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Radar Clutter, its avoidance and rejection Methods

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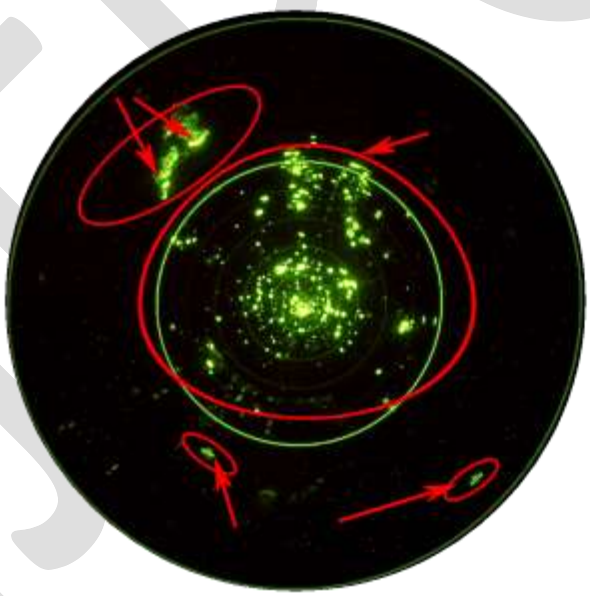
Abstract: Radar clutter may be defined as unwanted signals in a search Radar. Different types of clutters, their identification, avoidance and various types of techniques are illustrated in this paper. Clutter rejection, various radars used for this purpose, and the applications of such radars are discussed in this paper. Illustrative samples have also been discussed for emulators

Keywords— Radar, ATC, TSC, RAGCLEM, ARI, ARPA, UWB, DAR

I INTRODUCTION:

Radar returns are produced from nearly all surfaces when illuminated by radar. Therefore, in competition with the return from an aircraft, there are many sources of unwanted signals. Unwanted signals in a Search Radar are generally described as noise and clutter. Clutter is the term used and includes ground returns, sea returns, weather, buildings, birds and insects. The definition of clutter depends on the function of the Radar. For Instance, weather is not clutter in a weather detecting radar.



PPI screen of an ATC Radar with targets

II.TYPES OF CLUTTER: Clutter can be fluctuating or non-fluctuating. Ground clutter is generally non-fluctuating in nature because the physical features are normally static. On the other hand, weather clutter is mobile under the influence of wind and is generally considered fluctuating in nature. Clutter can be defined as homogeneous if the density of all the returns is uniform. Most of the surface and volume clutter are analyzed on this basis, however, in practice, this simplification does not hold good in all cases. Non-homogeneous clutter is non-uniform clutter where the amplitude of the clutter varies significantly from cell to cell. Typically non-homogeneous clutter is generated by tall buildings in built up areas.

The basic types of clutter can be summarized as follows:

Surface Clutter: Ground or sea returns are typical surface clutter. Returns from geographical land masses are generally stationary; however, the effect of wind on trees etc… means that the target can introduce a Doppler shift to the radar return. This Doppler shift is an important method of removing unwanted signals in the signal processing part of a radar system. Clutter returned from the sea generally also has movement associated with the waves. Doppler shift can be calculated by $\Delta\lambda/ \lambda_0 = V/C$, where

$\Delta\lambda$ is the shift in wavelength.

λ_0 is the wavelength of source not moving/ stationary source.

V is velocity of source-line of site

C is speed of light.

Doppler shift can be either Red-shift (a shift of frequency to a lower wavelength, away from the observer) or Blue-shift (a shift of frequency to a higher wavelength, towards the observer). The power received from the clutter is given by

$$C= P_tGA_e\sigma_c/[(4\Pi)^2R^4]$$

Where P_t is the transmitter power

G is gain of Antenna

A_e is antenna effective aperture

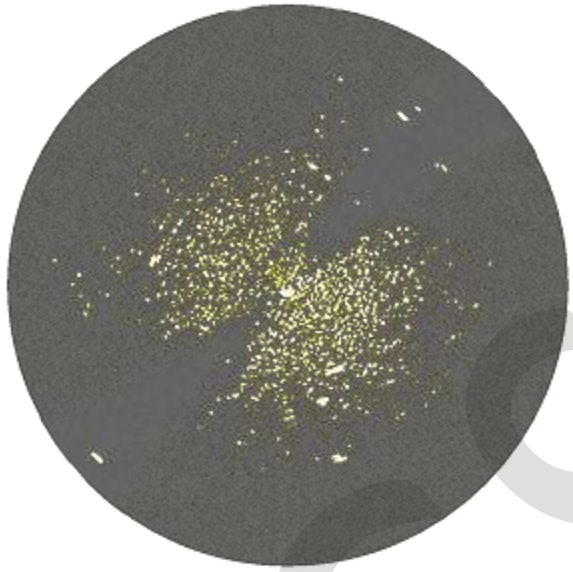
R is Range

σ_c is clutter cross-section.

Volume Clutter: weather or chaff are typical volume clutter. In the air, the most significant problem is weather clutter. This can be produced from rain or snow and can have a significant Doppler content.

Point Clutter: Birds, windmills and individual tall buildings are typical point clutter and re not extended in nature. Moving point clutter is sometimes described as angels. Birds and insects produce clutter, which can be very difficult to remove because the characteristics are very much like aircraft.

Sea-Clutter: Sea Clutter are disturbing radar-echoes of sea wave crests. This clutter gets also a Doppler-speed by the wind. This means, the scenario, moves away i.e. changes with time, while for ground clutter, it stays the same. Therefore, in practice, Sea-Clutter is very difficult to control without some loss in detection. Sea-Clutter can be seen here in the below picture, the wind comes from about 3100(NO) or from the opposite direction. (Unfortunately, whether the Doppler frequency is positive or negative cannot be recognized on the PPI-Scope. But this region, in which the radial speed of the waves is very small, is cleaned by the MTI system very clearly.



SEA-CLUTTER ON A PPI-SCOPE

III DETECTION AND REDUCTION MECHANISMS: Airborne maritime surveillance radars must detect small targets against a background of sea clutter whilst maintaining surveillance over a large area of sea. This task is very demanding and requires the radar to dynamically adapt to the local environment in order to obtain the best possible detection sensitivity. An aircraft flying at, say 3000 ft would be able to observe an area of sea of about 49,000 km, with a range to the horizon of about 124 km. Over this area, the clutter characteristics observed the radar will be continuously changing as a function of range and look direction. These characteristics will vary in a manner dependent on the prevailing conditions, the radar characteristics and the viewing geometry. In practice, the radar must cope with a very wide dynamic range of signal amplitude, with amplitude statistics varying from those of thermal noise to very spiky sea clutter and land. Continuous adaptation to this environment is required as a function of range and bearing. The dynamic behaviour of the radar as it adapts in this way is often a much more relevant measure of performance than more traditional static measures such as detection range.
Methods used to adapt to the environment are surveyed in this paper, together with indications of how their dynamic behavior can influence performance.

With the advent of a new airborne radar signal processing technology entitled, "space-time adaptive processing (stap)," previous testing methods have proven inadequate. stap algorithms minimize the amount of interference competing with the desired signal. the algorithms are complex and their reaction to an actual in the air scenario difficult to predict via analysis and simulation. the desired test is to evaluate the performance on the ground in a controlled environment prior to installation and test in the air. the problem is that although jamming signals can be relatively easily generated, ground clutter, which depends on the aircraft speed, antenna beam width and antenna look-angle is difficult to represent realistically. Technology service corporation (TSC) has developed a realistic radar ground clutter emulator (ragclem) which can be used to test stap processors.

The problem of clutter rejection when processing down-looking Doppler radar returns from a low altitude airborne platform is a paramount problem. With radar as a remote sensor for detecting and predicting wind shear in the vicinity of an urban airport, dynamic range requirements can exceed 50 dB because of high clutter to signal ratios. This presentation describes signal processing considerations in the presence of distributed and/or discrete clutter interference. Previous analyses have considered conventional range cell processing of radar returns from a rigidly mounted radar platform using either the Fourier or the pulse-pair method to estimate average wind speed and wind speed variation within a cell. Clutter rejection has been based largely upon analyzing a particular environment in the vicinity of the radar and employing a variety of techniques to reduce interference effects including notch filtering, Fourier domain line editing, and use of clutter maps. For the airborne environment the clutter characteristics may be somewhat different. Conventional clutter rejection methods may have to be changed and new methods will probably be required to provide useful signal to noise ratios. Various considerations are described. A major thrust has been to evaluate the effect of clutter rejection filtering upon the ability to derive useful information from the post-filter radar data. This analysis software is briefly described. Finally, some ideas for future analysis are considered including the use of adaptive filtering for clutter rejection and the estimation of wind speed spatial gradient directly from radar returns as a means of reducing the effects of clutter on the determination of a wind shear hazard.

The ARI Radar/ARPA simulator is a complete simulation solution meeting the requirements for simulators as per regulation I/12 of STCW 2010 and incorporates all the required features pursuant to MSC Res. 64(67) and MSC Res. A. 823(19) and is a complete emulation of shipboard Radar/ARPA equipment. The Radar Simulator can be used to conduct the IMO Model course 1.07 and has been type approved by the DGS, Government of India for that purpose. It may be used to conduct Radar/ARPA courses for navigators at both operational and management levels.

IV SPECIAL SIMULATOR APPLICATIONS: The simulator emulates a variety of the functionalities found in modern marine radar and provides control over traffic density, waterways, sea state and weather conditions. The ARI Radar/ARPA simulator is an extremely efficient and cost-effective solution which can be used in standalone mode for self-teaching, or in networked mode along with an Instructor console. The advanced mathematical design of this simulator enables replication of wide variety of control to provide training in a highly realistic environment. Features available include:

1. Environment Effects like wind, current and waves
2. True and Relative Motion Displays
3. X-Band or S-Band
4. Pulse Length
5. Clutter Suppression
6. Ground or Sea Stabilized
7. Course Up, North Up, Head Up Display
8. Range Rings On/Off
9. Gain Control
10. Brilliance
11. EBL/VRMs
12. Trial Manoeuver
13. Roll and Pitch Effects
14. Set and Drift Effects
15. Parallel Indexing
16. Target Acquisition; auto or manual
17. Target Tracking; saves up to 50 targets in memory
18. Target Data Display
19. CPA/TCPA Limit Setting
20. True and Relative Vectors
21. Guard Zones
22. Visual and Audio Alarms
23. Realistic Interference: Starring, Spoking, Multiple Echoes, Side Lobe Effect, Blind Sector, Shadow Sector
24. Performance Monitor
25. RAMARK and RACONS
26. SART activated by Instructor

The **W1905 Radar Model Library** saves development time and verification expense in R&D for radar system architects, algorithm developers, and system verifiers.

The library provides approximately 90 highly-parameterized simulation blocks and several dozen ready-made reference designs for creating working radar system scenarios, including radar processing blocks, environmental effects items such as clutter, targets, and even hardware measurements. Instead of modeling an entire scenario from primitive function calls for each object, simply connect realistic reference designs with RF models and test equipment to study and verify radar system architectures. The W1905 library can be applied to a wide range of radar technologies, making it a useful algorithmic reference for both commercial and military applications.

The W1905 library recently added 3D inertial modeling "layers" above the baseband radar signal processing references (see Figure 4 below). They account for the 3-D positions, velocities, rotations, and beam forming directions of each transmitter, receiver and target, allowing modelers to create and script meaningful airborne, ship borne and multi-static scenarios or environments.

Radar Technologies

(a) ultra-wideband (UWB) radars, and wideband receivers

(b) phased array and digital array radars (DAR), with dynamic coordinates, attitude, and beam forming weights

(c) synthetic aperture radars (SAR) and beam forming for raster imaging and mapping

(d) stepped-frequency radars (SFR) for ground- and wall-penetrating applications

(e) frequency modulated continuous-wave (FMCW) radars for automotive applications

(f) MIMO radars for increased range resolution and robustness

(g) Multi-static radars with multiple TX and RX locations, which can be in motion (vehicle/ship/air/space-borne)

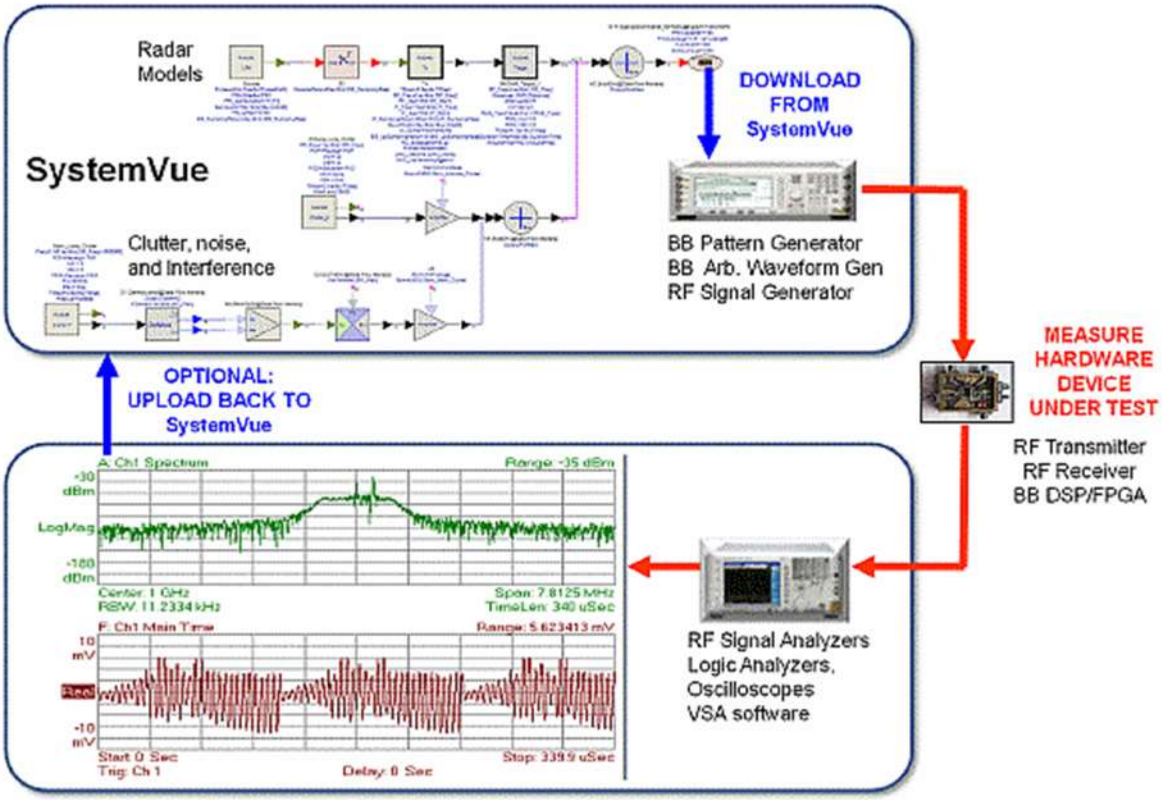
(h) signal generation for embedded simulators and test & measurement applications

(i) Pulsed and pulsed-Doppler (PD) radar architectures for telemetry and EW applications

The W1905 block set and its example workspaces serve as algorithmic and architectural reference designs to verify radar performance under different signal conditions. These can include target and RCS scenarios, clutter conditions, jammers and environmental interferers, and more. By accounting for a diverse set of environmental effects, while maintaining an open modeling environment (.m, C++, VHDL, test equipment), the Radar system designer can explore architectures with high confidence in early R&D, without requiring expensive outdoor range testing or hardware simulators.

V SYSTEM VUE'S ALGORITHM MODELS: SystemVue connects baseband algorithm modelers with a variety of other domains. SystemVue can also be used to create reference signals for download to test equipment, as well as post-process signals captured from test equipment, to create virtual verification systems at low cost.

SystemVue's W1905 radar library helps model the signal processing algorithms as well as the radar environment, and connects to UWB test equipment, such as the new Keysight M8190A AWG, M9703A digitizer, and Keysight's 90000-series oscilloscopes as shown in the figure below.



Recent Upgrades (as of SystemVue 2013.08 SP1)

a. Now provides an inertial coordinate framework for modeling moving platforms, targets, clutter, and including the effect of dynamic RCS and beam forming patterns in 3-dimensions. This allows easier creation of multi-static airborne and ship-borne scenarios.

b. New blocks and examples for MIMO Radar, Phased Array Radar with dynamic beam forming, Stepped-Frequency Radar (SFR), Synthetic Aperture Radar (SAR), Automotive Radar, electronic warfare (EW) and electronic counter measures (ECM)

c. New and updated models for user-defined antenna patterns and scanning, clutter models, moving targets, polarization, time-gating, pulse compression, CFAR, Direction of Arrival, MUSIC, SPIRIT and other algorithms

d. External scriptability and control of the SystemVue platform, allowing integration with other application providers, such as terrain map databases and structured verification suites

Updated instrument drivers for Keysight's family of wideband arbitrary waveform generators (AWG), such as M8190A. SystemVue also includes a new waveform utility called "Waveform Sequence Composer". Sources can also now include jitter and programmable pulse offsets.

Applications:

a. Create proposals and assess feasibility quickly

b. Accurate radar system architecture and scenario analysis
   1. Include realistic RF effects, clutter, fading, and directly-measured waveforms
   2. Leverage your existing math, HDL, and C++ algorithms
   3. Continue into hardware test using the same SystemVue environment and IP
   4. Multi-Emitter Environment Test Signals

c. Algorithmic reference & test vector generation for baseband DSP hardware design

d. Precisely-degraded BB/RF signal generation for receiver testing
   1. Reduce the need for expensive chambers, hardware emulators, faders, and field testing in the early phases of design
   2. Reduce NRE and scripting with regression suites of simulated scenarios
   3. Save time by verifying algorithms prior to targeted FPGA/ASIC implementation

e. Minimize project costs with easily reconfigured Keysight simulation tools and test equipment

VI CONCLUSION: Thus we can use various methods like ARPA, Systemvue's simulation techniques for detection and reduction of radar clutter in almost all the applications.

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