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ENHANCEMENT OF MTI IMPROVEMENT FACTOR PERFORMANCE BY USING DOUBLE-DELAY FILTER AT TWO PERIOD STAGGERED

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Abstract

The use of (MTI) technique, an ideal method to trace the moving targets in RADAR operation system, and utilize the characteristics of special kind of notch filters, via multi adaptive moving targets approach (AMTI). In this paper, we shall discuss and define the fundamentals of MTI, essential stages to evaluate the optimize results, without tacking in to consideration blind speed encounters.

Keywords: RADAR, MTI, two period stagers

INTRODUCTION

RADAR system essentially used in determine and defense against target, in which appears in forwardly atmosphere. The applications that benefit from the idea of detection; while a certain challenge in some kind of pulse RADAR system, is whether the target steady, or moves as well as the direction. Thus, another accurate kind MTI RADAR system should be used, in order to determine the direction of objects with respect to detecting unit. Based on this method, the system could be eliminating the steady objects along with overall range by using delay line canceller.

1. Concept of MTI Technique:

This system principle of detection, and distinguish; in which diverse among multi objects return's signals, the system in this case use filtering procedure to discriminate and eliminate unwanted objects, making just wanted object's to deal with. Logically it can be occurring via calculate the Doppler effect of each object, depending on shifting from sending signal and received echo, in which mean moving target; otherwise marked as steady object.

The accuracy of detection and discrimination of the affected by several unstable elements, such as "wind noise" caused by unified motion of clutter mass scanning noise "due to modulation of the clutter return by scanning antenna, plate form motion noise occurring in air born or shipboard radars and caused by translation antenna and instability noise. In order to derivate the signal; a single loop canceller can be used, as shown in Fig. (1)

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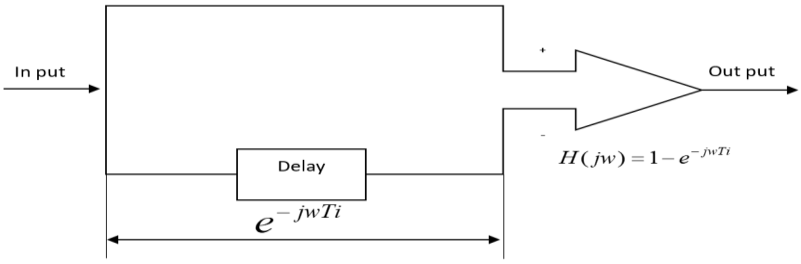
Fig 1: Single Loop Canceller



Where:

e^{jwTi}, *Frequency response*

wTi , *phase shift in time domin*

Ti *pulse period*

2. Characteristics of MTI Filter:

In fact, MTI canceller is a filter possessing in periodic transmission form, as we noticed, the zeroes effect are correspond to individual lines in the RADAR spectrum. (DLC) acts as a filter, in which eliminate most DC component of the clutter, and energy of the pulse repetition frequency due to its periodic nature, as shown in Fig. (2).

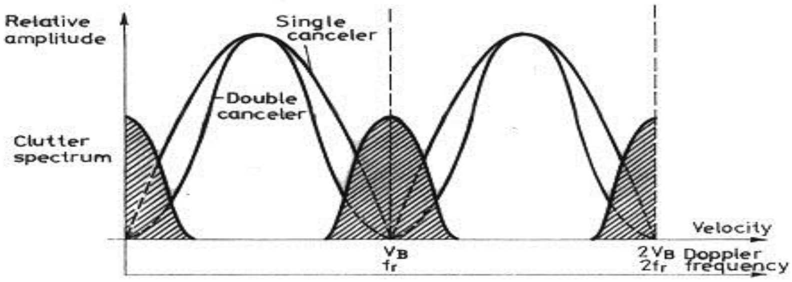


Figure 2: (MTI Velocity Responses)

$$H(jw)=1-e^{-jwTi} \quad (1)$$

By taking the magnitude of this expression

$$|H(jw)|=(1-\cos wTi)^2+(\sin wTi)^2 \quad (2)$$

Therefore, in voltage response

$$|H(jw)|=2\sin\frac{\pi ft}{fr} \quad (3)$$

The Seybold Report
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Where;

Li. Transmitted frequency (MHz).

fr, Pulse repetition frequency (Hz).

It has been seen that if the ratio f_t / f_r = is the integer number, the frequency response characteristics are equal to zero, that is, mean a blind speed occurred in the transfer function. But if the ratio f_t / f_r = 1, that means the transfer function characteristic is maximum, as shown in the Fig. (3)

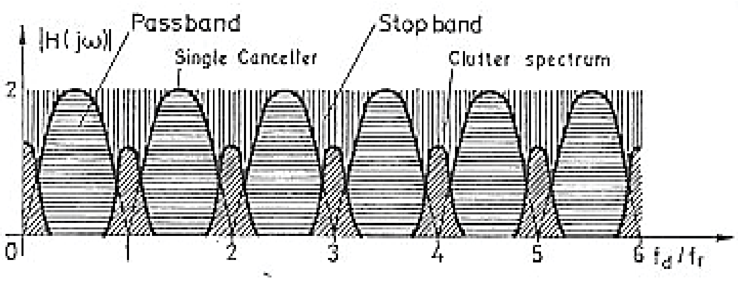

Figure 3: Transfer Function Curve with Clutter Spectrum

3. Improvement Factor:

Improving accuracy of any digital system means reduce as much as possible unwanted affection; in the case of target's detection and distinguish it's important to reduce the clutter residue affection, in which describes the canceling circuit. Improvement of (Signal /clutter) ratio due to canceller describes maximize the average gain, as noticed in Eq. (4) below:

$$I = \frac{\frac{So}{Co}}{\frac{Si}{Ci}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; (4)$$

Where, each unwanted response should be attenuate, that the signal to be averaged over echoes of moving targets, consider all possible radial speeds equiprobable.

Improvement factor related to more widely used clutter attenuation by noise gain G of the canceller.

$$I = G.CA \qquad (5)$$

The analytical expression of the frequency transfer function given as:

$$|H_1\ (F)| = 2\sin\left(\frac{\pi f d}{fr}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 6$$

$$|H_2\ (F)| = 4\sin^2\left(\frac{\pi f d}{fr}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 7$$

Where, Eq. (6) deal with single canceller, and (7) for twice effect.

ISSN 1533-9211
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Referring to Eq. (4) above, single loop canceller can be used to evaluate improvement factor, so that:

G, gain of the MTI filter, $G = \frac{S_o}{S_i}$ area under the curve, as shown in Fig. (4)

$\frac{C_i}{C_o}$ Is the MTI clutter attenuation, clutter echoes i/p with respect to clutter residual o/p.

$$I = \frac{1}{1 - e^{-2\pi^2\sigma^2 Ti^2}} \quad (8)$$

Eq. (8), above describe the average power gain of the MTI filter, in Fig. (4) The Gaussian curve represent spectrum power at the input.

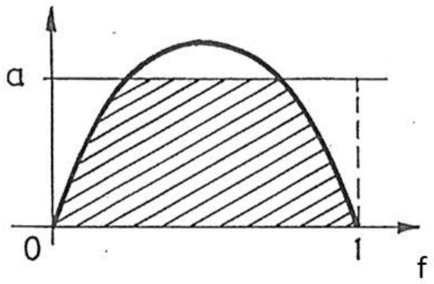

Fig 4: Freq. Loop Canceller

$$G_i = \int_{-\infty}^{\infty} k\, e^{-\frac{f^2}{2\sigma^2}}\, df \quad (9)$$

Where, σ : standard deviation of the spectrum clutter.
Solve the integration, get:

$$C_i = \sqrt{2\pi} k\sigma \quad (10)$$

Output spectrum power from the filter given by the Eq. (11) below:

$$C_0 = \int_{-\infty}^{\infty} k\, e^{\frac{-f^2}{2\sigma^2}}\, |H(jw)|^2\, df \quad (11)$$

Where, |H(jw)| : is freq. response of filter; the result after solve the integration, we get:

$$C_0 = 2\sqrt{2\pi} K\sigma\ (1 - e^{-2\pi^2\sigma^2 Ti^2}) \quad (12)$$

Since, the improvement factor is given by:

$$I = \overline{C}\ C_i / C_0 \quad (13)$$

$$I = 2\frac{\sqrt{2\pi}k\,\sigma}{2\sqrt{2\pi}k\sigma(1-e^{-2\pi^2\sigma^2T^2})} \qquad (14)$$

In case of improvement factor for single canceller, the Eq. (14) below shall use:

4. Blind Speed Problems:

Radar signals already shifted in the system to distinguish different targets direction and speed, in which MTI being blind, in other word, the moving objects recognition dependent on the shifted received signal.

Scanning principle depends on pulse-to-pulse staggering, to obtain perfect response each scan, it's important to set exact velocity in which evaluated of the Doppler than other signal, to maintain the exact intervals given in a scan-to-scan cycle. Since pulse-to-pulse staggering modulates the Doppler one at the most proper frequency of the canceller.

MTI filter has certain cutoff band, in this case it may be useless, some blind target speeds for which the Doppler falls in.

$$f_d = k\frac{2v}{\lambda} \qquad (15)$$

For MTI number of cutoff speeds, the Eq. (16) below may be used:

$$F_d = k.f_r \qquad (16)$$

5. In case of Double Delay Non-Staggered MTI Filter:

As formerly did for single delay,

$$I = \frac{1}{1-e^{-2\pi^2T^2\sigma^2}} \qquad (17)$$

Where:

σ: the standard deviation of the clutter

T: the time period .

We are going to derive formulas concern double delay improvement factor staggered for non-staggered MTI factor, also find the optimal stagger for required for two period frequency staggered.

In case of a non-staggered:

Double delay power transfer MTI filter is given in Eq. (18) below:

$$|H_2(w)| = |H_1(w)|^2 \qquad (18)$$

The Seybold Report
ISSN 1533-9211
DOI 10.17605/OSF.IO/EAX5D

Where:

$$|H_1(w)| = 4\sin^2 \pi \frac{f}{fr} \qquad (19)$$

MTI filter avg. Gain is given by:

$$\overline{G} = |\overline{H(f)}| = \frac{1}{f_1}\int_0^{f_1} |H(f)|^2 df \qquad (20)$$

Where:

$$\overline{G} = \frac{1}{f_1}\int_0^{f_1} 16\sin^4 \pi \frac{f}{fr} df \qquad (21)$$

Where:

$$T = \frac{1}{fr} duration\ of\ repetition$$

By simplifying the equation

where:

$T = 1/fr$: duration of repetition pulse.

By simplifying the equation we get:

$$\overline{G} = \frac{16}{f_1}\int_0^{f_1} \frac{1}{8}(\cos 4af - 4\cos 2af + 3)df \qquad (22)$$

Where:

$a = \pi T$ (23)

The depths of the minimum in $|H(f)|^2$ are analysed via the purpose and plot of $|H(f)|^2$ in the required area.

$f = 0$ to $f = N/T$

Nil point of $|H_s(f)|^2$, is obvious *at* $f = N/T$

By substitution the *limits* $(0 - \frac{N}{T})$ with respect to integer *(N)*, we obtain:

$$\overline{G} = 3$$

Double delay MTI improvement factor in non-staggering case, the following are depend:

$$I = \overline{G}\frac{c_i}{c_0}$$

Where;

c_i, MTI filter clutter line,

c_0, MTI filter clutter residue,

ISSN 1533-9211

DOI 10.17605/OSF.IO/EAX5D

$$C_i = \int_{-\infty}^{\infty} k,\, e^{\frac{-f^2}{2\sigma^2}} df \qquad (24)$$

And

$$C_0 = \int_{-\infty}^{\infty} k.\ \ e^{\frac{-f^2}{2\sigma^2}}\ |H(f)|^2\, df \qquad (25)$$

Then:

$$I = 3\frac{\int_{-\infty}^{\infty} k.\ e^{\frac{-f2}{2\sigma^2}} df}{\int_{-\infty}^{\infty} k.\ e^{\frac{-f2}{2\sigma^2}}\ |H(f)|^2\, df} \qquad (26)$$

To obtain improvement factor;

$$I = 3.\frac{\frac{1}{2}\sqrt{2\pi}\sigma}{16.\frac{1}{8}\int_{-\infty}^{\infty}(\cos 4af - 4\cos 2af + 3)e^{\frac{f^2}{2\sigma^2}} df}$$

Then:

$$I = 3.\frac{\frac{1}{2}\sqrt{2\pi}\sigma}{\frac{1}{2}\sqrt{2\pi}\sigma e\frac{-16\pi^2T^2 2\sigma^2}{4} - 4\frac{1}{2}\sqrt{2\pi}\sigma e^{\frac{-4\pi^2T^2}{4}} 2\sigma^2 + \frac{1}{2}\sqrt{2\pi}\sigma}$$

Finally, the improvement factor of Double delay non-staggered MTI filter is given by:

$$I = \frac{1}{1 + \frac{1}{3}e^{-8\pi^2T^2\sigma^2} - \frac{4}{3}e^{-2\pi^2T^2\sigma^2}} \qquad (27)$$

A computer Program done for the Expression (27) above, and by solving it, obtain the resultant square form signal as shown in Fig. (9).

ISSN 1533-9211

DOI 10.17605/OSF.IO/EAX5D

6. Double delay with two period Staggered MTI Filter:

Tack the Fig. (5) As a reference, we obtain:

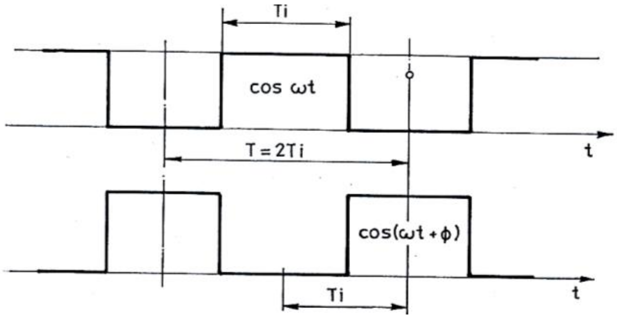

Fig 5: Transmitted waveform

$$S_1(t) = \frac{a_0}{2} + \sum a_k \cos k \frac{\pi}{T_1} t \tag{28}$$

Similarly,

$$S_2(t) = S_i(t - T_i) = \frac{a_0}{2} + \sum a_k \cos k \frac{\pi}{T_i}(t - T_i) = \frac{a_0}{2} + \sum a_k \cos(k \frac{w_i}{2} t - k\pi) \tag{29}$$

For k integer

$$\cos \ k\pi = (-1)^k$$

Therefore:

$$S_2(t) = \frac{a_0}{2} + \sum (-1)^k ak \cos k \frac{w_i}{2} t$$

From Fourier series we have:

$$a_k = \frac{1}{T_i} \int_{-T_i/2}^{T_i/2} \cos k \frac{\pi}{T_i} t = \frac{1}{T_i} \frac{T_i}{k} \sin k \frac{\pi}{T_i} \Big|_{-T_i/2}^{T_i/2}$$

Therefore:

$$a_k = \frac{2}{k\pi} \sin \frac{k\pi}{2} \tag{30}$$

Then,

K= 2 n-1 (ak = +- 1)

Where: k, ak are values of odd number.

K= 2n (ak =0) for even number

While (k) is odd number

(-1) k = -1

The Seybold Report
ISSN 1533-9211
DOI 10.17605/OSF.IO/EAX5D

So

$$s_2(t) = \frac{a_0}{2} - \sum a_k \cos k\frac{\pi}{2}t = \frac{a_0}{2} - \sum a_k \cos k\frac{w_i}{2}t$$

Then

f1 (t) = S1 (t) coswt

$$f_1(t) = \frac{1}{2}\cos wt + \frac{1}{2}\Sigma a_k \cos(w + k\frac{w_i}{2})t + \frac{1}{2}\Sigma a_k \cos(w - \frac{w_i}{2})t \quad (31)$$

Similarly

$$f_2(t) = S_2(t)\cos(wt - w\Delta T)$$

Then

$$f_2(t) = \frac{1}{2}\cos(wt - w\Delta T) - \frac{1}{2}\Sigma a_k \cos[(w + k\frac{w_i}{2})t - w\Delta T] - \frac{1}{2}\Sigma a_k \cos[(w - k\frac{w_i}{2})t - w\Delta T] \quad (32)$$

Therefore:

$$f(t) = f_1(t) + f_2(t) \quad (33)$$

$$f(t) = \cos(wt - w\frac{\Delta T}{2})\cos w\frac{\Delta T}{2} - \Sigma a_k \sin[(w + k\frac{w_i}{2})t - w\frac{\Delta T}{2}]\sin w\frac{\Delta t}{2} - \Sigma a_k \sin[(w - k\frac{w_i}{2})t - \frac{w\Delta T}{2}]\sin w\frac{\Delta T}{2}$$

Then:

$$f(t) = \cos w\frac{\Delta T}{2}\cos(wt - w\frac{\Delta T}{2}) - \sin w\frac{\Delta T}{2}\Sigma a_k \sin[(w + k\frac{w_i}{2})t - \frac{w\Delta T}{2}]\sin w\frac{\Delta T}{2})\Sigma a_k \sin[(w - \frac{w_i}{2})t - \frac{w\Delta T}{2}] \quad (34)$$

The pulse envelope at the imput to the canceller has been resolved into three components:

1. a sinusoidal envelope of component (W), amplitude $\cos w\frac{\Delta t}{2}$
2. a sinusoidal envelope of component $(w + k\frac{wi}{2})$, amplitude $\sin w\frac{\Delta t}{2}$
3. a similar envelope of component $(w - k\frac{wi}{2})$ amplitude $\sin w\frac{\Delta t}{2}$

Finally,

$$f_{0|p}(t) = H(w)\cos w\frac{\Delta T}{2}\cos(wt - w\frac{\Delta T}{2}) + \sin w\frac{\Delta T}{2}\Sigma a_k H(w + k\frac{w_i}{2}).\sin[(w + k\frac{w_i}{2})t - \frac{w\Delta T}{2}] + \sin\frac{w\Delta T}{2}\Sigma a_k H(w - k\frac{w_i}{2})\sin[(w - \frac{w_i}{2})t - \frac{w\Delta T}{2}]$$

ISSN 1533-9211
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The canceller's periodic frequency response @ (w_i), where, $H(w+k\frac{w_i}{2})=H(w-k\frac{w_i}{2})$, all responses may be gathered, so:

$$f_{0|p}(t)=H(w)\cos w\frac{\Delta T}{2}\cos(wt-w\frac{\Delta T}{2})-H(w+k\frac{w_i}{2}).\sin w\frac{\Delta T}{2}[\Sigma a_k \sin\ (w+k\frac{w_i}{2})t-\frac{w\Delta t}{2}\}+\sin(w-k\frac{w_i}{2})t-\frac{w\Delta t}{2}\}]$$

Simplifying the above expression to get:

$$f_{0|p}(t)=H(w)\cos w\frac{\Delta T}{2}\cos(wt-w\frac{\Delta T}{2})-2H(w+\frac{w_i}{2})\sin w\frac{\Delta T}{2}.\sin(wt-\frac{w\Delta T}{2})\Sigma a_k \cos\frac{kw_i}{2}t \qquad (35)$$

From Fourier series we have:

$$S_1(t)=\frac{a_0}{2}+\Sigma a_k \cos k\frac{w_i}{2}t$$

Then

$$\Sigma a_k \cos k\frac{w_i}{2}t=S_1(t)-\frac{a_0}{2}$$

We have $a_0 = 1$

Then

$$\Sigma a_k \cos k\frac{w_i}{2}t=S_1(t)-\frac{1}{2}$$

For the following waveform:

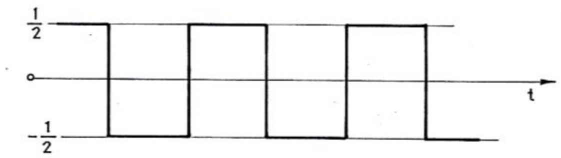

Fig 6: Transmitted Waveform

$$\Sigma a_k \cos k\frac{w_i}{2}t=\pm\frac{1}{2} \qquad (36)$$

$$f_{0|p}(t)=H(w)\cos w\frac{\Delta T}{2}\cos(wt-w\frac{\Delta T}{2})-2H(w+\frac{w_i}{2})(\pm\frac{1}{2})\sin w\frac{\Delta T}{2}.\sin(wt-w\frac{\Delta T}{2})$$

Now, let us assume,

$$H(w)\cos w\frac{\Delta T}{2}=A$$

$$wt-w\frac{\Delta T}{2}=\alpha$$

The Seybold Report
ISSN 1533-9211
DOI 10.17605/OSF.IO/EAX5D

$$2H(w+\frac{w_i}{2})(\pm 1/2)\sin w\frac{\Delta T}{2} = B$$

Then:

$$f_{0|p}(t) = A\cos\alpha \pm B\sin\alpha$$

$$\overline{(f_{0|p}(t))^2} = \overline{(A\cos\alpha \pm B\sin\alpha)^2} = \overline{(A^2\cos^2\alpha \pm 2AB\sin\alpha\cos\alpha + B\sin^2\alpha)}$$

But,

$$\bar{f}_{0/p} = \frac{1}{2\pi}\int_0^{2\pi} f_{0|p}^2\,dt$$

Then

$$A^2\frac{1}{2\pi}\int_0^{2\pi}\cos^2\alpha\;dt = \frac{A^2}{2}$$

$$\pm 2AB\frac{1}{2\pi}\int_0^{2\pi}\cos\alpha\sin\alpha dt = 0$$

$$B^2\frac{1}{2\pi}\int_0^{2\pi}\sin^2\alpha\;dt = \frac{B^2}{2}$$

Then:

$$\bar{f}^2{}_{0/p} = \frac{1}{2}A^2 + \frac{1}{2}B^2$$

$$= \frac{1}{2}[H^2(w)\cos^2 w\frac{\Delta T}{2} + H^2(w+\frac{w_i}{2})\sin^2\frac{w\Delta T}{2}]$$

Finally,

$$|\overline{H_s(w)}|^2 = \frac{\overline{f_{in\,out}^2}}{\overline{f_{in}^2}} = |H(w)|^2\cos^2\frac{w\Delta T}{2} + |H(w+\frac{w_i}{2})|^2\sin^2\frac{w\Delta T}{2} \quad (36)$$

$$|\overline{H_s(w)}|^2 = \sin^4(\pi fT)\cos^2(\pi f\Delta T) + \cos^4(\pi fT)\sin^2(\pi f\Delta T) \quad (37)$$

When:

$T_1 = T + \Delta T$

$T_2 = T - \Delta T$

T: mean period, equal to canceller delay

ΔT : *stagger delay*

The Seybold Report
ISSN 1533-9211
DOI 10.17605/OSF.IO/EAX5D

Mean freq is given by:

$$T = \frac{1}{f_r},\ f_r$$

Applying: $\frac{\Delta T}{T} = \frac{M}{N}$

Therefore:

$$\Delta T = T\frac{M}{N} \qquad (38)$$

The power transfer characteristic will be:

$$|\overline{H_s(t)}|^2 = \sin^4(\pi fT)\cos^2(\pi fT\frac{M}{N}) + \cos^4(\pi fT)\sin^2(\pi fT\frac{M}{N})$$

Assume,

V_{bn}, non-staggered initial blind speed.

V_{bs} , staggered initial blind speed.

Obtain;

$$V_{bn} = \frac{\lambda}{2} \quad . \quad f_r = \frac{\lambda}{2T} \qquad (39)$$

V_{bs}, obtained by initial nil of $|H_s(f)|^2$, by assume; $f = \frac{N}{T}$

Then; $f = \frac{2V_{bs}}{\lambda}$, by substitution, we get: $\frac{N}{T} = \frac{2V_{bs}}{\lambda}$

Then, $V_{bs} = N\frac{\lambda}{2T} = NV_{bn}$ (40)

When $|H_s(f)|^2 = V_{bs}$,

Then:

$$f = \frac{2v}{\lambda} \qquad T = \frac{\lambda}{2V_{bs}} \quad \text{And,} \quad \pi fT = \pi(\frac{v}{v_b})$$

Simplified Eq. (40) above,

$$v_{bs} = Nv_{bn}$$

ISSN 1533-9211
DOI 10.17605/OSF.IO/EAX5D

Then

$$\pi f T = \pi N(\frac{v}{v_{bs}})$$

Finally,

$$\pi f T\frac{M}{N} = \pi M(\frac{v}{v_{bs}}) \quad (41)$$

Freq. response c/s being;

$$|H_s(v)|^2 = \sin^4(\pi N\frac{v}{v_{bs}})\cos^2(\pi M\frac{v}{v_{bs}}) + \cos^4(\pi N\frac{v}{v_{bs}})\sin^2(\pi M\frac{v}{v_{bs}}) \quad (42)$$

Improvement factor in case of two period double stagger, use Double delay MTI filter.
Average gain of MTI filter;

$$|H_s(f)|^2 = \sin^4(\pi f T)\cos^2(\pi f T\frac{M}{N}) + \cos^4(\pi f T)\sin^2(\pi f T\frac{M}{N}) \quad (43)$$

To solving the above equation, assume that:

$$\pi T = a$$

$$\pi T\frac{M}{N} = b$$

$$|H_s(f)|^2 = \sin^4 af\,\cos^2 bf + \cos^4 af\,\sin^2 bf$$

Then

$$|H_s(f)|^2 = 1/8(-4\cos 2af\ \ \cos\ 2bf + \cos 4af + 3) \quad (44)$$

From the definition of frequency response characteristic

$$|H_s(f)|^2 = 16[1/8(-4\cos 2af\cos 2bf + \cos 4af + 3)] \quad (45)$$

The average gain shall be:

$$|\overline{H(f)}|^2 = \frac{1}{f_1}\int_0^{f_1}|H(f)|^2 df \quad (46)$$

By solving above, obtain:

$$|\overline{H(f)}|^2 = \frac{T}{N}\int_0^{N/T}(-4\cos 2af\cos 2bf + \cos 4af + 3)df \quad (47)$$

By solving the integral (46) we obtain:

$$|\overline{H_s(f)}| = 1/N[\frac{\sin 2\pi N(1+\frac{M}{N})}{\pi(1+\frac{M}{N})} - \frac{\sin 2\pi N(1-\frac{M}{N})}{\pi(1-\frac{M}{N})} + \frac{\sin 4\pi N}{4\pi} + 3N] \quad (48)$$

If (M) and (N) are integers: and the optimum case when M/N=1

ISSN 1533-9211

DOI 10.17605/OSF.IO/EAX5D

RESULT

$$|H_s(f)|^2 = \frac{1}{N}[\frac{-\sin 4\pi N}{2\pi} + \frac{\sin 4\pi N}{4\pi} + 3N] \quad (49)$$

Finally:

$$|H_s(f)|^2 = \frac{1}{N} \quad 3N \qquad = 3$$

Improvement factor is $(I) = \overline{G}\frac{C_i}{C_0}$

Then,

$$I = 3.\frac{1/2\sqrt{2\pi\sigma^2}}{\int_0^\infty (-4\cos 2\pi Tf \cos \pi Tf \frac{M}{N} + \cos 4\pi Tf + 3)e^{\frac{-f^2}{2\sigma^2}} df}$$

By solving the expression, we got:

$$I = \frac{3}{3 + e^{-8\pi^2T^2\sigma^2} - 2e^{-2\pi^2T^2\sigma^2(1+\frac{M^2}{N^2})}(e^{-4\pi^2T^2\sigma^2 \frac{M}{N}} + e^{-4\pi^2T\sigma^2 \frac{M}{N}})}$$

Then:

$$I = \frac{3}{3 + e^{-8\pi^2T^2\sigma^2} - 4e^{-2\pi^2T^2\sigma^2(1+\frac{M^2}{N^2})}.\cosh(4\pi^2T^2\sigma^2 \frac{M}{N})}$$

Finally,

$$I = \frac{1}{1 + \frac{1}{3}e^{-8\pi^2T^2\sigma^2} - \frac{4}{3}e^{-2\pi^2T^2\sigma^2(1+\frac{M^2}{N^2})}.\cosh(4\pi^2T^2\sigma^2 \frac{M}{N})} \quad (50)$$

The computer program has been done for expression (50) above,

Improvement factor $_{\text{(double stagger)}}$ = f (clutter) $_{\text{Std. dev.}}$, as shown in plots (10), (17) respectively.

Frequency deviation $\sigma(Hz)$	Improvement factor (dB)	Stagger delay (M)	Canceller Delay (N)
100	- 0.5	1	25
100	- 0.5	4	25
100	- 0.4	5	25
100	1.3	7	25

ISSN 1533-9211

DOI 10.17605/OSF.IO/EAX5D

100	2.3	9	25
100	2.8	10	25
100	3.8	12	25
100	4.8	14	25
100	5.2	16	25
100	5.9	18	25
100	6.2	19	25
100	6.8	21	25
100	7.1	22	25
100	7.4	23	25
100	7.5	24	25

Table 1: Improvement Factor (I) Vs. Stagger Delay (M) at Constant Frequency Devation (σ) and Canceller Delay (N)

Frequency deviation $\sigma(Hz)$	Improvement factor (dB)	Stagger delay (M)	Canceller Delay (N)
100	- 0.4	1	30
100	- 0.4	3	30
100	- 0.4	5	30
100	- 0.3	6	30
100	0	8	30
100	0.9	10	30
100	1.9	12	30
100	2.7	14	30
100	3.2	15	30
100	3.9	17	30
100	4.6	19	30
100	4.9	20	30
100	5.7	22	30
100	6	23	30
100	6.4	25	30
100	6.7	26	30
100	6.9	27	30
100	7.2	28	30
100	7.5	29	30

Table 2: Improvement Factor (I) Vs. Stagger delay (M) at Constant Frequency Devation (σ) and Canceller Delay (N)

Figure 9: Improvement FACTOR for non-Staggered Case

ISSN 1533-9211
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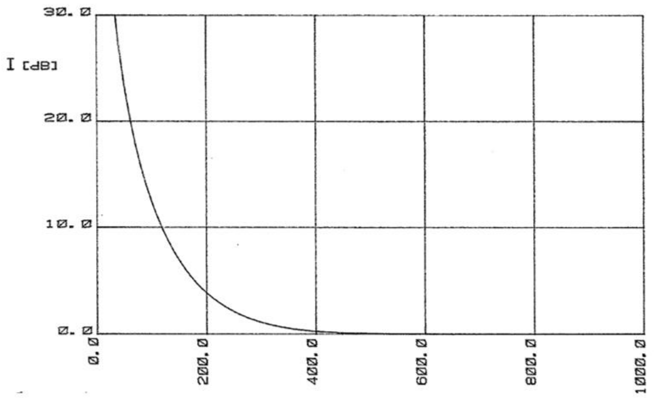

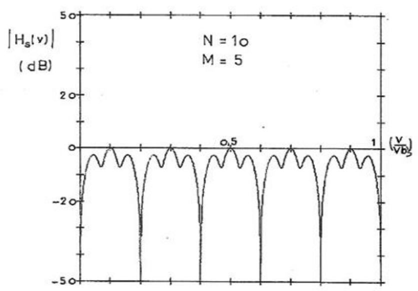

Figure. (10) Velocity Response at Stagger Ratio 5:15

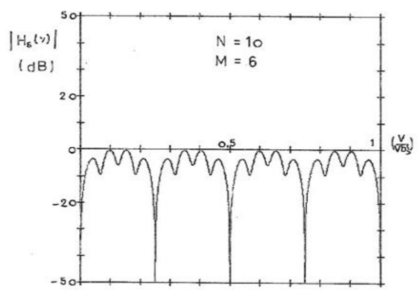

Figure. (11) Velocity Response at Stagger Ratio 4:16

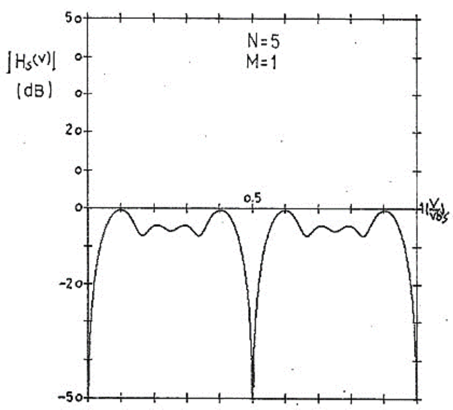

Figure 12: Velocity Response at Stagger Ratio 4:6

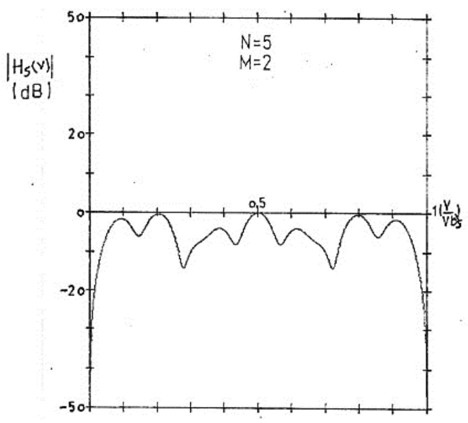

Figure 13: Velocity Response at Stagger Ratio 3:7

ISSN 1533-9211

DOI 10.17605/OSF.IO/EAX5D

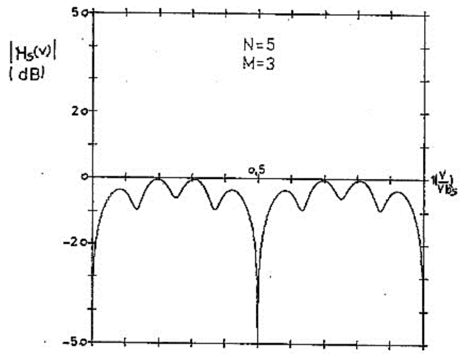

Figure 14: Velocity Response at Stagger Ratio 2:8

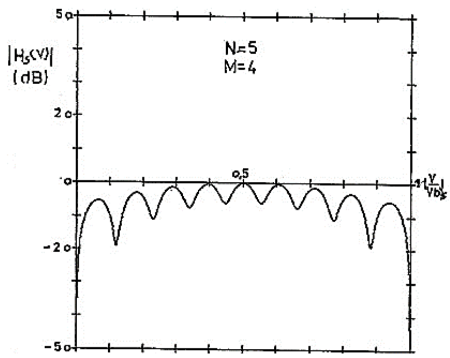

Figure 15: Velocity Response at Stagger Ratio 1:9

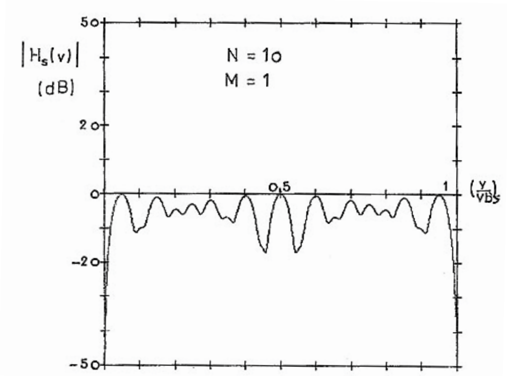

Figure 16: Velocity Response at Stagger Ratio 9:11

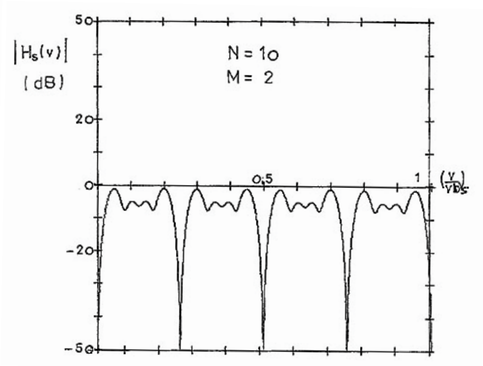

Figure 17: Velocity Response at Stagger Ratio 8:12

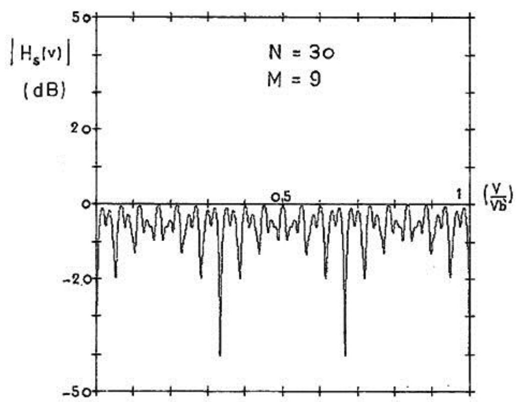

Figure 18: Velocity Response at Stagger Ratio 21:39

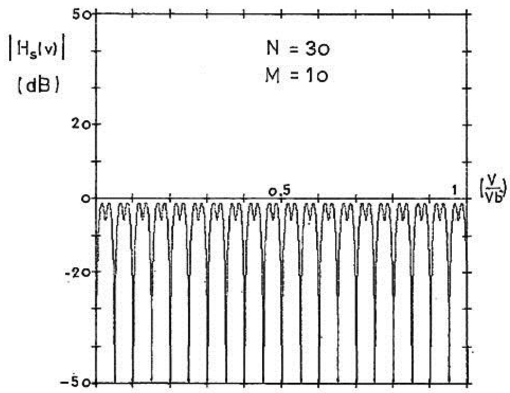

Figure 19: Velocity Response at Stagger Ratio 20:40

ISSN 1533-9211

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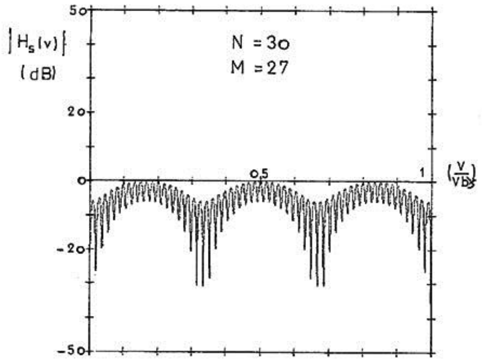

Figure 20: Velocity Response at Stagger Ratio 3:57

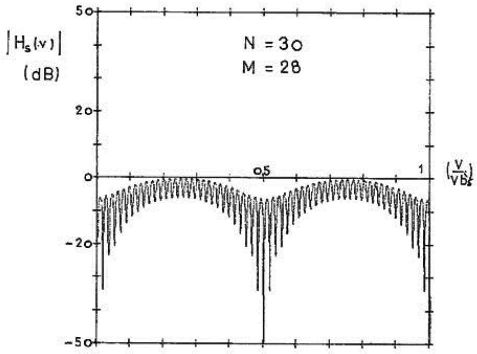

Figure 21: Velocity Response at Stagger Ratio 2:58

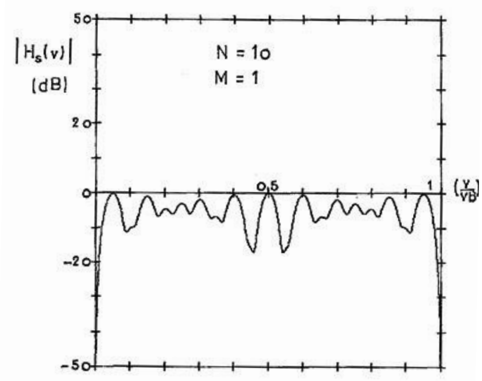

Figure 22: Velocity Response at Stagger Ratio 9:11

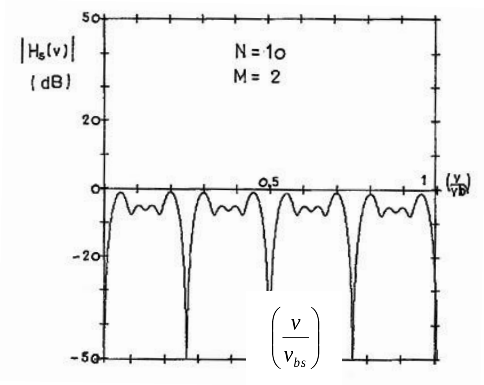

Figure 23: Velocity Response at Stagger Ratio 8:12

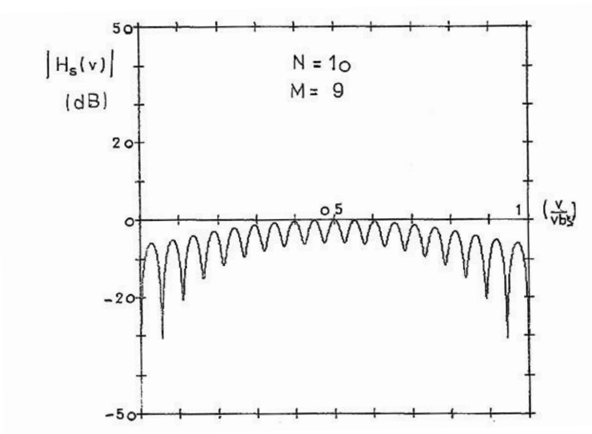

Figure 24: Velocity Response at Stagger Ratio 1:19

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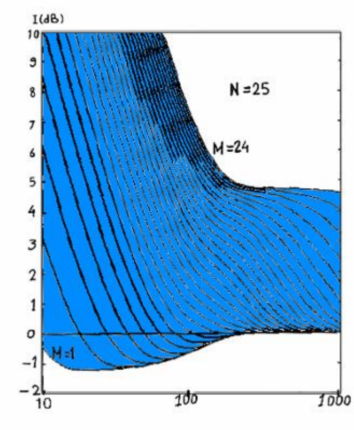

Figure. (25) Improvement Factor for Two Period Stagger

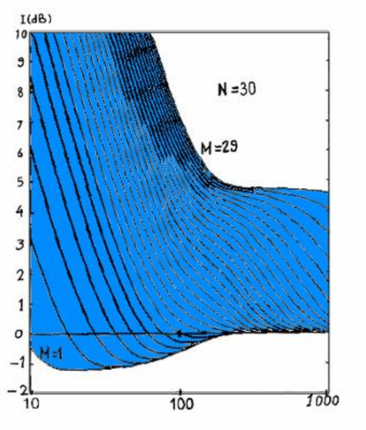

Figure. (26) Improvement Factor for Two Period Stagger

CONCLUSION

By completion the theoretical concept comprise evaluation the staggered optimum ratio useful in MTI Radar system, in which exclude all blind speeds to improve other factors. By Apply (M=N-I) the staggering method approved, and lowest point is the initial blind speed; also this is not satisfied in the center of the response relation, while lowest nils seen near both ends of the curve.

By assume, M=I as shown in fig. (25-26); double staggered was examined and seen the optimum ratio verified at M=N-I, that because (N) increased by twentieth times, while deepest Min. is constant.

When (T1/T2) increased, the depth of the nils amongst blind speeds increase a lots in response graph; the ratio are (1/3, 1/4, 3/4,...etc.); for many deepest Min. Points equal to (-50dB) each, this called unverified case. When the staggered ratio is 1/2, the final result may be obtained;

a. N = 10, M = 5, N = 20, M = 10, N = 30, M = 15, respectively.

Furthermore, value of (N) is inverse proportional than improvement factor; that means, choosing value of (N) as small as possible. The deepest Min. occur while staggered delay (M) is Even No., with respect to value of (-50dB) when staggered ratio less than one integer, optimum achieved at M= N-1 as shown in Fig.(25). By apply the average intervals of delay line (N), are (10, 20, 30), the plot vs. staggered delay (M), shows the effect of (Odd, Even) No.'s in the staggering method.

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