RTT TECHNOLOGY TOPIC
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A longer look at radar

In last month's Technology Topic on radio and radar we reviewed some of the trends in radio frequency technologies over the past seventy years and their relevance to present day and future radio communications design.

We mentioned briefly the role of radar in the Second World War and some of the cross over that occurred between broadcast receiver and radar receiver design.

At component level we sang the praises of the new all glass technology of the EF50 valve which provided the basis for high gain broadband IF amplification and the parallel impact that the magnetron had on microwave system design.

This month we take a 'longer look' at radar, again using case studies from the past to provide a broader perspective on present and future radar technologies and radar applications and to highlight the future potential of integrated radio and radar system technologies.

Co existing with the analogue world around us
In our December 2005 Technology Topic, 'Superphones' ,we described three classes of cellular phone, standard phones that allow us to communicate, smart phones that supposedly make us more efficient and a new generation of super phones which help us to interact with the physical world around us.

To an extent this has happened or is happening with the inclusion of GPS combined with a digital compass capability combined with a dead reckoning capability combined with advanced imaging and audio capture capabilities and we may as well add a nice old fashioned barometer.

A similar shift is taking place or will take place at system level with a much closer integration of communication and sensing platforms and fixed and mobile communication and sensing devices.

Evolving radar systems integrated with evolving radio systems are part of that story. Initially they are of particular relevance to specialist user communities, homeland security or public safety and disaster relief but in the longer term more generic consumer applications will emerge.

So bear with us, this is a history lesson with a broader purpose.

Radar in the early 20th century
In the early years of the last century there were various attempts to build systems to detect large moving objects using reflected radio waves. Christian Huelsmeyer organised demonstrations of a 'telemobilscope' spark gap based system in Germany

and the Netherlands in 1904.

By the mid 1930's practical pulsed radar systems were being built in the US operating at 25 MHz and similar devices were built and demonstrated in Germany. The Dutch were also working on higher frequency systems.

These were initially fixed installations for example the VHF Chain home system of VHF transmitters on the South Coast mentioned in last month's article.

Pulsed radar allowed an object to be tracked both in terms of its location, velocity and direction of travel.

The quest for mobility - mobile radar
So the next challenge was to shrink wrap a radar system into a small form factor that could be made mobile - effectively a 1940's version of a mobile cellular cell site or rather a mobile mobile cellular cell site.

The example illustrated is a 1944 anti aircraft gun control station presently being restored to working condition at Duxford aerodrome.

This particular design has a frequency range of operation between 3 and 3.1 GHz and a transmit power of 250kW. The machine is capable of detecting a Spitfire at 25000 yards or a plane the size of a Beaufighter at 36000 yards not that there are many of those about today.

The RF stages use EF 50 thermionic valves and a magnetron as the final transmitter output stage.

Practically one of the biggest challenges was to realize the mechanics of a 5ft parabolic dish that had to rotate twenty times and do an elevation scan every four seconds. This resulted in a trailer weighing just over five tons. Mobility is a relative term.

Performance compromises in radar
In common with all pulsed radar systems both then and now there is always a trade off between pulse length and pulse power which in turn determine resolution and range.

Say a pulsed radar system sends a pulse which is one microsecond in duration. It will then turn off so it can see the returning pulse - a classic time division duplex radio device. The elapsed time between the transmitted and returned signal determines the distance to the target but the length of the burst determines the resolution achievable from the measurement.

For example a one microsecond pulse provides a radio burst of 300 meters. To achieve a better range resolution requires a shorter pulse but this needs more power to achieve the same range. The device becomes power limited.

Fast forward to the present - the return to continuous wave transmitters and their similarity to two way radio systems

Over the next 50 years progressive refinements were made to radar systems including the use of pulse compression and signal shaping techniques to improve resolution.

It was also realest that a pulsed signal could be replaced with a coded signal that could be made to fulfil a similar ranging function but at much lower power.

In parallel, smart antenna systems evolved that could provide repetitive scanning functionality without the need to physically move the antenna.

So a modern radar system can actually be rather similar to a low power cellular base station with similar design issues. The example product shown has a power output of one watt transmitted continuously and is an FM modulated continuous wave system using a chirp modulated waveform where the frequency rises (or falls) over a defined period.

Blighter radar- picture courtesy of Plextek Limited

Chirp signals are called chirp signals because they sound like a bird call if translated into the audio band. This particular device generates a 16 GHz transmission that sweeps up by 15 MHz over 200 microseconds.

The advantage of a chirp system is that the RF stages are handling a relatively long duration signal but the received signal can be put through an FFT transform and turned back into a relatively short impulse.

However certain design preconditions are needed to make these systems work.

Firstly the linearity of the transmit path has to be carefully managed to preserve the shape of the transmitted chirp waveform. The phase shifting required for the fixed swept antennas also requires a highly linear transmit and receive path. This is similar to the design requirements of a cellular base station with a smart antenna capability.

Secondly the transmitter and receiver are on at the same time and the transmitter can potentially desensitize the receive path. This is similar to the design of a 3G cellular base station or 3 G cellular phone.

Thirdly the dynamic range of the device has to be in the order of 180 dB, significantly more onerous than either a cellular base station or cellular handset.

In the 1940's companies with knowledge and experience of broadcast receiver design and two way radio design were well placed to produce efficient effective radar systems.

This remains directly true today.

Modern enabling technologies
A modern radar system and modern broadcasting or cellular radio system also share a fundamental dependency on digital signal processing techniques.

Digital signal processors perform the FFT transform in OFDM radio systems and the chirp transform in a modern radar system

Digital signal processors perform signal pre shaping in OFDM radio systems and modern radar systems.

Digital signal processors perform receive signal post processing in OFDM radio systems and modern radar systems.

The 1940's portable radar system could detect a Beau Fighter at 32 kilometers away but weighed 5 tons.

The portable radar illustrated weighs 15 kg and can detect a car at 5 kilometers, a man at 2 kilometers or someone crawling slowly at half a mile an hour one kilometer away.

The difference represents a direct measure of 60 years of technology and engineering progress.

Audio and video integration - a human analogy
In common with the 1940's radar, the modern radar analyses the received reflected signals to provide a distance and difference measurement over time. The difference

measurement provides speed and direction.

Each object however has a unique radio signature which can be transformed from the demodulated baseboard signal to an audio signal.

So for example if the radar is looking at a street and a car appears around a corner there will be a whistling sound that increases with frequency as the car approaches the radar. The rate of increase is a measurement of the speed of approach. The Doppler effect will occur in reverse for cars going away from the radar.

However the sound varies depends on the type of car - a sports car sounds significantly different from a post van. An adult pushing a pram down a street with two children beside him/her will produce a low audio mutter with a composite rhythmic pulse determined by the leg movements of all three people. A bike going pass has another unique radio and audio signature.

The question is what to do with this information.

Modern imaging systems can deliver some of this functionality by day at a lower cost through the use of pattern recognition and vector analyses of changing pixel patterns and can work at night in the infra red band.

Imaging systems require line of site visibility but then so does a 16 GHz radar system.

The answer is that radar systems can do some things better than imaging systems and imaging systems can do some things better (and at lower cost) than radar systems. Imaging systems for example are compromised by fog, snow or heavy rain. Depending on the frequencies used, radar can be more resilient to weather effects.

As humans we depend on multiple sensory inputs to detect danger or opportunity. We may assume that vision is a predominant sensing mechanism but sound often conveys more information. We can hear what is happening behind us, something our eyes cannot do, we use sound to gauge proximity and direction and speed of moving objects within audio range.

Radar just provides an extension of this listening and awareness functionality in the same way that radio communication provides a range extension of an audio exchange.

Many of us already use or interact with radar devices in our everyday lives- the parking sensor in modern cars being one example. Many of us have been at the wrong end of a hand held police radar sensor.

Adding a radar capability to a mobile phone might seem ridiculous but is no more ridiculous than a fifteen kilogram portable radar would have seemed to a 1940's radio and radar engineer.

Studying the past allows us to predict the future. Radar phones are potentially a part of that future.

About RTT Technology Topics

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We aim to introduce new terminology and new ideas to clarify present and future technology and business issues.

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Contact RTT

RTT, the Shosteck Group and The Mobile World are presently working on a number of research and forecasting projects in the cellular, two way radio, satellite and broadcasting industry.

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