Advances in Radar Techniques

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Most of the clutter received by L, S, C, X, and Ku band radars obeys a Weibull distribution. To suppress such Weibull-distributed sea and weather clutter, Weibull CFAR techniques are applied to data taken by an X-band radar using computer in real time. The results show the usefulness of Weibull CFAR.

Keywords : radar clutter, Weibull distribution, Weibull CFAR

In radar signal processing, an important problem is to suppress various clutter and to improve target detectability over such clutter. Clutter is defined as the unwanted reflected waves from irrelevant targets, for example, ground clutter, sea clutter, sea-ice clutter, weather clutter by clouds, rainfall, angel echo by birds, insects and atmospheric fluctuation, and chaff by artificial interference.

In order to improve target detectability in the presence of such clutter, various anti-clutter techniques have been utilized. For example, an MTI(Moving Target Indicator) is used against ground clutter, and the LOG/CFAR(Logarithmic Constant False Alarm Rate) system is used against Rayleigh-distributed sea and weather clutter having a large dynamic range. The LOG/CFAR system reduces the clutter output to about the receiver noise level by means of a logarithmic amplifier and a CFAR circuit. When the clutter are not distributed according to a Rayleigh distribution, the output level is not kept constant and discrimination of the target from clutter is no longer easy. Recently, non-Rayleigh distributed clutter has been observed with relatively high-resolution radars. For example, ground, sea, sea-ice and weather clutter obey a Weibull distyribution, which incorporates the Rayleigh distribution as a special case. Thus, recently, there has been a continuing great interest in various Weibull-distributed clutter.

A general form of the Weibull distribution is given by

$$p_w(x) = \frac{c}{b} \left(\frac{x}{b} \right)^{c-1} e^{-(x/b)^c}$$

where b is a scale parameter and c is a shape parameter; for $c=1$ and $c=2$, this distribution is identical to an exponential distribution and a Rayleigh distribution, respectively. The shape parameters are a function of surface condition, grazing angle, wavelength and polarization. It is reported that various clutter obey a Weibull distribution with shape parameters from $c=0.5$ to $c=2.0$ corresponding to a Rayleigh distribution. If various clutter obey a Weibull distribution, perfect suppression of the clutter cannot be attained by using the conventional LOG/CFAR system, since the output clutter level is dependent on the variance and hence depends on the shape parameters of the Weibull distribution. The shape parameters and false alarm probability are shown in Fig.1. If the shape parameters decrease from $c=2.0$ to 0.5 , the false alarm rate increases. To maintain a CFAR, we transform from the Weibull distribution to the Rayleigh distribution. This circuit is

shown in Fig. 2. After transformation, the signals pass through the conventional cell-averaging LOG/CFAR circuit.

Figure 3 shows raw data of Tokyo Bay in clear sky taken by an X-band radar. Figure 4 shows sea clutter with high sea state taken by the same X-band radar. Figure 5 shows the result by using the Weibull CFAR in Fig. 2. Sea clutter was suppressed and the targets were clearly detected. Figure 6 shows weather clutter in typhoon season. Figure 7 shows the result by considering the Weibull CFAR in Fig. 2. These processes are performed by

Fig. 1. False alarm probability versus shape parameter

Fig. 2. Transformation from Weibull to Rayleigh distribution

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Fig. 3. Raw data in clear sky

Fig. 6. Weather clutter

Fig. 4. Sea clutter

Fig. 7. Weibull CFAR

Fig. 5. Weibull CFAR

computer in real time and shows the validation of Weibull CFAR.
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