Journal of Information Systems and Communication
ISSN: 0976-8742 & E-ISSN: 0976-8750, Volume 3, Issue 1, 2012, pp.-332-334
Available online at http://www.bioinfo.in/contents.php?id=45

CLUTTER REJECTION IN OUTDOOR RADAR OPERATION BY CORRELATION METHOD FOR KNOWN TARGET

KANDAR D.[1], GUCHHAIT A.[2], ADHIKARI A.[3], PADMA PRASANNA S.[1], KALPANA R.A.[1], REVATHY J.[1], MAJI B.[4]

[1]SKP Engineering College, Thiruvannamalai, Tamilnadu, India.
[2]Surendra Institute of Technology & Management, Dhukuria, Siliguri-734009, India.
[3]Bengal College of Engineering & Technology, Bidhan Nagar, SSB Sarani, Durgapur-713212, India.
[4]National Institute of Technology, Durgapur-713209, India.
*Corresponding Author: Email- kdebdatta@rediffmail.com

Received: January 12, 2012 , Accepted: February 15, 2012

Abstract- The major problem in RADAR signal detection is to detect a target in a non-stationary noise and clutter environment. In the past, there have been several approaches dealing with the problem of signal detection in various types of clutter. In this paper, our goal is to extract target information in a clutter prone environment. In simulation, we introduced random clutters having returns comparable to target in channel model. Cross-correlation process has been introduced for clutter rejection. After cross-correlation process we further introduced signal processing to suppress clutter returns and the target information has been extracted.
Keywords- Clutter, Cross-Correlation, Spread Spectrum, Software Defined Radio, Neural Network.

Citation: Kandar D., et al. (2012) Clutter Rejection in Outdoor RADAR Operation by Correlation Method for Known Target. Journal of Information Systems and Communication, ISSN: 0976-8742 & E-ISSN: 0976-8750, Volume 3, Issue 1, pp.-332-334.

Introduction

Due to clutter from the ground the SCR is low (typically about -50 dB to -60 dB) for static targets and the detection is very difficult[1]. For small target detection clutter rejection is often an essential task, making the choice of a clutter rejection algorithm extremely important. Many different clutter rejection algorithms have been developed[2,3] by various groups seeking to address this problem.

Ground Clutter Consideration

Factor that affecting radar performance is ground clutter. Ground clutter is an unavoidable form of radar contamination. It occurs when fixed objects, such as buildings, trees, or terrain, obstruct the radar beam and produce non-meteorological echoes. Echoes resulting from ground clutter are usually exaggerated in both size and intensity and may cause radar systems to overestimate precipitation intensity near the radar. Clutter is normally found close to the antenna where the radar beam is nearest to the ground. Further out, the beam points gently skyward and overshoots most obstacles. Under certain circumstances, however, clutter may exist far away. A tall mountain range would be a good example of this. The key to dealing with ground clutter is operator awareness and experience[4].

High resolution RADAR image can be formed by processing Radar Cross Section (RCS) data [5] and measurement of which (RCS) under the outdoor condition is different from the measurements inside the indoor condition [6,7]. Radar cross section is the measure of a target's ability to reflect radar signals in the direction of the radar receiver, i.e. it is a measure of the ratio of backscatter power per steradian (unit solid angle) in the direction of the radar (from the target) to the power density that is intercepted by the target. The conceptual definition of RCS includes the fact that not all of the radiated energy falls on the target. A target's RCS is most easily visualised as the product of three factors:

- projected cross section,
- reflectivity,
- directivity.[8]

During the outdoor measurements dynamic channel conditions effect on measurement accuracy. Presence of ground itself changes the outdoor scenario, specially for low gazing angles[9]. Due to presence of ground, the target under test (TUT) is illuminated by many paths of transmitted electromagnetic rays. Similarly the return from target towards the receiving antenna also follows more paths. These reflected rays interfere with the direct rays and thus change the amplitude and phase distribution across the test-zone (Quiet-zone). RADAR's capability to detect targets depends on the Signal-to-Clutter Ratio (SCR) instead of Signal-to-Noise Ratio (SNR). Normally, clutter signal level is much higher than the receiver noise level. Grazing angle (Ψ_g), surface roughness, and the RADAR wavelengths mainly affect the amount of clutter in the RADAR operation. RADAR can distinguish target returns from clutter echoes which are based on the target RCS (s_t) [10], and the anticipated clutter RCS (sc). Clutter RCS can be defined as

$$sc = s^0 A_c \quad (1)$$

Where s^0 (m^2/m^2) is the clutter scattering coefficient, expressed in dB.

The clutter area $\boldsymbol{A_c}$ and **SCR** are defined as

$$A_c \approx R\theta_{3dB} \frac{c\tau}{2\tau} \mathrm{Sec}\Psi_g \quad (2)$$

$$SCR = \frac{2\sigma_t \cos\Psi_g}{\sigma^0 \theta_{3dB} R\, c\tau} \quad (3)$$

Clutter-to-Noise (CNR) is defined as

$$CNR = \frac{P_t G^2 \lambda^2 \sigma_c}{(4\pi)^3 R^4 K T_0 B F L} \quad (4)$$

P_t is the peak transmitted power, G is the antenna gain, λ is the wavelength, K is Boltzman.s constant, T_0 is the effective noise temperature, B is the RADAR operating bandwidth, F is the receiver noise figure and L is the total RADAR losses. For Gaussian clutter, the clutter and noise can be combined and RADAR measurement can be derived from the Signal-to-clutter + Noise ratio is given by

$$SIR = \frac{1}{\left(\frac{1}{SNR} + \frac{1}{SCR}\right)} \quad (5)$$

Clutter Rejection By Cross-Correlation Method

Recently, Spread Spectrum RADAR [11,12,13], Space-Time Adaptive Processing RADAR [14,15,16,17,18,19], Cognitive RADAR [20,21,22] have got attention in outdoor RADAR operation but, still it requires further signal processing. The clutter returns can be suppressed in a signal processor of the radar system by cross-correlation method. Cross-correlation computes the sample cross-correlation function (XCF) between two univariate, stochastic time series. In telecommunications, a matched filter is obtained by correlating a known signal, or template, with an unknown signal to detect the presence of the template in the unknown signal. This is equivalent to convolving the unknown signal with a conjugated time-reversed version of the template (cross-correlation). The matched filter is the optimal linear filter for maximizing the signal to noise ratio (SNR) in the presence of additive stochastic noise. Therefore, the matched filter output can be computed from the cross-correlation between the radar received signal and a delayed replica of the transmitted waveform. If the received signal is the same as the transmitted signal, the output of the matched filter would be the autocorrelation function of the received (or transmitted) signal.

MATLAB Simulation

Chirp Signal

We, consider a chirp signal as transmitted waveform. The complex Chirp signal can be expressed as

$$S(t) = u(t)\, e^{2\pi f_0 t} = \frac{1}{\sqrt{T}} rect\left(\frac{t}{T}\right) e^{j2\pi\left(f_0 t + \frac{Kt^2}{2}\right)} \quad (6)$$

where the complex envelop *u*(*t*) is defined as

$$u(t) = \frac{1}{\sqrt{T}} rect\left(\frac{t}{T}\right) e^{j\pi K t^2} \quad (7)$$

Where, *T* is the pulse width. The instantaneous frequency of the Chirp signal is defined as

$$f_i = \frac{1}{2\pi}\frac{d}{dt}\left[2\pi\left(f_0 t + \frac{Kt^2}{2}\right)\right] = f_0 + Kt \quad (8)$$

where K = B/T is the frequency slope, B is the frequency range. The cross-correlation of two complex functions *f(t)* and *g(t)* of a real variable t, defined by

$$f * g \equiv \bar{f}(-t) * g(t), \quad (9)$$

where * denotes convolution and $\bar{f}$ *(t)* is the complex conjugate of *f(t)*. Since the convolution is defined as

$$f * g \equiv \int_{-\alpha}^{+\alpha} f(-\tau)\, g(t-t)\, dt, \quad (10)$$

it follows that

$$[f * g](t) \equiv \int_{-\alpha}^{+\alpha} \bar{f}(-\tau)\, g(t-t)\, dt, \quad (11)$$

Putting t' ≡ -t, dt' = -dt, so equation c becomes to

$$f * g = \int_{+\alpha}^{-\alpha} \bar{f}(\tau' * g(t+t')(-dt') \quad (12)$$

$$= \int_{-\alpha}^{+\alpha} \bar{f}(\tau * g(t+t)\, dt \quad (13)$$

By correlation process and baseband processing at the RADAR receiver, we successfully simulated a clutter rejection method in Matlab. In Matlab, the transmitted (Tx) and received (Rx) signal can be represented by Equation 14 and 15.

$$u_t(t) = \exp(i\, p\, (B/T)\, t^2) \quad (14)$$

$$u_r(t) = \exp(i\, p\, (B/T)\, (t + 2R/c)^2)) \quad (15)$$

The 'R' represents the target range information.

Simulation Results

Fig. 1 and Fig. 2 depicts the transmitted and received signal (without any processing) respectively. We, introduced additional random clutters (clutter return comparable to target return) to the intended signal in the channel model. At the received end after introducing matched filter, we are able to eliminate the lower valued clutter with respect to target returns. Multiple targets have been detected after correlation process as shown in Fig. 3. Equation 16 represents the cross-correlation between the Tx and Rx signals.

$$[out, lag] = cross\_corr(u_t, u_r), \quad (16)$$

Where cross_corr represents the cross-correlation function written in Matlab and 'out' returns the cross-correlation sequence over the lag range. The plot of cross-correlation coefficient with range gives the target as well as clutter information as shown in Fig. 3.

As, in our case, the target distance is known, by further processing (special zero padding), clutter can be rejected as shown in Fig. 4.

In our design, we consider 26 mSec pulse width and 100 MHz bandwidth. The two targets were positioned at 32m and 46m distance. After correlation process, the two targets along with random clutters are plotted in

Fig 3. As, the target positions are predefined, we replaced clutter return by zero padding and the processed data has been plotted in Fig 4. Thus, the prominent clutters have been suppressed and targets at 32m and 46m have been detected.

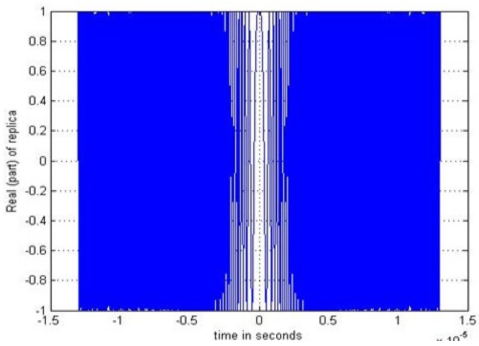

Fig. 1- Transmitted Signal

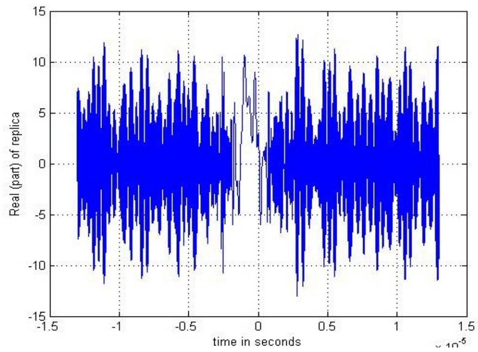

Fig. 2- Received Signal

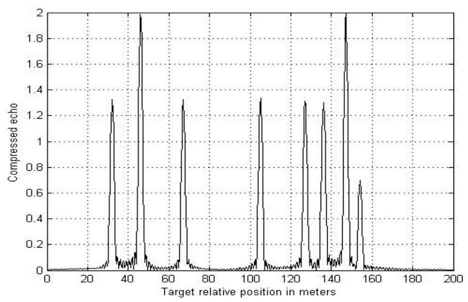

Fig. 3- Detection of Targets along with Clutters

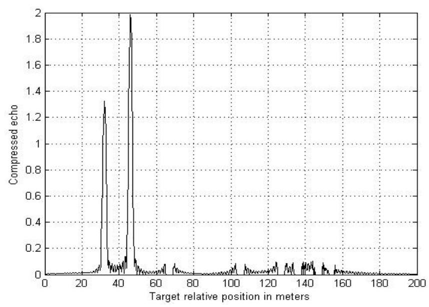

Fig. 4- Target Detections Without Clutters

Conclusion

Clutter rejection by cross-correlation method is very useful technique in RADAR measurement. As the target position is fixed, the distance between the RADAR and target is predetermined, it helps us to suppress clutter again by further signal processing. Our mathematical model for outdoor RADAR operation has been tested in simulation. Further attention required for actual scenario.

References

[1] Wang G., Xia X.G., Root B.T., Chen V.C., Zhang Y. and Amin M. (2003) *IEEE -Radar Sonar Navig*, 150(4).
[2] Richard J. Dunn, Price T. Bingham, Charles A. Bert Fowler (2004) *Ground Moving Target Indicator Radar Ground Moving Target Indicator Radar and the Transformation*.
[3] Hans Torp (1997) *IEEE transactions on ultrasonics, ferroelectrics, and frequency control*, 44(2).
[4] *http://www.tpub.com.*
[5] Mesa D.L. (1991) *High Resolution Radar Cross-Section Imaging*.
[6] Bera R., Bera J., Sil S., Kandar D. and Dey D. (2004) *spread spectrum based cellular phone technology to digital radar*, 1-3.
[7] Kandar D. and Bera R. (2005) *Development of an imaging radar instrumentation system using DS-UWB wireless technology*, *International Union of Radio Science.*
[8] Ioan Nicolaesu, Teofil Orian (2001) *IEEE transactions on Telecommunications in Modern Satellite, cable and broadcasting service*.
[9] Simon Haykin (2007) *Adaptive Radar Signal Processing*.
[10] Knot E.F. (2006) *Radar Cross-Section Measurement*.
[11] Skolnik M. (2002) *Introduction to Radar System*.
[12] Knott E.F. (2004) *Radar Cross Section*.
[13] Sinha N.B., Kandar D. and Bera R. (2008) *Electromagnetics Research*, 1, 185-195.
[14] Monzingo R.A. and Miller T.W. (2003) *SciTech*.
[15] Klemm R. (2002) *Institute of Electrical Engineers*, 12.
[16] Qu Y., Liao G.S., Zhu S.Q., Liu X.Y. and Jiang H. (2008) *Electromagnetics Research,* 123-134.
[17] Bliss D.W., Forsythe K.W. (2003) *Multiple-Input Multiple-Output (MIMO) Radar and Imaging: Degrees of Freedom and Resolution", IEEE*.
[18] Guerci R., Wicks M.C., Bergin S., Techau M. and Pillai S.U. (2008) *Theory and Application of Optimum and Adaptive MIMO Radar, IEEE.*
[19] Ward J. (1998) *IEEE Colloquium,* 2.
[20] Joseph R. Guerci (2010) *Cognitive Radar : The Knowledge-Aided Fully Adaptive Apporoach*.
[21] Haykin S., *IEEE Signal Processing Magazine,* 23, 33-40.
[22] Fulvio Gini and Muralidhar Rangaswamy (2008) *Knowledge-Based Radar Detection, Tracking and Classification*.