly to the receiver chain. The rotary joint, allows the electric connection of the antenna to the remaining part of the radar notwithstanding the mechanical rotation of the antenna. Rotary joint with low loss and optical fibres for the transportation of signals are today available.

2.2.5. Receiver:

It provides frequency conversion, interference rejection and low noise amplification. The noise reduction is an important consideration in radar receiver design and is accomplished by the matched filter technique which maximises the SNR at the output. Signal down conversion in frequency is done in a number of steps up to base band where the signal is transformed in digital format via analogue-to-digital conversion (ADC) devices. Modern radar performs the ADC directly at intermediate frequency (IF); the advantage is to eliminate the unbalance between the I (in phase) and quadrature (Q) channels with corresponding advantages in terms of coherent rejection of clutter & jammer and integration of target echoes. The trend today is towards a so called digital radar where the ADC is done very close to the antenna.

2.2.6. Signal processor:

This determines the presence or absence of targets while rejecting unwanted signals due to ground clutter, sea clutter, weather, radio-frequency interference, noise sources and intentional jammers. It is performed by coherent and/or not-coherent processing of time samples of received signals. The coherent processing acts on the I and Q components of signal collected during the time on target, while the non-coherent processing occurs after phase information is suppressed in the envelope detector. Detection is accomplished by comparing the processed video output with a threshold value, the crossing of the threshold being declared detection.
The signal processor is implemented in real time special-processor hardware; more recently due to the extraordinary advances of the digital technology the processor makes extensive use of COTS (Commercial Off The Shelf) devices. Basic operations routinely implemented are: pulse compression, moving target indicator (MTI), pulse Doppler processing, moving target detector (MTD), CFAR. Also some modern phased-array radar have implemented in their signal processors the adaptive spatial filtering of jammers NCTR is another function that may be implemented in modern radar.

2.2.7. **Data extractor& Processor:**

This provides the target measurements in range, angles (azimuth, elevation) (via moving window or monopulse), radial speed and possibly target signature for NCTR. In general, target may cause several detections in adjacent cells in range, Doppler and angles; the centroid (referred to as “plot” in the sequel) of the corresponding pattern of detections gives an estimate of the target measurement. The target extractor was implemented in a dedicated microcomputer; today COTS technology is used also here. It is essentially where the tracking filtering is implemented.

2.2.8. **User:**

The output is generally a display to visualise the information contained in the radar echo signal in a form suitable for operator interpretation and action. There could be a link to convey data in a centre or in a computer for further processing. The visualised information on the display is called synthetic video. The plan position indicator (PPI), the usual display employed in radar, indicates the range and azimuth of a detected target. A modern radar display includes alphanumeric characters and symbols for directly conveying additional information; this is useful when target identity and altitude are to be displayed. Also the track is displayed with arrows and symbols.

2.2.9. **Controller:**

This decodes commands from the operator and sets up the operation modes, the appropriate system timing and the signal generator together with the processing functions on the received signals according to range, azimuth and elevation sectors. The controller also analyses signals for fault detection. It normally comprises a set of software programs implemented on a digital computer; used technologies are multiprocessor architectures based on COTS (Power PC and the like); programming languages can be Ada and C; real time operative system may be Lynx-OS or similar.
2.3. RADAR LIMITING FACTORS

The various factors which limit the operation of Radar are

2.3.1. Beam path and range:

The radar beam would follow a linear path in vacuum but it really follows a somewhat curved path in the atmosphere due to the variation of the refractive index of air. Even when the beam is emitted parallel to the ground, it will raise above it as the Earth curvature sink below the horizon. Furthermore, the signal is attenuated by the medium it crosses and the beam disperse as its not a perfect pencil shape. The maximum range of a conventional radar at a certain height above ground is thus limited by the maximum non-ambiguous range determined by the Pulse repetition frequency (PRF), the two way intensity of the returned signal according to the radar equation and the Earth curvature.

2.3.2. Noise:

Signal noise is an internal source of random variations in the signal, which is generated by all electronic components. Noise typically appears as random variations superimposed on the desired echo signal received in the radar receiver. The lower the power of the desired signal, the more difficult it is to discern it from the noise (similar to trying to hear a whisper while standing near a busy road). Noise figure is a measure of the noise produced by a receiver compared to an ideal receiver, and this needs to be minimized. Noise is also generated by external sources, most importantly the natural thermal radiation of the background scene surrounding the target of interest. In modern radar systems, due to the high performance of their receivers, the internal noises is typically about equal to or lower than the external scene noise. An exception is if the radar is aimed upwards at clear sky, where the scene is so "cold" that it generates very little thermal noise.
2.3.3. Interference:

Radar systems must overcome unwanted signals in order to focus only on the actual targets of interest. These unwanted signals may originate from internal and external sources, both passive and active. The ability of the radar system to overcome these unwanted signals defines its signal-to-noise ratio (SNR). SNR is defined as the ratio of a signal power to the noise power within the desired signal. In less technical terms, SNR compares the level of a desired signal (such as targets) to the level of background noise.

2.3.4. Clutter:

Clutter refers to radio frequency (RF) echoes returned from targets which are uninteresting to the radar operators. Such targets include natural objects such as ground, sea, precipitation (such as rain, snow or hail), sand storms, animals (especially birds), atmospheric turbulence, and other atmospheric effects, such as ionosphere reflections, meteor trails, and three body scatter spike. Clutter may also be returned from man-made objects such as buildings and, intentionally, by radar countermeasures such as chaff. Some clutter may also be caused by a long radar waveguide between the radar transceiver and the antenna. In a typical plan position indicator (PPI) radar with a rotating antenna, this will usually be seen as a "sun" or "sunburst" in the centre of the display as the receiver responds to echoes from dust particles and misguided RF in the waveguide. Adjusting the timing between when the transmitter sends a pulse and when the receiver stage is enabled will generally reduce the sunburst without affecting the accuracy of the range, since most sunburst is caused by a diffused transmit pulse reflected before it leaves the antenna..

2.3.5. Jamming:

Radar jamming refers to radio frequency signals originating from sources outside the radar, transmitting in the radar's frequency and thereby masking targets of interest. Jamming may be intentional, as with an electronic warfare (EW) tactic, or unintentional, as with friendly forces operating equipment that transmits using the same frequency range. Jamming is considered an active interference source, since it is initiated by elements outside the radar and in general unrelated to the radar signals.
Jamming is problematic to radar since the jamming signal only needs to travel one-way (from the jammer to the radar receiver) whereas the radar echoes travel two-ways (radar-target-radar) and are therefore significantly reduced in power by the time they return to the radar receiver. Jammers therefore can be much less powerful than their jammed radars and still effectively mask targets along the line of sight from the jammer to the radar (Mainlobe Jamming). Jammers have an added effect of affecting radars along other lines of sight, due to the radar receiver's sidelobes (Sidelobe Jamming).

3. RADAR SIGNAL PROCESSING

Radar signal processing can be defined as the manipulation of the received signal, represented in digital format, to extract the desired information whilst rejecting unwanted signals. In particular, a surveillance radar takes a decision about the presence or absence of targets whilst cancelling radar echoes caused by ground clutter, radio frequency interference and noise source. An airborne radar accomplishes the same job in spite of the strong clutter return and its Doppler spread caused by the platform motion. A tracking radar, in addition to detection, is concerned with an accurate estimation of the target kinematics parameters (resort is made to maximum likelihood estimation procedure and its sub-optimum implementations). The list could be extended to other radar systems as the low probability of intercept, the synthetic aperture radar, the space-based radar and the multistatic radar.

Whatever the radar system, the basic operations performed by the signal and data processors are as follows: detection of presence of targets, if any; extraction of information from the received waveform to determine a wealth of relevant parameters of the targets (such as position, velocity, shape, and electromagnetic signature). The first step of the design can be recognised in the formulation of mathematical models more adherent to the real environment in which the radar operates. Several major areas of research and development can be singled out in connection with radar detection: theory of optimum detection, adaptive detection theory, detection of signals having non-Gaussian probability density function (pdf), multidimensional processing and super resolution algorithms. Some techniques have been successfully implemented in real radar systems.
3.1. TASKS OF RADAR SIGNAL PROCESSOR

3.1.1. Decision making:

After a signal has been transmitted, the receiver starts receiving return signals, with those originating from near objects arriving first because time of arrival translates into target range. The signal processor places a raster of range bins over the whole period of time, and now it has to make a decision for each of the range bins as to whether it contains an object or not. This decision-making is severely hampered by noise. Atmospheric noise enters into the system through the antenna, and all the electronics in the radar's signal path produces noise too. Even if atmospheric attenuation can be neglected, the return from a distant object is incredibly weak. Target returns often are no stronger than twice the average noise level, sometimes even buried under it. It is quite difficult to define a threshold for the decision whether a given peak is noise or a real target. If the threshold is too high then existing targets are suppressed, that is, the probability of detection (PD) will drop. If the threshold is too low then noise peaks will be reported as targets, that is, the probability of false alarms (PFA) will rise. A common compromise is to have some 90% probability of detection and a false alarm rate of $10^{-6}$.

3.1.2. Combining information:

Secondary surveillance radars like those located on airports can ask an aircraft's transponder for information like height, flight number or fuel state. Pilots may also issue a distress signal via the transponder. The ground radar's signal processor combines this data with its own measurements of range and angular direction and plots them all together on the appropriate spot on the scope.

3.1.3. Forming tracks:

By correlating the data sets which were obtained in successive scan cycles, the radar can calculate a flight vector which indicates an aircraft's speed and expected position for the next scan period. Airport radars are capable of tracking hundreds of targets simultaneously, and flight safety depends heavily on their reliability. Military tracking radars use this information for gun laying or guiding missiles into some calculated collision point.
3.1.4. Resolving ambiguities in range:

Depending on the radar's pulse repetition frequency (PRF), the readings for range, Doppler or even both are ambiguous. The signal processor is aware of this and selects a different PRF when the object in question is measured again. With a suitable set of PRFs, ambiguities can be eliminated and the true target position can be determined.

3.1.5. Ground Clutter Mapping:

Clutter is the collective term for all unwanted blips on a radar screen. Ground clutter originates from buildings, cars, mountains etc, and a clutter map serves to raise the decision threshold in areas where known clutter sources are located.

3.1.6. Time and power management:

Within a window of some 60°x40°, phased array radars can instantly switch their beam position to any position in azimuth and elevation. When the radar is tasked with surveying its sector and tracking dozens of targets, there's a danger of either neglecting part of the search sector or losing a target if the corresponding track record isn't updated in time. Time management serves to maintain a priority queue of all the tasks and to produce a schedule for the beam steering device. Power management is necessary if the transmitter circuitry runs the danger of overheating. If there's no backup hardware then the only way of continuing regular operation is to use less power when less power is required, say, for track confirmation.

3.1.7. Countering interference:

Interference can be a) natural, or b) man-made. Natural interference can be heavy rain or hail storms, but also varied propagation conditions. Man-made interference, if created on purpose, is also called jamming and is one of the means of electronic countermeasures.
3.2. APPLICATIONS OF RADAR SIGNAL PROCESSING

The information provided by radar includes the bearing and range (and therefore position) of the object from the radar scanner. It is thus used in many different fields where the need for such positioning is crucial. The first use of radar was for military purposes; to locate air, ground and sea targets. This has evolved in the civilian field into applications for aircraft, ships and roads.

In aviation, aircraft are equipped with radar devices that warn of obstacles in or approaching their path and give accurate altitude readings. They can land in fog at airports equipped with radar-assisted ground-controlled approach (GCA) systems, in which the plane's flight is observed on radar screens while operators radio landing directions to the pilot.

Marine radars are used to measure the bearing and distance of ships to prevent collision with other ships, to navigate and to fix their position at sea when within range of shore or other fixed references such as islands, buoys, and lightships. In port or in harbour, Vessel traffic service radar systems are used to monitor and regulate ship movements in busy waters. Police forces use radar guns to monitor vehicle speeds on the roads.

Radar has invaded many other fields. Meteorologists use radar to monitor precipitation. It has become the primary tool for short-term weather forecasting and to watch for severe weather such as thunderstorms, tornadoes, winter storms precipitation types, etc... Geologists use specialised ground-penetrating radars to map the composition of the Earth crust. The list is getting longer all the time.
4. DRIVER ASSISTANCE (DA) SYSTEMS

Radar sensor based Driver Assistance Systems are already available for some luxury cars and heavy transport vehicles. First radar systems generation supports limited functionality like Adaptive Cruise Control (ACC), where the main tasks are to detect targets, infer useful information, and adjust the speed of the vehicle accordingly. Today’s generation is more sophisticated. It proposes to handle multiple complex features such as collision avoidance, prediction of dangerous situations, lane change assistance, parking assistance, and many others. It consists of the use of Frequency-Modulated Continuous Wave (FMCW) modulation which allows managing complex detection scenarios.

Fig 2: System level architecture of DA radar-based system
4.1. DIFFERENT DRIVER ASSISTANCE SYSTEMS

4.1.1. Night vision:

An automotive night vision system is a system to increase a vehicle driver's perception and seeing distance in darkness or poor weather beyond the reach of the vehicle's headlights. They are currently offered as optional equipment on certain premium vehicles.

4.1.2. Adaptive Cruise Control:

These systems use either a radar or laser setup allowing the vehicle to slow when approaching another vehicle and accelerate again to the preset speed when traffic allows. ACC technology is widely regarded as a key component of any future generations of intelligent cars. The system consist of a forward looking Radar which sees slower vehicles ahead. Now the system automatically adjusts speed and maintains a selectable following distance. The desired speed is resumed when the way ahead is clear. Some ACC systems use digital maps to enhance operations.

4.1.3. Collision avoidance:

A collision avoidance system is a system of sensors that is placed within a car to warn its driver of any dangers that may lie ahead on the road. Some of the dangers that these sensors can pick up on include how close the car is to other cars surrounding it, how much its speed needs to be reduced while going around a curve, and how close the car is to going off the road. The system uses sensors that send and receive signals from things like other cars, obstacles in the road, traffic lights, and even a central database are placed within the car and tell it of any weather or traffic precautions. A situation that provides a good example of how the system works is when a driver is about to change lanes, and there is a car in his blind spot. The sensors will detect that car and inform the driver before he starts turning, preventing him from potentially getting into a serious accident. Collision avoidance systems are especially useful in bad weather conditions. The sensors in the car would be capable of detecting the poor conditions and would inform the driver on how to drive in them.
4.1.4. **Driver impairment monitoring:**

This system examine if the driver is fit to drive? It monitor the driving performance such as lane keeping, steering wheel monitoring and physiological factors like ocular measures, head position monitoring etc. It is equipped with a proximity array sensor system.

4.1.5. **Lane departure warning:**

In road-transport terminology, a lane departure warning system is a mechanism designed to warn a driver when the vehicle begins to move out of its lane (unless a turn signal is on in that direction) on freeways and arterial roads. These systems are designed to minimize accidents by addressing the main causes of collisions: driving error, distraction and drowsiness.

There are two main types of systems:

- Systems which warn the driver if the vehicle is leaving its lane. (visual, audible, and/or vibration warnings)
- Systems which warn the driver and if no action is taken automatically take steps to ensure the vehicle stays in its lane.

4.1.6. **Automatic parking:**

Automatic parking is an autonomous car maneuvering from a traffic lane into a parking place to perform parallel parking, perpendicular or angle parking. The automatic parking aims to enhance the comfort and safety of driving in constrained environments where much attention and experience is required to steer the car. The parking maneuver is achieved by means of coordinated control of the steering angle and speed which takes into account the actual situation in the environment to ensure collision-free motion within the available space.
5. FPGA SIGNAL PROCESSING FOR DRIVER ASSISTANCE SYSTEM

Radar and sonar applications are signal-processing intensive and heavily rely on the efficient implementation of such digital signal-processing (DSP) algorithms as filtering, transforms and modulation. In past systems, conventional digital signal processors were used to perform many of these algorithms. However, field-programmable gate arrays (FPGAs) deliver an order of magnitude higher performance than traditional DSPs. A key reason is that an FPGA can side step the classic Von Neumann architecture's instruction — fetch, load/store bottleneck — found in most DSPs. Another reason is the FPGA's lower power consumption.

As FPGAs increase in density and performance capability, more signal-processing functions can be incorporated and migrated to the front end containing the exciter/receiver of the radar (or sonar) system. This may include waveform generation, filtering, matrix-inverse operations, and signal correlation.

5.1. AN ALL-FPGA DESIGN FOR SIGNAL PROCESSING

Fitting multiple DSP functions into a single FPGA has many integration challenges, but also offers significant advantages to the designer in performance and flexibility. The primary reasons for integrating DSP functions into a single FPGA are system-level reductions in size, weight and power. For example, eliminating the transfer pathways between separate FPGAs and DSPs significantly reduces power consumption and, therefore, heat. This, in turn, reduces the system-cooling burden of the design. Recent releases of design and place-and-route software, such as Altera's Quartus II design suite, have advanced power-awareness features that significantly reduce dynamic power use of the FPGA. These options can be important to the designer; the benchmark of device logic density among competitive FPGA providers is beginning to give way to functionality-per-watt metrics, due to the sensitivity of power and cooling requirements in emerging systems.
Performance is also a key driver as FPGA-pipelined signal processing has become more reliable and faster than traditional processing technologies. In applications where performance is the driving parameter, efficiency can be sacrificed for application speed, where a memory-intensive, massively parallel floating-point math operation is desired. Alternatively, highly iterative DSP calculations can be implemented for applications where moderate performance is allowable, but where logic-element usage is limited. This leads to the advantage of flexibility. The designer has the flexibility to decide between high-speed performance and the number of logic elements in every DSP operation, whereas calculation bandwidths and iterations would be more difficult and costly to modify in a dedicated DSP device. In addition, consolidating DSP functions within an FPGA allows for post-design system changes in the signal-processing architecture, whereas using separate DSPs locks the designer into a fixed set of chip interfaces once the board is designed. FPGA designers can alternately switch between 9-bit, 18-bit or 36-bit or 18-bit complex math functions without changing the system hardware.

Additional flexibility can be designed into the system when the designer uses fast-embedded processors for the execution or routing of complex floating-point operations. These functions are useful for radar applications.

5.2. FPGA DSP FUNCTIONS IN RADAR/SONAR APPLICATIONS

Several DSP functions are needed for radar or sonar processing near the receiver element. Each function should be closely examined to determine whether the application will show substantial speed and performance improvements through implementation in an FPGA. In some cases, these operations can be efficiently implemented using an FPGA embedded processor, even for highly complex and adaptive operations.

When a radar or sonar application calls for these operations to be performed with floating-point arithmetic, FPGAs have significant flexibility advantages if the design team takes advantage of a strong architecture-based design approach. Large floating-point math operations can be performed in standard logic cells (the least efficient option), in dedicated reduced-instruction-set-computer (RISC) embedded processors (the most flexible option), or in dedicated floating-point multiplier logic (the most efficient option).
FPGA providers and third-party developers offer efficient and accurate floating-point operators, Fourier-transform tools and filter compilers to FPGA designers as intellectual property (IP). Engineers should conduct their own research on the current availability of advanced DSP functions, but a great deal of preliminary information can be obtained through the technical representatives of programmable logic device (PLD) vendors.

5.3. DIGITAL UP/DIGITAL DOWN SIGNAL CONVERSION

The upconversion and downconversion of high-frequency signals are experiencing a dual migration, into the digital domain, and into the same monolithic device (either the ASIC or FPGA) that performs the baseband processing. This push toward more digital, software-radio-style signal-processing techniques provides significant advantages to the system in signal accuracy and speed. The closer to the RF front end (or the acoustic transceiver front end in sonar systems) that signals can be digitized, the fewer the analog-signal vulnerabilities that are introduced to the system. This includes high-order mixing products, error-vector-magnitude (EVM) impairments due to phase/magnitude imbalance, carrier feed-through, harmonics, and sideband noise.

More important than signal integrity, however, is the design flexibility that the digital domain allows the radar-system designer. Dynamic filtering and conditional signal-processing algorithms significantly improve performance, as well as reduce implementation losses and the time required for the design cycle. While these advantages involve trade-offs between power consumption and digital bandwidth, modern FPGAs provide designers much greater flexibility in mitigating power consumption, including the support of selectable core voltages, or critical-path power analyses.

The greater the numbers of on-chip resources available in FPGAs, the more designers are enabled to incorporate polyphase filtering and downconversion in the digital domain. Multiple onboard or external numerically controlled oscillators (NCOs) can allow very high phase discrimination with high-capacity FPGA devices. This application is useful for prototyping, research and development, where designers can incorporate and test multiple-phase resolutions without significant hardware investments by using hardware-in-the-loop test methodologies.
5.4. ALGORITHMIC FUNCTIONS

Examples of algorithmic math functions in radar systems include recursive least-square and square-root operations. Many designers have implemented these functions in C-based processors (in fixed-decimal and floating-point operations), or with proprietary FPGA VHDL operations. The current generation of FPGA devices include embedded processor and logic-cell resources to efficiently implement these processes; future generations will also have these capabilities. Additionally, IP cores and reference designs are becoming available to transition anywhere from dozens to hundreds of these operations into a single FPGA.

Tools are available to translate processor-based algorithms from C code to hardware languages, such as very high-level descriptive language (VHDL). These tools can be used to optimize certain logic functions from a standard main processor into an FPGA co-processor operating in parallel with the main processor, or to move entire operations from the main processor to the FPGA hardware. This provides an additional dimension of flexibility to the radar- or sonar-architecture designer's toolkit.
5.5. COMPLEX MATRIX INVERSION

Matrix inversion is an important element of adaptive-array designs and standard spatial-transceiver-array processing (STAP). These operations are commonly performed in fixed hardware elements, though efficiently implemented embedded processing has been demonstrated in some radar/sonar development programs. The logic-element size and potential parallelism of a matrix inversion engine depends on the size of the array used in the radar system. As the size of the array is increased, so does the number of floating-point multiplications required by the system. Therefore, in larger arrays, there are more trade-off options between the speed of the system and the number of logic elements required by the system (both of which increase as the parallelization of the architecture increases).

Implementing this function using a combination of a DSP and a group of internal memory blocks is the most likely design path for radar-system designers. As these operations are often tailored to the adaptive-array algorithms of the radar system, they are likely to be custom designed in VHDL. However, reference designs that are optimized for the place-and-route capabilities of an FPGA device can be offered or designed to order from the FPGA manufacturer, if required for the radar or sonar system.

5.6. FAST-FOURIER TRANSFORMS

The bandwidths of many systems, including radar/sonar and test/measurement systems, are beginning to exceed the capabilities of dedicated DSPs. Implementing fast-Fourier transforms (FFTs) and their inverses in FPGA logic has advantages in prototyping and scalability, and offers design flexibility between a system's speed and the number of required logic elements. For example, massively parallel implementations can be designed and distributed among the logic elements of a single or multiple FPGAs. However, while these implementations can significantly reduce latency, they impose the penalty of a greater number of logic elements.
In fact, the primary flexibility advantage of an FPGA for FFTs is the ability to select the optimal balance between these two parameters in the initial design. This is fortunate, because the implementation of large or complex FFTs should be the primary factor in any design, and the advantages of an FFT implementation in an FPGA are apparent. However, creating code or modifying existing code from previous designs can be cumbersome when testing and verifying code units. Therefore, what is needed is a comprehensive suite of FFT design tools that allows a nearly infinitely scalable FFT design. These tools should allow scripted logic distribution among multiple FPGAs where necessary. They should also be able to automatically generate numerical coefficients having floating-point accuracy. Customer inputs are being taken now for such tools.

Because radar, sonar and digital-communication system designers must focus on the complications of multi-element beam-forming and waveform generation not FFT design, programmable logic vendors such as Altera have internal tools and generators for conducting large, difficult element transformations. This includes reference designs and core IP wizards for standard and non-standard designs, as well as FFT co-processors, which are important design aids in the programmable logic offering.

Fig 4: Block diagram for an FPGA-based FFT implementation.
5.7. DESIGN FLOW

DSP logic designs are commonly executed from an initial model in simulation languages, such as Matlab or Simulink. These models are the most common, but not the only sources for designers to access optimized DSP IP offered through FPGA providers. The linkage between modeling and hardware implementation is important, not only for design simplicity, but for simulation and verification against the model. As the design density for FPGA-based sensor systems increase, full system modeling and simulation will become more time consuming. Compile, simulation, and place- and-route times will increasingly become discriminators when selecting FPGA and design-software vendors. Furthermore, multiprocessor and distributed processing options for design software will be necessary to keep up with design complexity.

To cope with these trends, and to achieve the greatest signal-processing performance in their sonar or radar systems, designers are encouraged to consider options beyond their own VHDL modules or other internally developed IP. Specifically, they should consider working with programmable logic manufacturers to develop tailored DSP cores, or find ways to improve and optimize their designs through advanced place-and-route methods available for FPGA design tools. This is because the advanced capabilities of integrated circuits enabled by increasingly sophisticated fabrication technologies cannot be fully harnessed without flexible and effective design techniques.
6. CONCLUSION

FPGA-based radar signal processing for a new generation automotive Driver Assistance system has been discussed in this paper. There is a lot of researches are going on in the field of Driver Assistance system. Automotive industry is increasingly enthusiastic to include radars in future vehicles. Automotive industry now look for consumers to become increasingly comfortable with driver aids and demand more relief from the tedium of driving and look for the technology to deliver.

Radar and digital signal processing are the key components of Driver Assistance system. FPGAs have been used in radar based Driver Assistance systems for some time, mostly in support functions. However, as FPGAs get more sophisticated, performing and integrating more DSP functions in FPGAs is becoming the standard. FFT are the key techniques for analysing the digital signal. The recent advances in signal processing are blended with many more algorithms to present an up-to date perspective and can be implemented in Digital Signal Processor because of their flexibility and the ability to attain high precisions.

DSP and FPGA solutions provide designers with a myriad of implementation options and solutions for today’s system designs. Along with these solutions comes a variety of design factors and considerations that need to be evaluated to select the best approach, depending on system requirements like ease of implementation, cost and performance as well as power consumption. Digital signal processors can provide the simplest implementation for a wide range of DSP algorithms and applications, but the cost/performance, implementation flexibility and hardware parallelism provided by an FPGA cannot be overlooked. From a price/performance comparison, FPGAs provide better performance for lower cost compared to a DSP approach. Additionally, if the FPGA is not fully utilized, more functionality and parallelism could be added to the FPGA to increase the amount of processing the FPGA is capable of without impacting the cost of the system. Also, from a function-to-function power comparison, we see that for the same function, an FPGA implementation is capable of consuming less power than a digital signal processor.
7. REFERENCES

