Clutter Mitigation of MTI Radar by Moderation of Blind Speed

Muhammd Saleem, Abdullah Sadiq, M.R. Anjum
The Islamia University of Bahawalpur, Pakistan
Pakistan
mr.saleem400@gmail.com
abdullahnoon1992@gmail.com
engr.muhammadrizwan@gmail.com

ABSTRACT: *In radar system to achieve high visibility of clutter, blind speed personate severe limitation on the proper detection and tracking of MTI radar. By changing the pulse repetition interval which can increase the tolerable values of the blind speed. A severe problem may arise in the form of blind Doppler, no detection of target. To eliminate these blind speeds possible method of PRF staggering is used. Instead of using two radar to alleviate the blind speed of two different PRF,s single radar can minimize the effect of blind speed by two or different PRFs. in this paper systematic method is designed to eliminate the blind speed.*

Keywords : MTI radar, Blind Speed, MTI filters, Clutter Supression.

Received : 13 February 2016, Revised 21 March 2016, Accepted 26 March 2016

1. Introduction

A moving target that moves at such speed and will appear stationary, the echoes of moving target is cancelled along the echoes of stationary targets .The speeds cause Doppler shift to be an integral multiple of 2 pi are known as blind speeds.It happened due to the large ground return at zero that prevent the detection of the desire target. Due to blind speed radar is unable to detect and track the target of interest, so radar is said to be blind for detection and tracking. PRF staggering is used to minimize the blind speed [1]. It happened because Doppler pulse repetition rate is the difference between transmitted pulse repetition and received pulse repetition rate when it will be zero. Any target which is moving at blind speed will be undetectable. Many interrelated parameter values are involve to design a radar system. However even if method is to be economical design, it is unsatisfactory in that one is never quite certain that the best solution has been found. A systematic design procedures is required to design a expense and complexity of modern radar that start from the specification and, step by step, lead to the simplest system that meet required specification and cost effective. A question raised for consideration to design of the blind speed elimination scheme in a MTI radar. In order to accomplish the low Doppler sidelobes needed for good clutter suppression, The system coherently process several pulses repeated at a uniform rate [2]. The result comes after the difference of transmitted and received pulses. Doppler ambiguities introduce blind Doppler zones at multiples of the PRF. The practical method to eliminate blind speeds , PRF staggering technique is used. This is use several different PRF are staggered at different interval of time. Maximum target Doppler is proportional to the carrier frequency for a specified maximum target speed. The number of effective anbigguities will l increase with carrier frequency so Doppler ambiguities are spaced at the PRF. To resolve the difficulties of blind speed elimination , we choose a higher frequency in order to meet the angular accuracy specifications. The selection of the number of PRF's, as the carrier frequency is increased the Doppler spread of the clutter will increase in proportion, for a given PRF ,a larger percentage of one PRF interval will be blind due to the clutter. It means more PRF's is required to eliminate the blind Doppler [3]

2. Doppler Principle and Magnitude of Target Speed

The Doppler principle is used to separate echoes of moving objects from that of stationary objects echoes. There is no Doppler effect on cross range velocity. Doppler frequency can be easily calculated by mixing the original frequency f and f_d echoes frequency which return after hitting with radial velocity v_r, so that

$$f_d = -\frac{2}{\lambda}\left(\frac{dR}{dt}\right) = \frac{2v_r}{\lambda} \tag{1}$$

So Doppler frequency is positive because target approaching ,it will be negative if target receding. The phase change $\Delta Ø$ between pulses can be expressed as

$$\Delta\phi = 2\pi\left(\frac{2\Delta R}{\lambda}\right) \tag{2}$$

ΔR represents the range change between pulses . To explain ,three specific conditions can be defined as,

$\Delta\phi < 2\pi$, the Doppler shift f_d can be unambiguously measured.

(i) $\Delta\phi = 2\pi$, the Doppler shift f_d equals the PRF. PRF is related to the time interval between pulse in the form:

$$PRF = \frac{1}{PRI}$$

(ii) $\Delta\phi > 2\pi$, denote that the target is always be detectable but Doppler shift can not represent the correct speed of target and will be incorrect by an integral multiple of PRF. The PRF staggering is used to eliminate the blind speed and to resolve the ambiguous measurement of target speed, the Doppler frequency can be represented more accurately as [5]:

$$F_d = \left(\frac{2v_r}{\lambda}\right) \tag{3}$$

3. Set of PF's For Maximum Ambiguous Doppler Effect

The following problem is to be carefully weighed that if a MTI radar uses a basic pulse with burst with pulse repetition frequency f_r resulting in an unambiguous Doppler of f_r.

For blind speed elimination, an additional burst on different PRF's added. The set of n PRF's has an unambiguous Doppler of $K_n f_r$ this is the lowest Doppler at which the blind zones can be overlap at all n PRF's. we initiated the basic burst with a PRF of $f_r = \frac{1}{T_r}$, T_r repreaent the pulse repetition period. Its receiver response is the integer multiple of f_r. [2] If a specific filter is blind by clutter ,for better distinguish between targets MTI filters are used. Width of the filter can define the width of the blind Doppler zone Δv_b is the width of the Doppler interval at which target can not be detected if the filter contains strong clutter [7].

4. Response Of A Single Cancler And Prf Staggering

A radar with two interpulse duration T_1 and T_2 , n_1 and n_2 are the integer so ,

$$\frac{T_1}{T_2} = \frac{n_1}{n_2} \tag{4}$$

The first true blind speed occur such that

$$\frac{n_1}{T_1} = \frac{n_2}{T_2} \tag{5}$$

PRF staggering ratio can be defined as:

$$k_s = \frac{n_1}{n_2} \tag{6}$$

Using staggering rations closer to unity pushes the first true blind speed farther out, so that the dip in the vicinity of $1/T_1$ become deeper ,if n PRF are staggered than [3] ;

$$\frac{n_1}{T_1} = \frac{n_2}{T_2} = ..n_N / T_N \tag{7}$$

The first true blind speed for the staggered waveform is defined if the first blind speed to occur for any of the individual PRFs is v_{blind1} ,

$$v_{blind} = n_1 + n_2 + n_3 + \ldots + \frac{nN}{N} V_{blind1} \tag{8}$$

Unambiguous range is inversely proportional to the PRF and if the PRF is to high 2nd time around clutter can be an issue.

5. Mitigation Of Blind Speed And Mti Improvement

In this paper two quantities are used to define the performance of MTI system and the two factors are MTI “Improvement factor” and Clutter attenuation. The ratio between these two factors are [4]:

$$CA = \frac{P_{ci}}{P_{co}} \tag{9}$$

P_{ci} is input clutter power and P_{co} is the output clutter power in MTI filter .

By using Gaussian shaped clutter power spectrum as:

$$W_f = \frac{Pc}{\sqrt{2\pi\sigma_t}} \exp(-\frac{f^2}{2\sigma^2_t}) \tag{10}$$

P_c define the clutter power which is constant, σ_t is the rms frequency of the clutter and can be defined as:

$$\sigma_t = \sqrt{\sigma_v^{\ 2} + \sigma_s^{\ 2} + \sigma_w^{\ 2}} \tag{11}$$

σ_v represent the clutter spectrum spread due the wind velocity, σ_s denotes the standard deviation for the clutter spectrum spread due to the antenna scanning., σ_v is the clutter spectrum spread due the radar platform motion if required [5]. So

$$\sigma_v = \frac{2\sigma w}{\lambda} \tag{12}$$

And clutter spectrum spread due to the antenna as:

$$\sigma_s = 0.285\left(\frac{2\pi}{aT_{sc}}\right) \tag{13}$$

$$P_{ci} = \int_{-\infty}^{+\infty} P_c \, {}^{1}\!/\!\sqrt{2\pi\sigma_t} \exp\left(-\frac{f^2}{2\sigma^2_{\ t}}\right) df \tag{14}$$

The constant P_c yield [3]:

$$P_{ci} = Pc\int_{-\infty}^{\infty} {}^{1}\!/\!\sqrt{2\pi\sigma_t} \exp\left(-\frac{f^2}{2\sigma^2_{\ t}}\right) df \tag{15}$$

$P_{ci} = P_c$ are equal ,then the output power of the MTI filter as [6]:

$$P_{co} = \int_{-\infty}^{\infty} Wf \left|H(f)\right|^2 df \tag{16}$$

6. Simulations And Computer Results

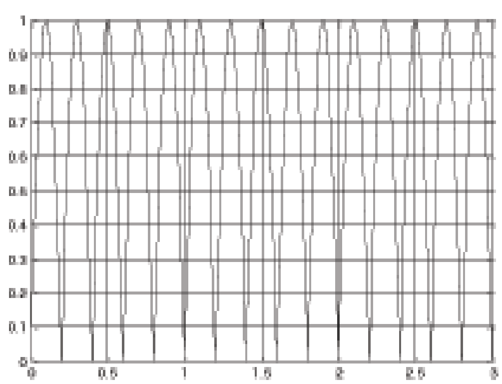

Figure 1. Frequency response of a single canceler which show the top plot correspond to T_1

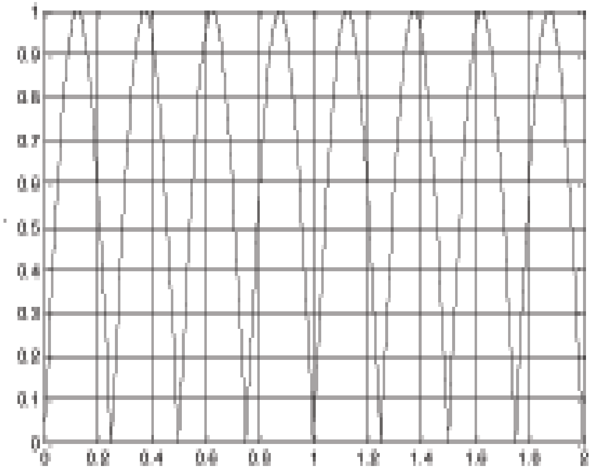

Figure 2. Frequency response of a single canceler which show the middle plot correspond to T_2

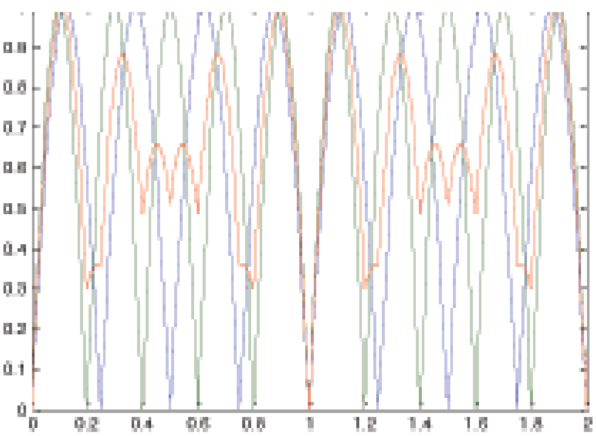

Figure 3. Stagger ratio $T1/T_2$=5/4 with bottom plot ,so Red line show the normalized frequency response of filter at staggering ratio T_1/T_2=5/4 blue line represents frequency response at stagger T_1, green line show stagger T_2

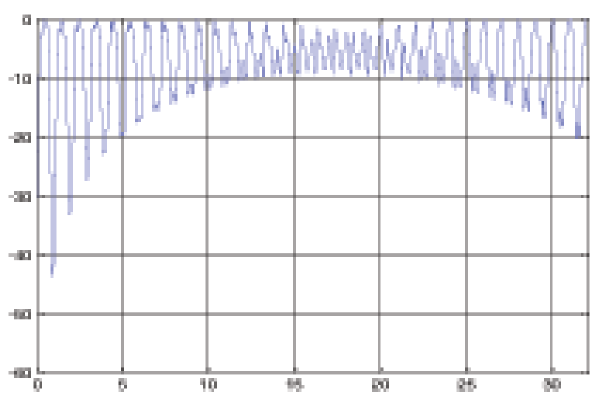

Figure 4. Target velocity relative to first blind ks= 73/74

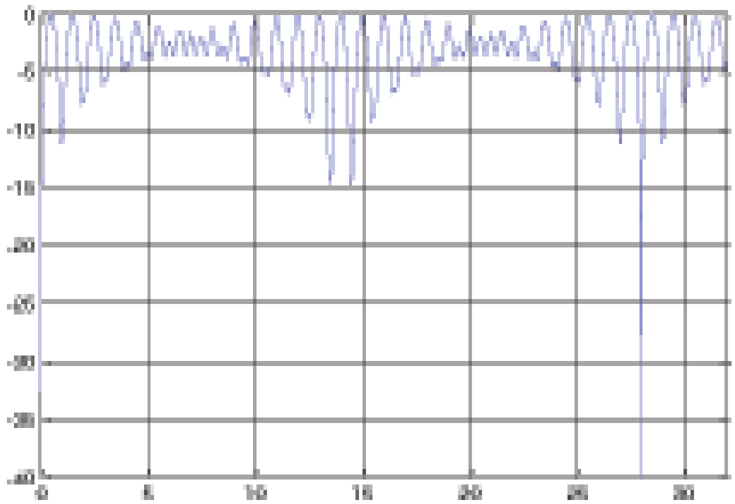

Figure 5. Target velocity relative to first blind
ks=29/28

Sr#	f (GHz)	PRT	λ(m)	Radar blind speed m/s
1	2	6	0.15	12500000
2	3	10	-0.2317	-1158500
3	5	12	0.4255	17729166
4	6	14	0.1759	6282142
5	7	16	0.1887	-5896875
6	8	18	-0.5085	-14125000
7	9	20	0.7316	18290000

Table 1. Blind Speeds

7. Conclusion

In this paper, we have demonstrated that PRF staggering technique to approach the problem of designing a scheme for blind speed elimination is a systematic manner. PRF nimbleness is used by changing the pulse repetition interval (PRI) between consecutive pulses. Assuming two radars which have different PRFs are used for detection. The blind speeds of two radars are distinct and also proportionals to the PRF. To assuage the problem of blind speeds by using two radar is costly process. Instead using two radar ,a single radar can be used with distinct PRFs. PRF staggering Also provides a practical solution to distinguish the moving and stationary objects because of repetitionof pulses to eliminate the blind speed [8].

References

[1] Rihaczek, A. W. (1973). A Systematic Approach to Blind-Speed Elimination, *Aerospace and Electronic Systems, IEEE Transactions on* 6. 940-947.

[2] Rihaczek, A. W. (1973). Choice of burst number for blind-speed avoidance, *Aerospace and Electronic Systems*, *IEEE Transactions on* 5: 778-781.

[3] Mahafza, Bassem R. (2013). Radar Systems Analysis and Design Using MATLAB Third Edition. CRC Press.

[4] Hall, Thomas M., William W. Shrader. (2007). Statistics of Clutter Residue in MTI Radars with IF Limiting. Radar Conference, (2007). IEEE. IEEE.

[5] Kolawole, Michael.(2003). Radar systems, peak detection and tracking. Newnes, (2003).

[6] Ispir, Mehmet., Candan, Cagatay (2013). Min-max design of MTI filters with non-uniform pulse repetition intervals, *In*: Signal Processing and Communications Applications Conference (SIU), 2013 21st. IEEE, (2013).

[7] Mahler, Ronald. (2015). Tracking “bunching” multitarget correlations. Multisensor Fusion and Integration for Intelligent Systems (MFI), (2015). IEEE International Conference on. IEEE, (2015).

[8] Gini, Fulvio., Rangaswamy, Muralidhar (2008). Knowledge based radar detection, tracking and classification. 52. John Wiley & Sons.