A Nexus between Radar System and Software Defined Radio to provide High-speed Communication System

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Abstract:

Digital Signal Processing (DSP) technology continues to transform radar systems and SDR systems. DSP technology has made it possible to improve dramatically the gains in radar sensitivity, range and image quality, as well as the gains in the SDR radio performance, data bandwidth and power efficiency.

Next generation radars with SDR systems can leverage advancing DSP technology with advanced techniques of detection, including synthetic beam forming and beam steering.

Beam forming technology requires high processing bandwidth, with computational speeds approaching several billion Multiply and Accumulate (MAC) operations per second. Such computationally demanding applications quickly exhaust the processing capabilities of conventional digital signal processing chips. FPGAs with embedded DSP blocks and high throughput memory subsystems provide a high-performance platform for beam forming.

A nexus between radar systems and SDR technology can use radars for high-bandwidth communications.

Key Words: SDR Systems, Software Defined Radio, High-speed digitizers, data acquisition systems, next-generation Radar, synthetic beam forming, beam steering

I Introduction

It's nearly two decades since the term "software defined radio" was coined by Dr. Joe Mitola in 1992. A **software defined radio system, or an SDR**, is a radio communication system where components that have been typically implemented in hardware (e.g. mixers, filters, amplifiers, modulators/demodulators, detectors, etc.) are instead implemented by means of software on a personal computer or embedded computing devices. These hardware functionalities can be accomplished via software running on digital signal processors or via embedded software programs running on microprocessors, DSP, FPGA or even microcontrollers. The human-to-machine interface (HMI) is accomplished in software once the analog-to-digital conversions are done.

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Modern high-speed digitizers and data acquisition systems maximize the quality of captured wideband signals, in terms of signal-to-noise ratio and spurious-free dynamic range over a very wide frequency bandwidth. These systems have the ability to acquire and transfer data simultaneously for high-speed signal recording and real-time digital signal processing.

Signal generation by DSP enables good control over the bandwidth and power efficiency. Modern semiconductors can provide good overall gain and power efficiency.

The paper is organized as follows:

- Section II talks about the SDR technology and their usage in Radar applications
- Section III covers the various Propagation modes to provide enhanced Range

II SDR for Radars

SDR combines high bandwidth digital back-end with a RF front-end having a variable center frequency over a wide frequency range. High-speed digital waveform generators are used to construct independent waveforms for each antenna and produces a synchronized multi-channel baseband transmit signal which is mixed and amplified for transmission. In the receive signal chain, the received energy is sampled at the baseband bandwidth synchronously across the multiple channels and fed to a FPGA-based real-time signal processor for multi-channel coherent process. Next-generation radars with SDR systems can leverage advancing DSP technology with advanced techniques of detection, including synthetic beam forming, beam steering and power control. Synthetic beam forming and beam steering systems typically use one-dimensional (linear array) or two-dimensional (matrix array) transceiver (TRx) antenna array elements. In so-called Active Electronically Scanned Array (AESA) radar systems, there may be hundreds or even thousands of such elements in the array. Each transmit-exciter and receiver element connects to a DSP, where the data processing computing element may be a programmable DSP chip, or a

FPGA. Fast acquisition is based on high-speed algorithms made practical with today's low-cost hardware.

The DSP engines scan the array, and apply complex (magnitude and phase) filter functions to the incoming Rx and outgoing Tx data streams to create a synthetically focused beam to enhance the Rx and Tx performance. In the case of radar, this technique eliminates traditional mechanical/electronic scanning, and enables highly agile target acquisition. Because the beam is synthetically derived from the antenna element data streams, multiple beams can be formed and steered on one array, up to the computing power limits of the DSP. This allows multiple targets to be acquired and tracked simultaneously. Adaptive beam forming offers enhanced range/sensitivity, interference immunity, and power efficiency compared to conventional antenna and digital base band processing technologies.

Beam forming technology requires high processing bandwidth, with computational speeds approaching several billion Multiply And Accumulate (MAC) operations per second. Such computationally demanding applications quickly exhaust the processing capabilities of conventional digital signal processing chips. FPGAs, with embedded DSP blocks and high throughput memory subsystems, provide a high-performance platform for beam forming

A nexus between radar systems and SDR technology can use radars for high-bandwidth communications.

SDRs can transmit and receive high-data-rate communications signals over the air. They can be connected to the IF stages of the Radars. They can provide Line-of-sight or Non Line-of-sight communications at long distances for air-to-air, air-to-ground, ground-to-ground, air-to-sea and sea-to-ground applications.

The radar can be used in a multi-role function to work as a wide band communication system. The radars can Chirp as well as Talk intelligently!! The following paragraphs give a brief on the various types of radars and how they can be adapted to function as a wide band communication system by integrating them with SDR technology.

Adhoc network similar to wireless network can be created by the radars systems most radar installations are well located geographically. Most Radars systems have sufficient power output ranging from one KW to hundreds of KWs along with high gain steer-able antennas with good pointing accuracies. All modern radars have accurate beam forming and aiming facility. Hence they can be seamlessly integrated to work as a highly directional communication system with high data rate capabilities.

Low spillover of the radiation can help maintain secrecy. Short bursts with high data rates can enable reconstruction of data received in less time.

Weather Radars

Weather Radar used for detecting weather pattern, wind direction, wind profile and wind shear forces can easily transmit data over long distances using the troposcatter mode.

The weather radars can cover our entire coast line. With the addition of the SDR systems one can send and receive high speed data through the radar instead of relying on the wired system of networking.

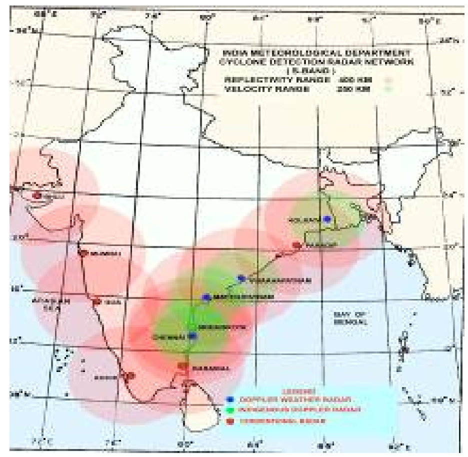


Figure 1: Cyclone Detection Radar Network (Source: imd.gov.in)

In a similar way, the fixed high powered radar installations could be used as a networked communication system spanning the length and breadth of our country. These radars could also provide important high-speed communication data links during emergencies to mitigate the vagaries of disaster our country regularly suffers from.

ATC Radars

ATC Radars can also transmit data required by the pilots of the aircraft instead of the voice and slow data link. The same can also be used to monitor the status of various on board equipments in the aircrafts etc.

Surveillance Radars

Most of the surveillance radars are placed at higher ground levels and can be supplemented with sufficient alternative sources of power. These can perform a secondary role as communication centers, much needed during disaster management.

Airborne Radars

We had two unfortunate incidents in our country recently where aircrafts were lost in un-accessible terrain. Modern Fighter aircrafts with SARs were sent on reconnaissance missions. The aircrafts had to return to bases and the data retrieved for analysis.

Valuable time was lost in this process. If the aircrafts could send out the large amount of data immediately, the data could have been processed almost instantaneously. The suggested method could enhance the capability of modern war-fighter birds.

Active electronically scanned array (AESA) radars can be modified to send and receive large amounts of information at high data rates. Thus, new-generation fighters would not only be able to collect large amounts of intelligence and targeting data, but also be able to send those large packets of information around the battlefield in seconds instead of tens of minutes or hours required to retrieve the data by current data links or other means. Another communication system for data link can be avoided hence saving premium space and weight.

The aircraft radar will immediately have a key role in network-centric warfare. In the future, it would be able to affect enemy communications by collecting their signals and inserting false or confusing data into those networks as the forward-most elements in an information war.

In the case of aircrafts with surveillance radars, the very sensitive and extensive receiver arrays can be used to both gather and exploit electronic and communications intelligence. This could be a platform based on an unmanned or manned aircraft and a launcher for cyber-weapons that can be released to penetrate air defenses to monitor enemy electronic activity at close range. The current UAVs can largely benefit with a single system to work as radar and a communication link.

Portable deployable radars

A time synchronized system consisting of several Radars could provide a wide aperture radar system by linking several fixed or portable units. This would enhance the ability to acquire large amount of data, collate the same to take necessary action from a central location.

The same method can also be employed on a convoy of ships or mobile radar units. Each radar is linked with others and work together to provide all round cover. High performance GPS receivers coupled with Inertial Navigation System and locally generated time standards would aid in enhancing the performance of the system. These could also form a very good direction finding system and could pin point the location of aircrafts, vessels and incoming projectile to facilitate evasive and counter action.

Coastal surveillance radars can also transmit and receive information to and from ships and boats and can also form a network similar to the Weather radars to provide a high speed communication link.

Munitions Radars

Proximity radars in missiles and guided munitions could be modified with small additional hardware and software/firmware. This highly-capable radar in a proximity sensor would then be able to receive vital instruction from the launch aircraft for corrective flight actions. This would allow the weapon to receive new targeting coordinates, even after it is in flight, and allows for the GPS information to be improved through updates. This combination of improved GPS accuracy and in-flight target location updates could improves the weapon’s capabilities.

III PROPAGATION MODES FOR ENHANCED RANGE

Natural phenomenon like scatter and technology-based modes like repeaters can be used to provide an enhanced range for a variety of radar applications.

Tropospheric scatter

In telecommunications, forward scatter has been employed for decades by the defence to provide long range communication. This is done by the deflection, diffraction, non-homogeneous refraction, or non-specular reflection by particulate matter of dimensions that are large with respect to the wavelength. This phenomenon is due to the density of the atmosphere at a height of around 10 km to 15 kms.

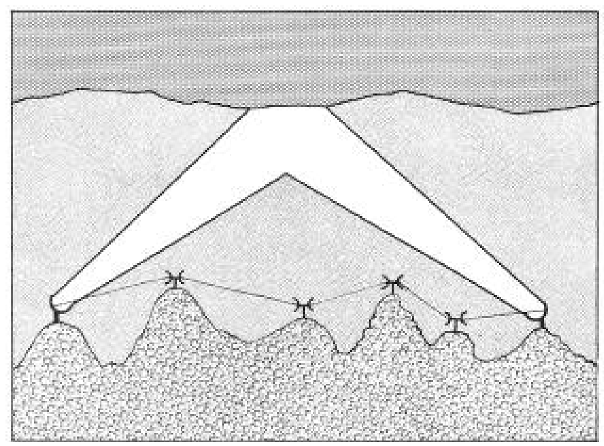


Figure 2: Tropo scatter compared to the microwave link (Source: www.ausairpower.net)

This region can scatter frequencies up to 10 GHz, allowing over-the-horizon communication between stations as far as 800 ~1000km apart.

Rain scatter

Rain scattering though not very appreciated by the TV viewers of DTH broadcast, is purely a microwave propagation mode and is best around 10 GHz, but extends down to a few Gigahertz — the limit being the size of the scattering particle size vs. wavelength. This mode scatters signals mostly forwards and backwards. Forward-scattering typically yields propagation ranges of 800 km.

This can be a useful mode of communication during the disasters accompanied by monsoon.

Meteor Scatter

As the earth moves along its orbital path, billions of particles known as meteors enter the earth's atmosphere every day; a small fraction of which have properties useful for point-to-point communication. When these meteors begin to burn up, they create a trail of ionized particles in the E layer of the atmosphere that can persist for up to several seconds. The ionization trails can be very dense and thus used to reflect radio waves. The frequencies that can be reflected by any particular ion trail are determined by the intensity of the ionization created by the meteor, often a function of the initial size of the particle, and are generally between 20 MHz and 500 MHz.

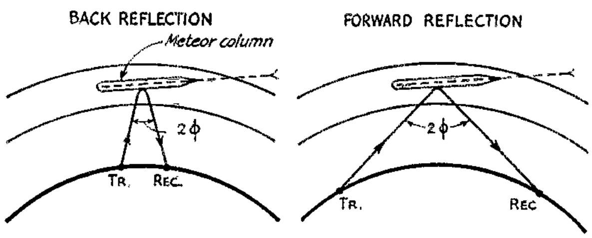


Figure 3: Meteor Scatter (Source: leonid.arc.nasa.gov)

Long distance communication is possible upto 1600-2000 kms. Using phase-steerable antennas directed at the proper area of the sky for any given time of the day. This system is free to use as opposed to satellites and other expensive channels. Real-time steering of antenna would greatly enhance this mode of radio propagation. The basic concept here is to use backscattered signals to pinpoint the exact location of the ion trail and direct the antenna to that spot and communication can be easily achieved round the clock.

Passive repeaters

Passive repeaters may be used to achieve NLOS links by deliberately installing a precisely designed reflector at a critical position to provide a path around the obstruction. Passive reflector NLOS links also incur substantial loss. However, they have been successfully used in rural mountainous areas to extend the range of LOS microwave links around mountains, thus creating NLOS links. In such cases, the installation of the more usual active repeater was usually not possible due to problems in obtaining a suitable power supply.

Active repeaters

An active repeater is a powered piece of equipment essentially comprising a receiving antenna, a receiver, a transmitter and a transmitting antenna. The repeater is placed typically midway in LOS with the two NLOS stations. The active repeater may simply amplify the received signal and re-transmit it un-altered at either the same frequency or a different frequency. The former case is simpler and cheaper but requires good isolation between two antennas to avoid feedback. A repeater that changes frequency would avoid any feedback problems but would be more difficult to design and expensive.

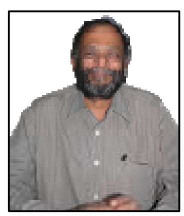
CONCLUSION

The Radar is an essential part of modern day defense and civilian applications. Its role can be enhanced with additions of SDR and necessary software. In combination it could provide a very good high data rate communication system in additional to its core functionality.

REFERENCES

1. Radar Handbook: David Pozar
2. Radio Propogation: Principles and Practice: RSGB Publication
3. Communication Receivers, DSP, Software Radios, and Design: by Ulrich Rohde

BIO DATA OF AUTHOR



Gajendra Kumar (GK) is a Principal Engineer at Mistral Solutions. He has been a Radio Engineer for more than four decades. GK has actively been designing and testing antennas that he uses to communicate with people from different parts of the world. He has also sent a signal to the moon and received it back using a self-designed antenna and LNA, transmitters and receivers. He has designed equipments that work from LF to Microwave range. GK has also set up communication hubs during disasters and emergency situations. He has been awarded several International laurels and holds numerous world records for his achievements in communication.