Coherent Solid State Radar System for Integrated Costal Surveillance

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Abstract :

This paper brings about a design philosophy ,realization approach, performance and application of Coastal surveillance radar for integrated costal surveillance. It is designed with sophisticated signal processing scheme to detect and track sub 20 meter targets under the heavy back ground of sea clutter. The engineering and packaging aspects of the radar is robust enough to make it 24x7 and all weather operation. The radar can operate both in X and S band. X band is for primary operation and S band is resorted in inclement weather. The state-of-the-art technology such as high bandwidth waveform generation with digital pulse compression (DPC), solid state power amplifier (SSPA) make the radar contemporary in Costal Surveillance application. The radar in installed and the performance is evaluated over a year of continuous operation. The new class of surveillance radar technology can directly extended for other applications such as navigation radars, surface surveillance radar and Airport surface surveillance radar.

Keywords: Costal Surveillance Radar, Digital Pulse Compression (DPC), SSPA(Solid State Power Amplifier).

I. INTRODUCTION

The Costal Surveillance Radar is the primary sensor for Integrated Costal Surveillance System (ICSS).It is designed for quick detection and monitoring of suspect vessels in a given coastal area. Radar is capable of detecting sub 20 meter boats such as country boats, dinghies, and fishing vessels in heavy sea clutter environment in all weather conditions. The radar is designed as an indigenous solution to meet the Indian Coast Guard requirements based on IALA (International Association on Lighthouse Authorities) specifications. The radar is capable of 24x7 operation. It has networking facility and can be operated remotely or locally. It is a dual band radar with both X and S band of operation. Primarily, radar operates in X band, and resorted to S band operation during inclement weather. The S band antenna utilizes circular polarization to suppress rain clutter. The detection range for small country boats (1 sqm) up to 10 Km. The instrumented range of the radar is 40 km. Radar is integrated with ICSS network, operated from Local Control Station (LCS) and tracks can be displayed at a distance of 25 km from Radar site.

The organization of the paper is as follows. Section II deals with s the design philosophy. Section III briefly discuss about all of the sub systems. Section IV high lights the special processing techniques. In section-V field results obtained during the trial of the radar is shown. The potential application of the radar is presented in section VI and the paper is concluded in section VII

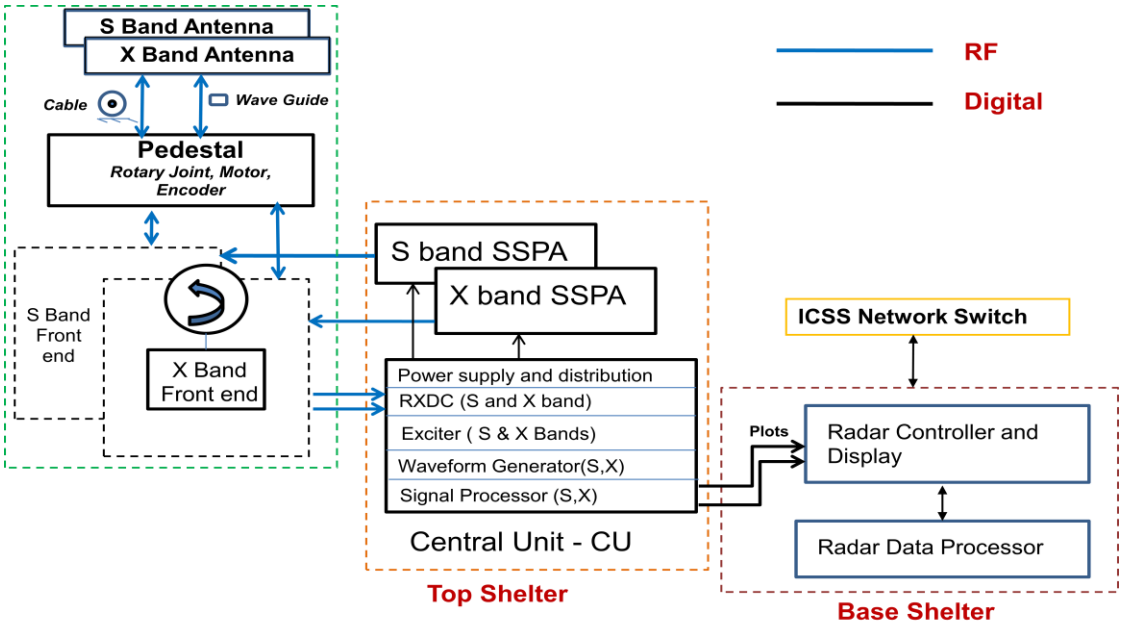
II CSR DESIGN PHILOSOPHY

The requirement of tracking large numbers of small boats, fishing vessels in the vicinity of coastal area, 24x7 continuous and all weather operation have put stringent constraint on size, mechanical design , choice of frequency of the radar and in turn on the entire design philosophy of the radar. The main requirement to track sub 20 meter boats needs high resolution both in range and azimuth. High frequency band such as X band provides high angular resolution in the order of 0.5 deg is achieved by six meter antennas. However, X band suffers from severe attenuation in heavy rain and bad weather condition. So, the S band option is provided which gives lesser attenuation in rain and circular polarization option in S band is chosen to mitigate the rain clutter effects.

Traditionally MTI based techniques which are popular for ground clutter suppression becomes ineffective in the case of sea clutter. Sophisticated proprietary signal processing techniques are adopted to detect small RCS targets against heavy rain, spiky sea clutter to meet the prescribed false alarm level. The challenge is to design a radar system for dual band operation, and the system is exposed to marine environment. For continuous reliable operation in all-weather operation, the mechanical engineering aspects such as design of enclosure, packaging and rain proofing have been carefully analyzed. In addition, high level of environmental qualifications standard have been rigorously followed.

III. RADAR SYSTEM DESCRIPTION

The modular design approach is followed in CSR so that it can be installed on tower or any high rising platform. The dual band antenna is put on pedestal and front end electronics are placed on tower top. The SSPA, Exciter- Receiver, signal processor, network switch are housed in top shelter just below the tower top. The radar display server with Radar controller, Plot extractor, Radar data processor (RDP), Display software and ICSS (Integrated Costal Surveillance) switch are kept at base shelter. The CSR block diagram is shown in Fig. 1.



Fig, 1 Block Diagram of CSR

1. Dual Band Antenna

Slotted waveguides provide exceptionally low loss and travelling wave slotted waveguide array antenna is an attractive candidate for high efficiency, high gain and low side lobe levels. The mechanically scanned operation is most suitable for CSR applications because of its light weight, rugged and compact structure. In addition, frequency scanning capability of SWG helps in implementing the frequency diversity which is unique capability and is not available in any other kind of antenna.

2. *Pedestal System*

The pedestal provides the 360 deg azimuth rotation with 16 bit encoder to provide accurate bearing information. The Pedestal can rotate up to 60 RPM at an increment of 1 RPM. The Pedestal is designed with programmable RPM and by selecting suitable combination of PRF and duty cycle, the slow decorrelation of sea clutter can be achieved, which is novel way to use variable revisit time for sea clutter mitigation

3. Solid State Power Amplifier (SSPA)

The solid state power amplifier (SSPA) is chosen for transmitter due to high duty and low peak power waveform. Solid state amplifier 400 W both in X band and S band with 15 percent duty cycle make the radar state-of-the art as most of CSR are non-coherent and magnetron based.

4. Wideband Exciter

Modern trend of CSR is of using of high range solution to primarily to discriminate closed formation of targets, improved intra clutter visibility. Due to the advent of high speed DDS (Digital Direct Synthesis) based waveform generator wideband waveforms of 20 MHz and 40 MHz bandwidth is developed. So, range resolution in the order of 7.5 m and 3.75 m is achieved in CSR. The polyphase code modulation and programmable wide band switching is achieved using FPGA and latest DDS chips. It makes CSR more agile and software configurable

5. Signal processor

The signal processor is designed to down convert 120 MHz signal to base band i.e 20 MHz/40 MHz, perform digital pulse compression, CFAR, binary integration. Custom signal processing schemes such as frequency diversity/agility and scan-to-scan cutter discrimination to mitigate sea clutter. The signal processor is a FPGA based and is highly programmable with a soft core NIOS II processor. It has more than 200 configurable words to optimize the signal processor in the field. The entire signal processor is realized in single board with a high density FPGA with very low power consumption

6. Radar Data Processor

The RDP utilizes the detection plots in the presence of sea clutter back ground to automatically create and associate consecutive radar observations of the same target into tracks, thus maintaining tracks for multiple targets and estimating heading and speed of a track visible within the radar coverage. The RDP performs automatic detection and tracking of up to 1500 sea surface targets for a range of 50kilometers (27 NM). It can handle 5000 raw measurements which is special of CSR tracker.

7. Site Deployment of CSR

Fig. 2. CSR at INS Dronacharya, KOCHI

IV. ADVANCED FEATURES OF CSR

1. ***Frequency Diversity/Agility:***

Clutter mitigation techniques such as frequency agility and frequency diversity are used to de-correlate the sea clutter. Clutter returns have a fairly short de-correlation period, typically of the order of 10ms, and are de-correlated from pulse to pulse by means of a radar employing frequency agility, provided that the radar frequency is changed from pulse to pulse by at least the transmitted pulse bandwidth. Clutter returns from high resolution radars can be modeled by two components. The first component is an underlying mean level which has a longer temporal de-correlation period and is not affected by frequency agility. The second component is the speckle component which has a mean level determined by first component of clutter model. The returns from any individual resolution cell have a short temporal de-correlation period (typically 10 ms) and are de-correlated from pulse to pulse by frequency agility and time diversity.

2. ***Scan-to-scan Correlation:***

For slowly fluctuating sea clutter which has a very high de-correlation time, PRF agility cannot be employed to de-correlate the same. Hence scan-to-scan correlation is necessary in such cases. Integration over periods of several seconds can help to discriminate against discrete clutter spikes. These spikes may appear target-like and persist over life times of typically between 0.1 and 2 s. There are three channel scan-to-scan decorrelation (i) Channel-1: three scan correlation for extremely slow moving targets (ii) Channel-2: Two scan correlation for medium speed target(iii)Channel-3: no correlation for high speed targets and these three decisions are fused using AND/OR logic get the final decision.

V. FIELD RESULTS

Three numbers of radar are developed and installed near coast and some of the results of radar targets being tracked is shown in Fig. 3 and Fig. 4 below.

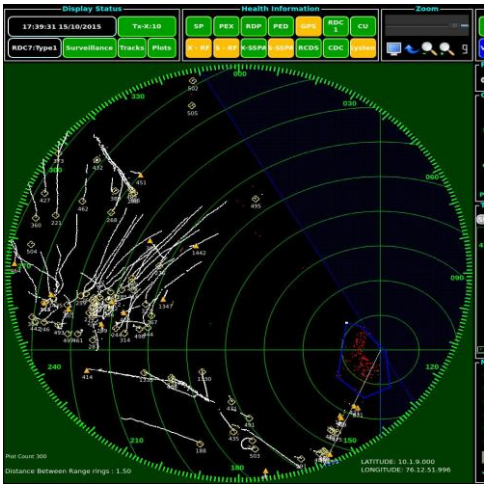


Fig.3 Dense target tracking by CSR

Fig.4 Another Target Scenario

The radar track also sent to COP(Common Operating Picture) for display and correlation with AIS and Indian IAIS. Some of the typical results obtained is shown in Fig XX

VI. POTENTIAL APPLICATION

Though the primary aim of the radar is to detect and track of small fishing vessels for Coastal surveillance application. The radar can be directly used for VTS (Vessel Traffic management Services) application, harbor surveillance, navigational radar. Since it is a solid state coherent radar with MTI option it can be directly used for Airport Surface Surveillance application as well.

VII. CONCLUSION

This paper presents a state-of-the-art design of a modern generation of coherent solid state Coastal Surveillance Radar (CSR) with frequency agility, wide band waveforms, sophisticated signal processing and tracking for integrated costal surveillance system. Robust mechanical design with day and night and all weather operation is one of the unique features of the radar. The modular design of the subsystem makes CSR high scalable and the radar can be used for various other applications.

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