Detection Performance Comparison for Wideband and Narrowband Radar in Noise

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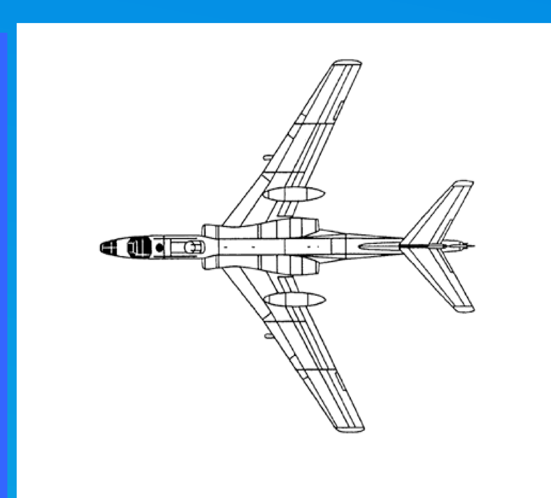
Organization in which you are working

Research questions

The aim of this paper is to evaluate the detection ability of the wideband radar in receiver noise and make a comparison with the narrowband radar. To compare the detection performance of wideband and narrowband radar, we assume the transmitting power, the pulse width, the noise temperature of the receiver, the target range and the target RCS of them are same. The SNR gain of matched filter is equal to the time-bandwidth product of the transmitting waveforms, so the output noise power of matched filter of wideband and narrowband radar are same in the above conditions. Then the factors affecting the detection performances of them are the target RCS fluctuation and detection algorithms.

Target fluctuation of wideband and narrowband radar

The narrowband radar target return is the phasor addition of the returns of all scatterers of the target, which is shown in the Fig.1. So the narrowband radar return is sensitive to the view aspect of the target, a little change of view aspect can cause a very large change of the amplitude of the target return. When the target scatters is resolved into different range cells by the wideband radar, the fluctuation of the target return is decreased. The RCS of the airplane TU-16 of 1GHz and 5MHz bandwidth Are Illustrated in Fig.2. It is clear that the fluctuation of 1GHz RCS is less than that of 5MHz.



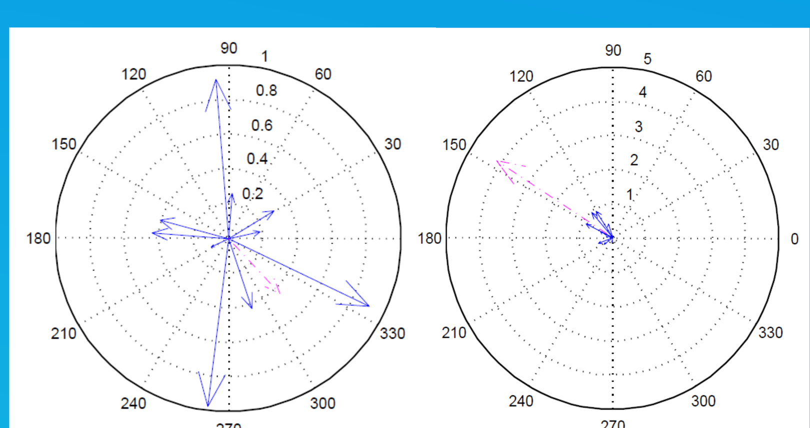


Fig.1 Phasor addition of components of Narrowband target backscatter

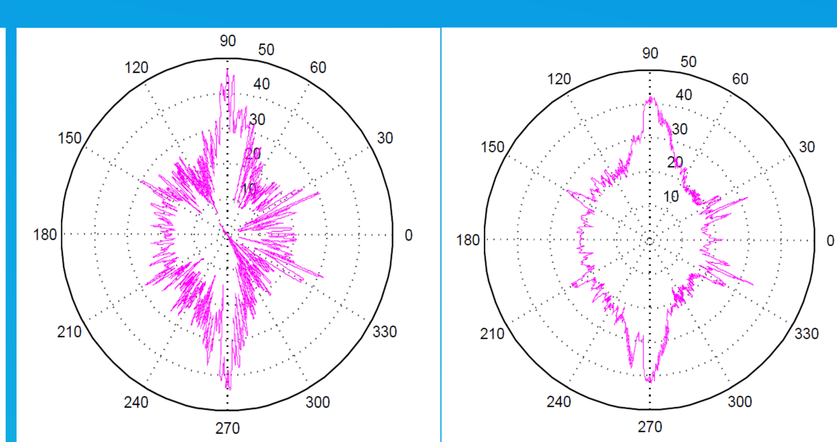


Fig.2 Wideband and Narrowband RCS of TU-16

Wideband Matched Reception

If the target impulse response is known, we can get the maximum SNR by matched reception, which is equivalent to perform coherent integration on the returns reflected by all scatterers, then t he detection performance of wideband radar will be improved in high SNR due to no fluctuation.

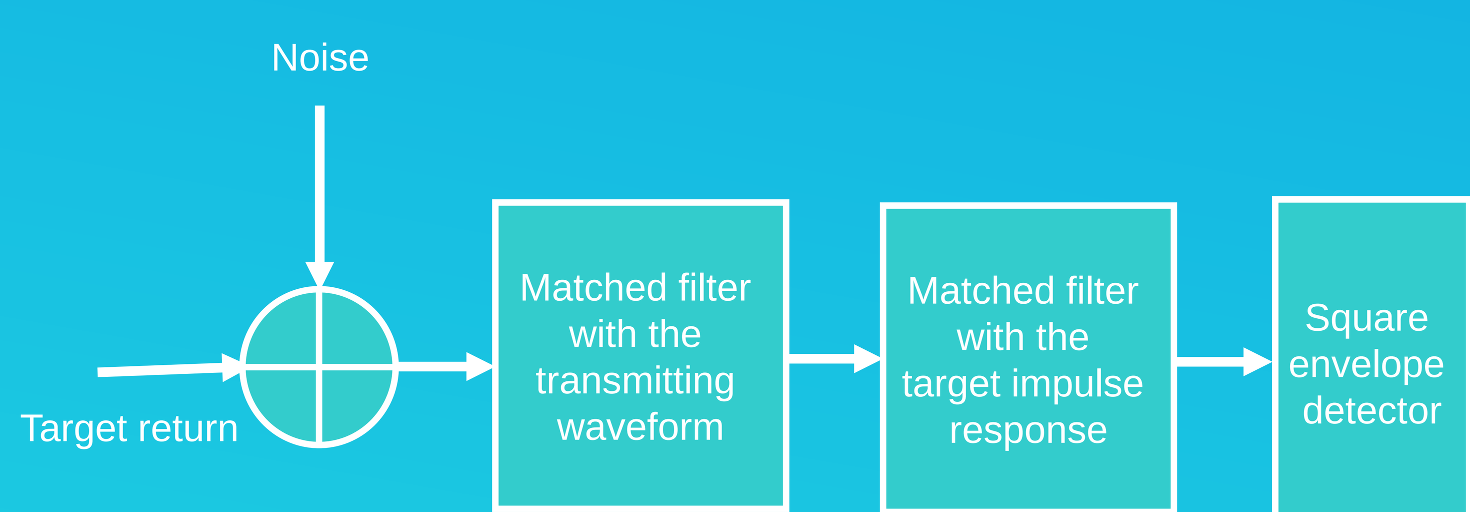


Fig.3 Structure of wideband matched reception

Detection probability:

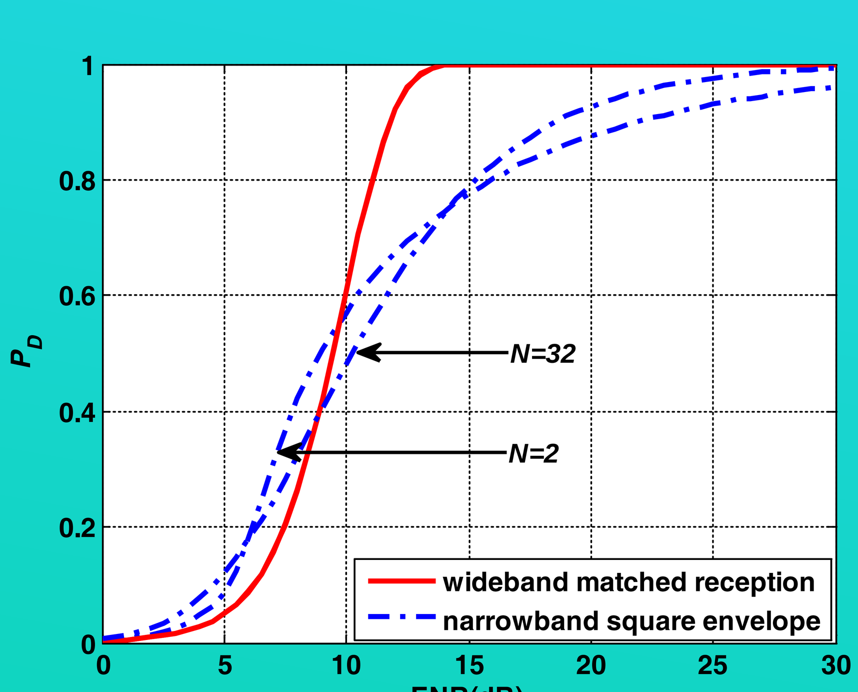
$$P_D=\int_{\eta}^{+\infty} f_T(t)\,dt=e^{-\frac{Na}{\sigma^2}}e^{-\frac{\eta}{2}}\sum_{i=0}^{+\infty}\frac{1}{i!}\left(\frac{Na}{\sigma^2}\right)^i\sum_{k=0}^{i}\frac{1}{k!}\left(\frac{\eta}{2}\right)^k$$

Probability density function of square envelope:

$$f_T(t)=e^{-\frac{t}{2}}e^{-\frac{Na}{\sigma^2}}\sum_{i=0}^{+\infty}\frac{1}{i!}\left(\frac{Na}{\sigma^2}\right)^i\left(\frac{t^i}{2^{i+1}i!}\right),\qquad t>0$$

Threshold:

$$\eta=-2\ln P_{\mathrm{fa}}$$



Remark1:
The performance of wideband reception is irrelative to the target impulse response;

More scatterers corresponds to worse performance for narrowband radar due to more fluctuation;

The more the scatters of the target is, the wideband r eception outperforms the narrowband detector.

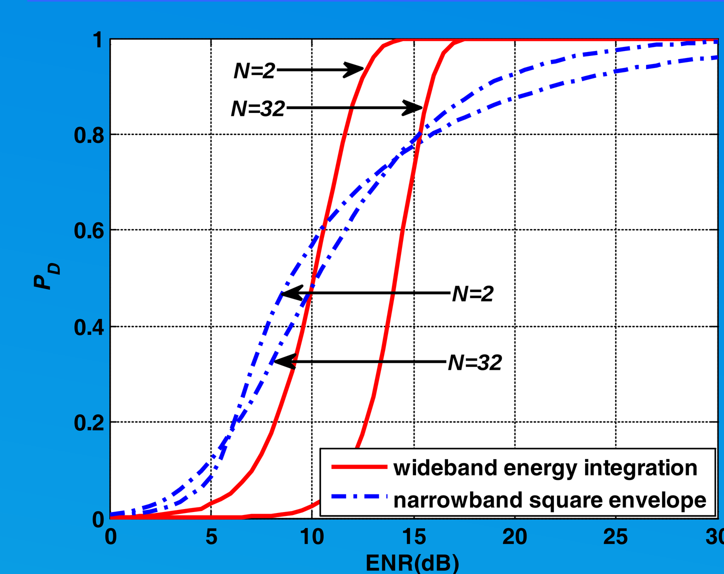
Fig.4 Detection probability curves of wideband reception and narrowband power detection (*N* is the number of range cell containing target scattering

Wideband energy integration

In practice, the target impulse response can not be known at the stage of detection. So the matched reception is infeasible, and the energy integration should be adopted. Unlike wideband reception, the energy integration will integrate the ps. ower of noise, which is a important factor deteriorating the detection performance. The performance of wideband energy integration detector s evaluated through wideband Swerling 0, Swerling I and Swerling III target model

Wideband Swerling 0 target

To some simple artificial targets, such missile, there are only several isolated scatterers. Supposing that wideband radar can resolve all the scatterers of the target, the wideband target returns will be not fluctuation.



Detection probability:

$$P_D=\int_{\gamma}^{+\infty} f_T(t)\,dt=e^{-\frac{\gamma}{2}}e^{-\frac{Na}{\sigma^2}}\sum_{i=0}^{+\infty}\left(\frac{Na}{\sigma^2}\right)^i\frac{1}{(i+N-1)!}\sum_{k=0}^{i}\frac{1}{k!}\left(\frac{\gamma}{2}\right)^k$$

Probability density function of energy integration:

$$f_T(t)=e^{-\frac{t}{2}}e^{-\frac{Na}{\sigma^2}}\sum_{i=0}^{+\infty}\frac{1}{i!}\left(\frac{Na}{\sigma^2}\right)^i\left[\frac{t^{i+N-1}}{2^{i+N}(i+N-1)!}\right],\qquad t\ge 0$$

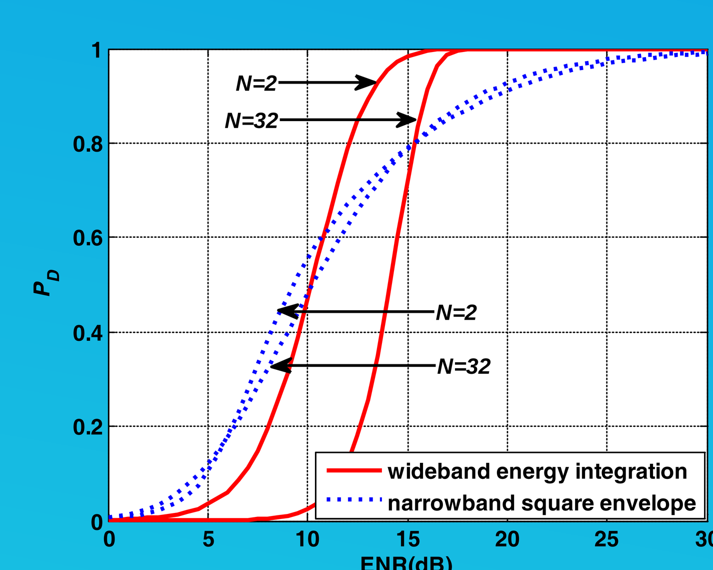
Threshold:

$$P_{\mathrm{fa}}=e^{-\frac{\gamma}{2}}\sum_{k=0}^{N-1}(\gamma/2)^k/k!$$

Fig.5 Detection probability curves of wideband energy integration and narrowband power detection for wideband Swerling 0 target

To some complex artificial targets, like airplanes, ships and vehicles, etc., the distribution of target s catterers is very complicated and there are unresolved scatterers still in each range cell to wideband radar. So the return of each range cell fluctuates. In [6], the authors analyzed the measured data of wideband radar returns and introduced two types' statistical models to describe different kinds of scatterer distribution in a range cell. They are: Rayleigh fluctuation model and Ricean fluctuation model, which corresponds to wideband Swerling I and Swerling III targets respectively.

Wideband Swerling III target



Detection probability:

$$P_D=\int_0^{+\infty}\int_{\gamma}^{+\infty}e^{-\frac{z}{\sigma^2}}e^{-\frac{t}{2}}\sum_{i=0}^{+\infty}\frac{1}{i!}\left(\frac{z}{\sigma^2}\right)^i\left(\frac{t^{i+N-1}}{2^{i+N}\Gamma(i+N)}\right)f_Z(z)\,dt\,dz$$
$$=e^{-\frac{Na}{b+\sigma^2}}e^{-\frac{\sigma^2\gamma}{2(b+\sigma^2)}}\sum_{i=0}^{+\infty}\frac{1}{i!}\left(\frac{Na}{\sigma^2}\right)^i\sum_{k=0}^{+\infty}\frac{1}{k!}\left(\frac{\gamma}{2}\right)^k\left(\frac{b+\sigma^2}{\sigma^2}\right)^{N-k-1}$$

$$f_Z(z)=e^{-\frac{Na}{b}}e^{-\frac{z}{b}}\sum_{i=0}^{+\infty}\frac{1}{i!}(Na)^i\left(\frac{1}{b}\right)^{2i+N}\frac{z^{i+N-1}}{\Gamma(i+N)},\qquad z\ge 0$$

Probability density function of energy integration:

Threshold:

$$P_{\mathrm{fa}}=e^{-\frac{\gamma}{2}}\sum_{k=0}^{N-1}(\gamma/2)^k/k!$$

Remark2:
The performance of wideband energy integration detector is the tradeoff between the fluctuation decreasing and integration loss. With the number of range cells increasing, the cross point of detection curves of the wideband and narrowband radar moves to higher detection ability. In the above analysis, the number and location of the range cells that containing target scatterers is assumed be known, but in practice this assumption is not always true, then the integration loss of wideband energy integration loss will be more.

Conclusions and future works

The results show that the detection performance of wideband radar return is better for high ENR due to its decreased fluctuation. To the wideband radar energy integration detector, however, slight fluctuation is concomitant with integration loss simultaneously which will increase with integration cells increasing. From the perspective of detection ability in noise, moderate wideband maybe better rather than large bandwidth. Since the performance of the wideband radar is deteriorated by integration loss, so we will design the wideband radar detector with less integration loss.

References

1. P. K. Hughes, "A High-Resolution Radar Detection Strategy," IEEE Trans on Aerospce Electronic System, vol. 19, pp. 663-667, May 1983.
2. E. Conte, A. D. Maio and G. Ricci, "GLRT-Based Adaptive Detection Algorithms for Range-Spread Targets", IEEE Trans on Signal Processing, vol. 49, pp. 1336-1348, July 2001.
3. K. Gerlach, M. Steiner and F. C. Lin, "Detection of a Spatially Distributed Target in White Noise," IEEE Signal Processing Letter, vol. 4, pp. 198-200, July 1997.
4. D. R. Wehner, High resolution Radar, 2nd ed, Boston: Artech House Publisher, 1994.
5. V. M. Orlenko andY. D. Shirman, "Non-Coherent Integration Losses of Wideband Traget Detection," First European Radar Conferences, pp. 225-228, Amesterdam, October 2004.
6. L Du, H Liu, Z Bao and J Zhang, "A two-distribution compounded statistical model for radar HRRP target Recognition," IEEE Trans on Signal Processing, vol.55, pp.1223-1237, April 2007.