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OPTIMAL SELECTION OF TARGETS IN THE PRESENCE OF CLUTTER AND EFFECTIVE INTERFERENCE

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Abstract

Staggered blind speeds of MTI radar can be eliminated to a large part by PRF optimization, and the depth of minimum value in the velocity area in the frequency response ($|Hs(f)|2$) or improvement factor can be optimized with suitable selection of stagger delay (M). When comparing the minimum gain in signal-to-clutter ratio (SCR) and improvement factor, several relative Optima exhibit large discrepancies. Small values of time on target and of radar Frequency with respect to the improvements factor are favored. Among the local optima, some good alternatives can be found that combine high improvements factor and high minimum SCR gain. 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).

Keywords: Two Period Staggers, Three Period Staggers, Deepest Minimum Frequency, Moving Target Indication (MTI) Filter, Frequency, Response, Doppler, Processing Clutter, Impulse, Response, PRF.

INTRODUCTION

The design of the MTI processor is mainly based on the design of filter structure for clutter attenuation, for stationary clutter attenuation, simple high pass filters provide sufficient attenuation, whereas higher-order filters provide sufficient attenuation, whereas higher-order filters can be required to sufficiently attenuate clutter with significant Doppler spread [1].

By reducing the return from stationary clutter return, moving target indication (MTI) filters increase the probability of detecting moving targets. Single line cancellers, the simplest and most well-known type of MTI filter, work by subtracting the received signal owing to two successive pulses to cancel the clutter. Using a constant pulse repetition interval (PRI) creates a blind speed problem, which is a significant drawback of MTI filtering. Changing the intervals between pulses can help eliminate the blind speed and frequency response nulls. Interpulse period are optimized by numerical methods. Combining analytical filter optimization with numerical interpulse period optimization, a new technique has been devised. The improvement. In the power ratio of signals-to-clutter as a function of frequency can be useful. We'll call this improvement in the signal-to-clutter ratio. It's closely related to improvement factor.

Staggered MTI PRF

However, the fact that the pulse spacing is uniform facilitates simplification a number of mathematical expressions defining performance, making the unstaggered PRF (MTI) a particular case of staggered PRF for which the pulse spacing is constant. While conventional processors still exhibit blind speed, this simplification allows for the invention of new classes of processors for the unstaggered PRF system and greatly simplifies the mathematical design.

How to Generate a Stagger Prf.

A three period stagger can be obtained with the same circuitry as that for two period stagger. The only alteration is the timing of the electronic switch. A switch is left in the upper position for two pulse and then moved down for one.

The three pules intervals now have a ratio:

$(Ti - \Delta T)\ ; Ti;\ (Ti + \Delta T)$ as shown in Fig (1).

Design of staggered MTI filters depend upon the radar system parameters that are related to the detectation probability and clutter attenuation based upon, staggered. MTI filter design comprises on the optimization of two sets of parameters: the inter pulse time duration and the filter coefficients. The unambiguous range and velocity specifications impose constraints on the interpulse period. The desired clutter attenuation affects the values of filter coefficients [2].

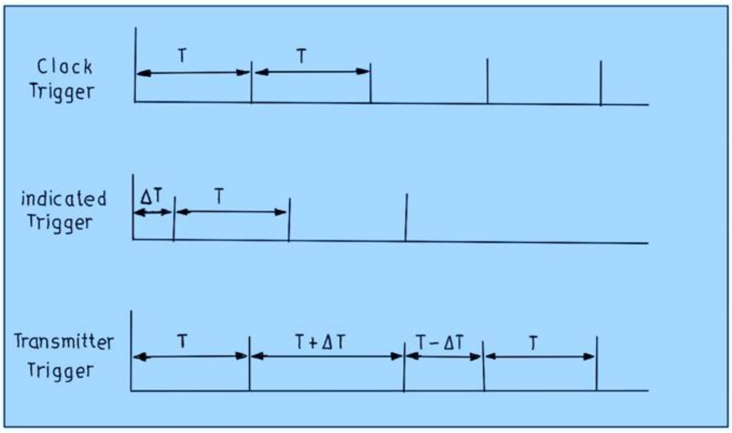

Figure 1: Three- Period – Stagger Ratio

$(Ti - \Delta T)\ Ti;\ (Ti + \Delta T)$

This operation is shown in Fig. (2) With its necessary block diagram.

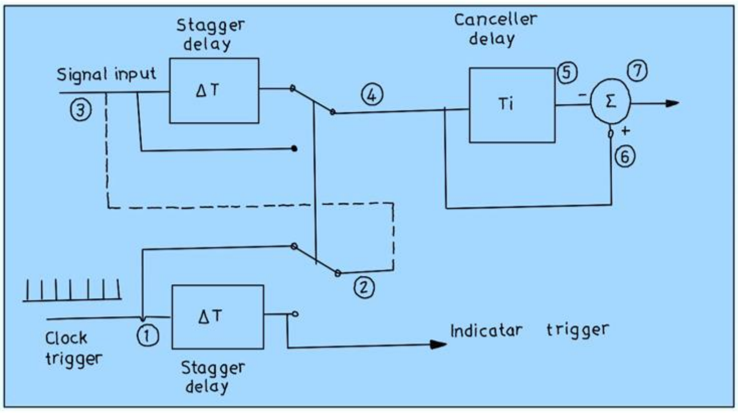

Figure 2: Block Diagram for Generating Staggered PRF

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It is difficult to distinguish a moving target in a ground – clutter or sea –clutter environment due to strong clutter echos. Detection of moving targets in these conditions is performed using Moving Target Indication (MTI) radar. The MTI radar is a type of pulse radar that uses the non-zero Doppler shift of moving targets for their detection [3] by cancelling the stationary background clutter.

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

By taking the magnitude of this expression

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

Therefore, in voltage response

$$|H(jw)| = \frac{\pi f t}{f r} \tag{3}$$

Where:

ft, Transmitted frequency (MHz)

fr, pulse repletion 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 in maximum, as shown in the Fig (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.

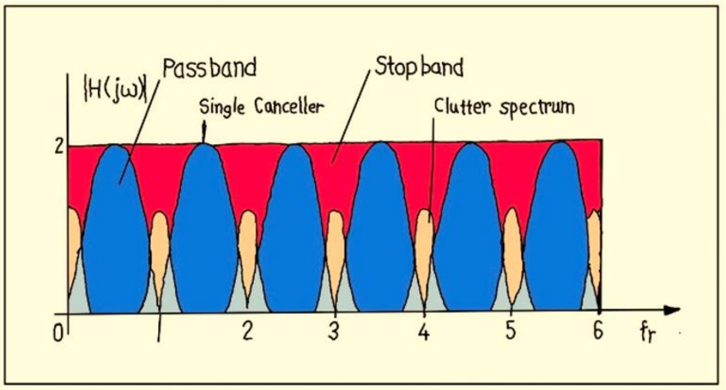

Figure 3: Transfer Function Curve with Clutter Spectrum

$$I = \frac{\frac{So}{Co}}{\frac{Si}{Ci}} \tag{4}$$

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

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

$$I = G.CA \tag{5}$$

The analytical expression of the frequency transfer function given as:

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

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

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

In case of improvement factor for singles canceller, the Eq. (8) below use:

$$1 = 2\frac{\sqrt{2\pi}k\sigma}{2\sqrt{2\pi}k\sigma\left(1-e^{-2\pi^2\sigma^2 Ti^2}\right)} \tag{8}$$

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. (4)

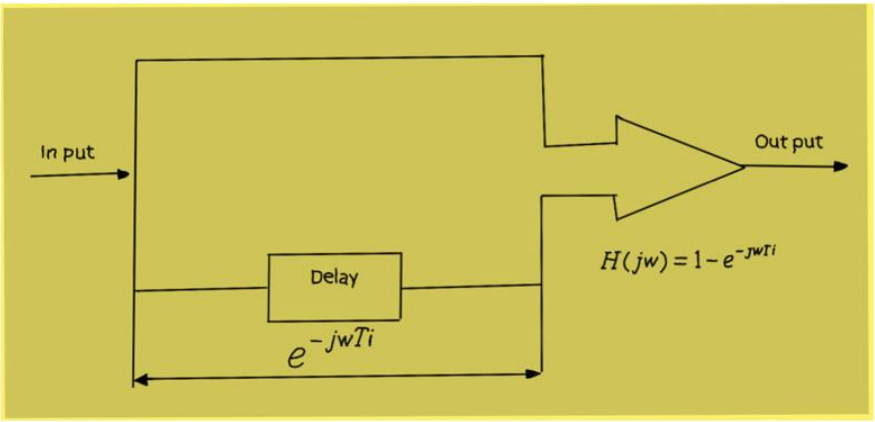

Figure 4: Single Loop Canceller

Where

e^{jwTi}, Frequency response.

wTi, phase shift in time domain.

Ti Pulse period

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. (5).

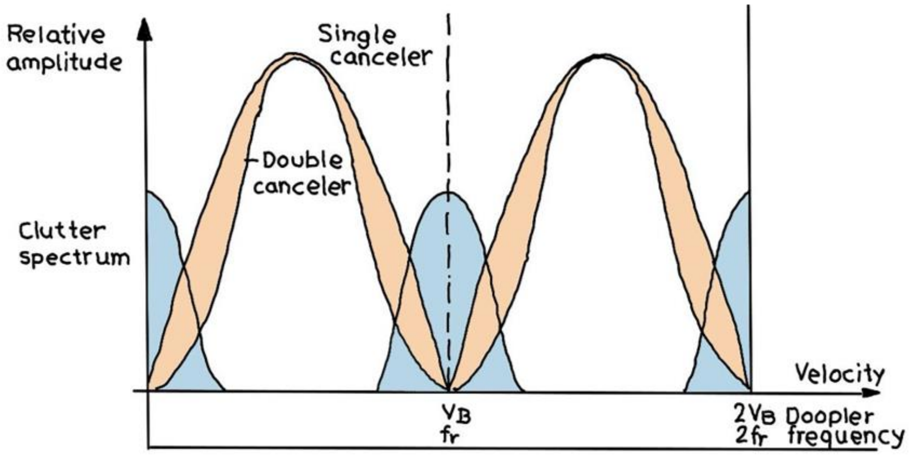

Figure 5: (MTI Velocity Responses)

In case of Double Delay Non-Staggered MTI Filter:

As formerly did for single delay,

$$I = \frac{1}{1-e^{-2\pi^2T^2\sigma^2}} \qquad (10)$$

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-MTI factor, also find the optimal stagger required for two period frequency staggered.

Double delay power transfer MTI filter is given in Eq. (11) below:

$$|H_2(w)| = |H_1(w)|^2 \qquad (11)$$

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

$$I = \frac{1}{1 + \frac{1}{3} e^{-8\pi^2 T^2 \sigma^2} - \frac{4}{3} e^{-2\pi^2 T^2 \sigma^2}} \qquad (12)$$

A computer Program done for the Expression (12) above, and by solving it, obtain the resultant square form signal as shown in Fig. (7).

Internal Fluctuation of Clutter

Although clutter targets such as buildings, water towers or mountains produce echo signals that are constant in both phase and amplitude as a function of time, many clutter types cannot be considered stationary. Echoes from trees, sea, rain and chaff fluctuate with time, and those fluctuations can limit the performance of MTI radar [15].

Because of its varied nature, it is difficult to describe precisely the clutter echo signal. However, for analysis, most fluctuating clutter targets may be represented by a model consisting of many independent scatterers within the radar's resolution cell. The echo at the radar receiver is the vector sum of the echo signals received from each scatterer. That is each scatterer's relative phase and amplitude influence the resultant composite signal. If the individual scatterers remain fixed from pulse to pulse, the resulting echo signal will also remain fixed [16].

Double delay with two period Staggered MTI Filter:

Tack the Fig. (6): As a reference, we obtain:

$$S_1(t) = \frac{a_0}{2} + \sum a_k \cos k \frac{\pi}{T_1} t \ldots\ldots\ldots \qquad (13)$$

Similarly,

$$S_2(t) = S_1(t - T_1) = \frac{a_0}{2} + \sum a_k \cos k \frac{\pi}{T_1}(t - T_1)$$
$$= \frac{a_0}{2} + \sum a_k \cos\left(k \frac{w_1}{2} t - k\pi\right) \ldots\ldots\ldots (14)$$

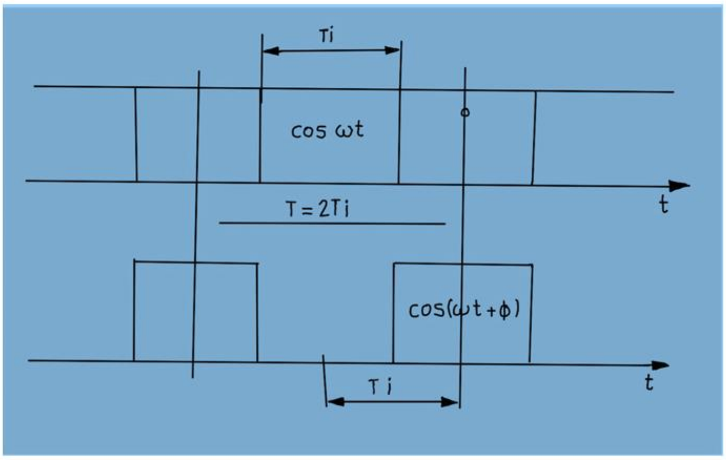

Figure 6: Transmitted Waveform

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Finally,

$$I = \frac{1}{1 + \frac{1}{3}e^{-8\pi^2 r^2 \sigma^2} - \frac{4}{3}e^{-2\pi^2 T^2 \sigma^2 \left(1+\frac{M^2}{N^2}\right)} . \cos\left(4\pi^2 T^2 \sigma^2 \frac{M}{N}\right)} \quad (15)$$

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

Frequency	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

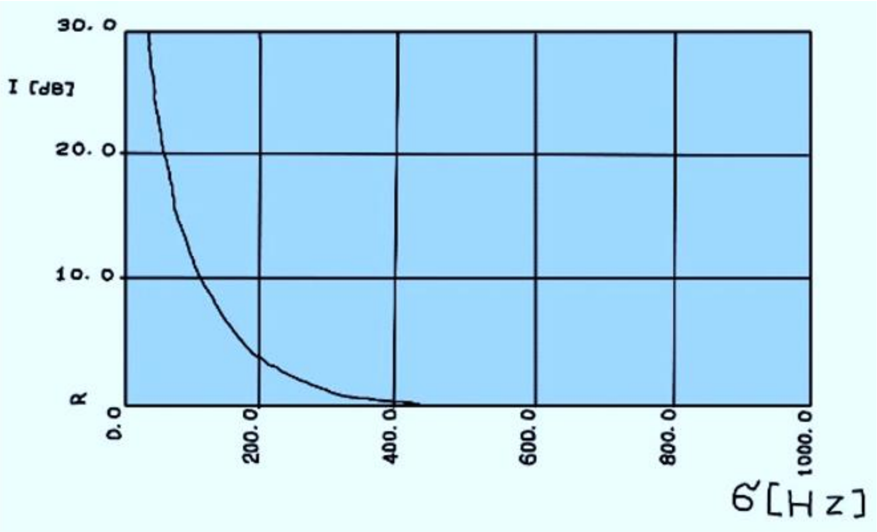

Figure 7: Improvement FACTOR for non-Staggered Case

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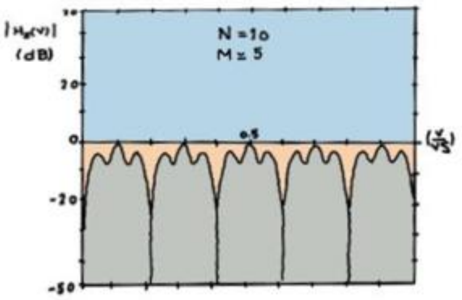

Figure 8: Velocity Response at Stagger Ratio 5:15

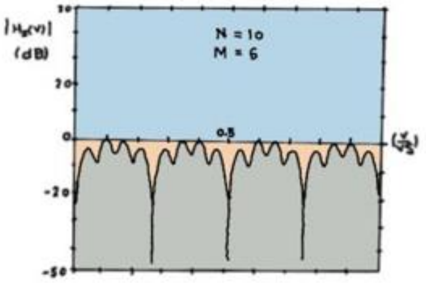

Figure 9: Velocity Response at Stagger Ratio 5:15

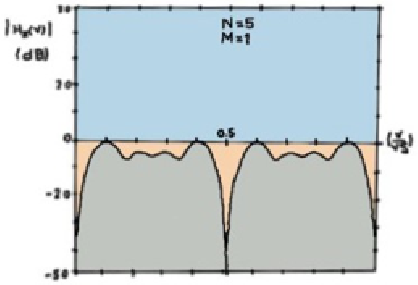

Figure 10: Velocity Response at Stagger Ratio 4:6

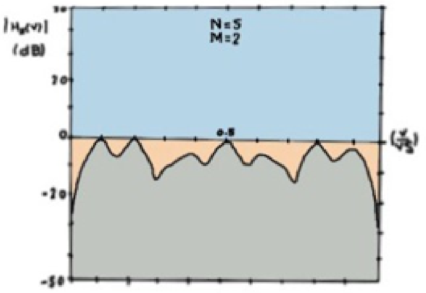

Figure 11: Velocity Response at Stagger Ratio 3:7

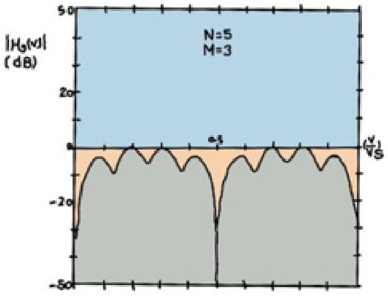

Figure 12: Velocity Response at Stagger Ratio 2:8

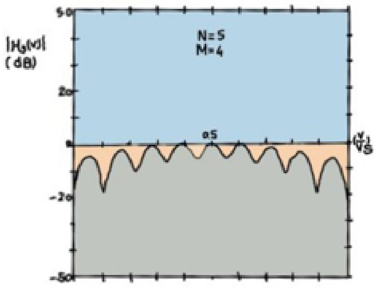

Figure 13: Velocity Response at Stagger Ratio 1:9

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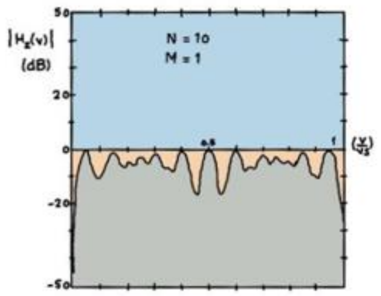

Figure 14: Velocity Response at Stagger Ratio 9:11

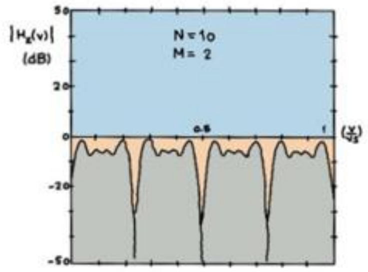

Figure 15: Velocity Response at Stagger Ratio 8:12

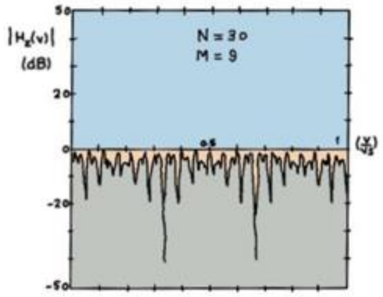

Figure 16: Velocity Response at Stagger Ratio 21:39

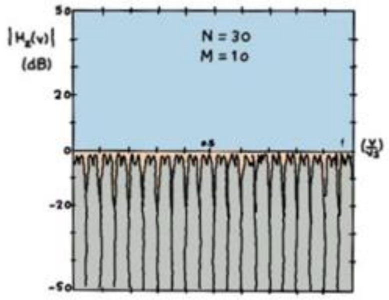

Figure 17: Velocity Response at Stagger Ratio 20:40

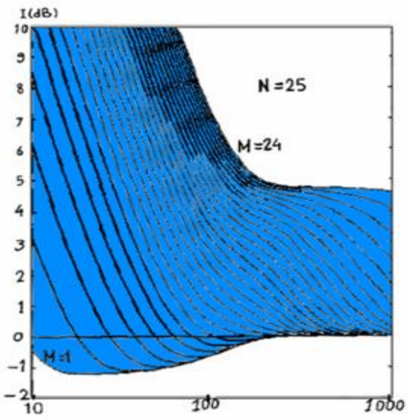

Figure 18: Improvement Factor for Two Period Stagger

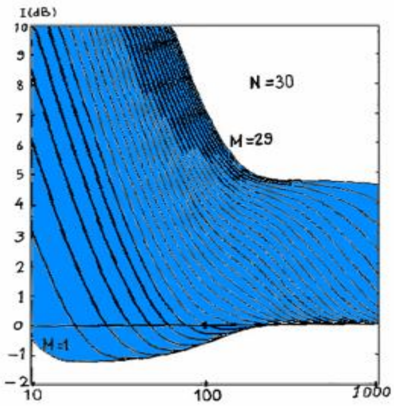

Figure 19: Improvement Factor for Two Period Stagger

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Double- Delay MTI Filter With Three Period Staggered:

The expression of frequency response characteristics for three period staggered has been obtained the expression (16).

$$|H_s(v)|^2 = \sin^4(\pi T f_d) - \tfrac{4}{3}\sin^2\left(\pi T f_d \tfrac{M}{N}\right)\sin^4(\pi T f_d) + \tfrac{1}{2}\sin^2\left(\pi T f_d \tfrac{M}{N}\right) \qquad (16)$$

A forming of computer program is done for (19) and six cases by choosing the mean period of main delay line (N) as (5, 10, 15, 20, 25 and 30) and changing the staggered delay (M) for each case from (1) to (M=N-1), to be able to analyze and predict the optimum case of staggering. By employing the expression (16), which indicates the frequency response characteristic in case of three-period staggered and assuming that:

$$\pi T = a$$

$\pi T \frac{M}{N} = b$ By applying the definition of average gain to get:

$$\bar{G} = \frac{T}{N}\int_0^{N/T}\left(\sin^4 af - \frac{4}{3}\sin^2 bf \sin^4 af + \frac{1}{2}\sin^2 bf\right)df \ldots\ldots \qquad (17)$$

Simplifying this expression to obtain

$$\bar{G} = \frac{T}{N}\int_0^{N/T}(1/3\cos 4af_d - 4/3\cos bf_d \cos 4af_d - 8/3\cos 2bf_d \cos 2a)\, df_d \ldots\ldots (18)$$

By applying the definition of improvement factor.

$$I = 3\frac{1/2\sqrt{2\pi\sigma}}{\frac{1}{2}\sqrt{2\pi\sigma}\left[\frac{1}{3}e^{-8(eT\sigma)^2} - \frac{4}{3}e^{-2(eT\sigma)^2} + 3 + \frac{2}{3}e^{-2(eT\sigma)^2\left(4+\frac{M^2}{N^2}\right)}\cosh 8(\pi T\sigma)^2\frac{M}{N} - \frac{8}{3}e^{-2(eT\sigma)^2\left(1+\frac{M^2}{N^2}\right)}\cosh 4(\pi T\sigma)^2\frac{M}{2}\right]}$$

Finally

$$I = \frac{1}{1+\frac{1}{9}e^{-8(\pi T\sigma)^2} - \frac{4}{9}e^{-2(\pi T\sigma)^2} + \frac{2}{9}e^{-(\pi T\sigma)^2\left(4+\frac{M^2}{N^2}\right)}\cosh 8(\pi T\sigma)^2\frac{M}{N} - \frac{8}{3}e^{-2(eT\sigma)^2\left(1+\frac{M^2}{N^2}\right)}\cosh 4(\pi T\sigma)^2\frac{M}{2}} \ldots\ldots (19)$$

Computer program has been done for (19) to indicate the improvement factor for three-period staggered as a function of standard deviation of clutter (σ) in (Hz). The results have drawn in figs (20) to (27).

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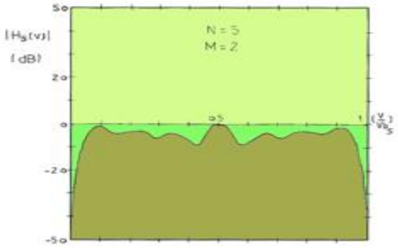


Figure 20: Velocity Response at Stagger Ratio 4:5:6

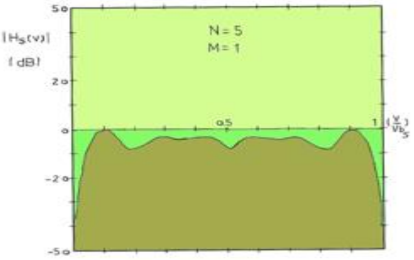


Figure 21: Velocity Response at Stagger Ratio 3:5:7

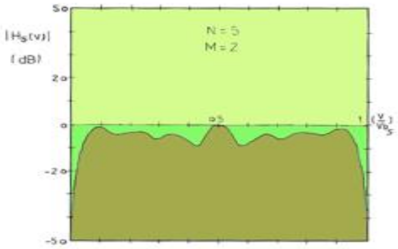


Figure 22: Velocity Response at Stagger Ratio 2:5:8

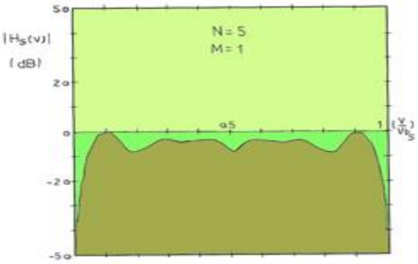


Figure 23: Velocity Response at Stagger Ratio 1:5:9

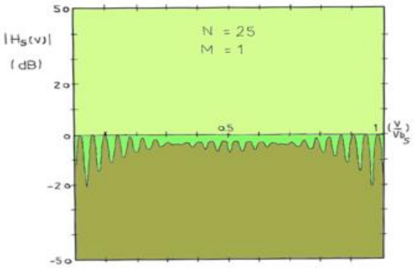


Figure 24: Velocity Response at Stagger Ratio 24:25:26

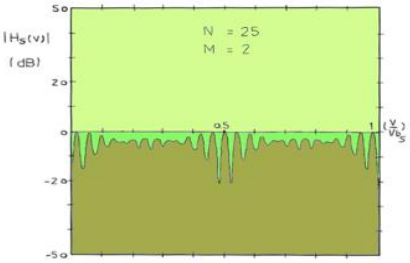


Figure 25: Velocity Response at Stagger Ratio 23:25:27

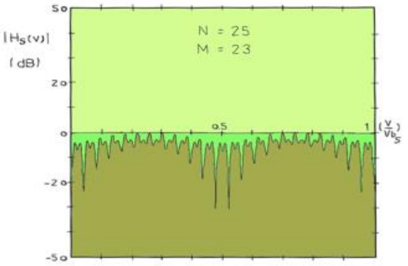


Figure 26: Velocity Response at Stagger Ratio 2:25:48

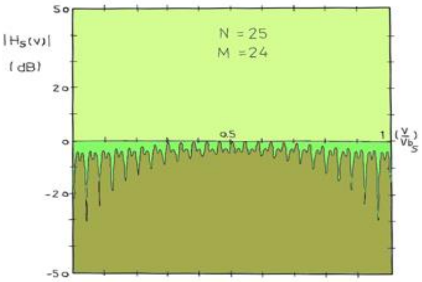
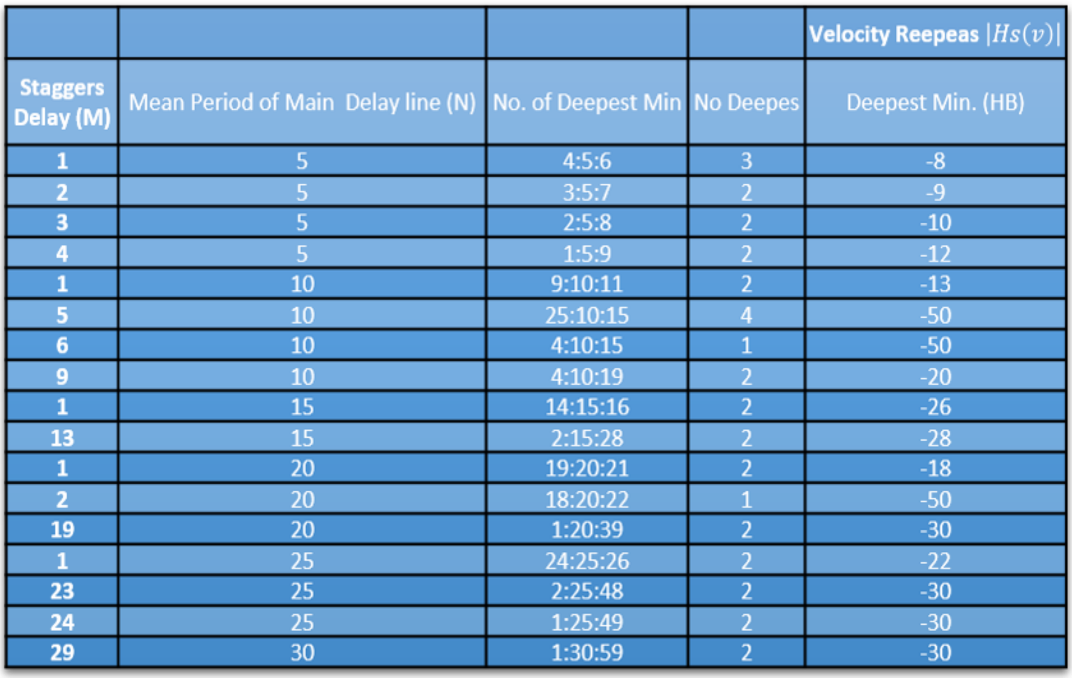


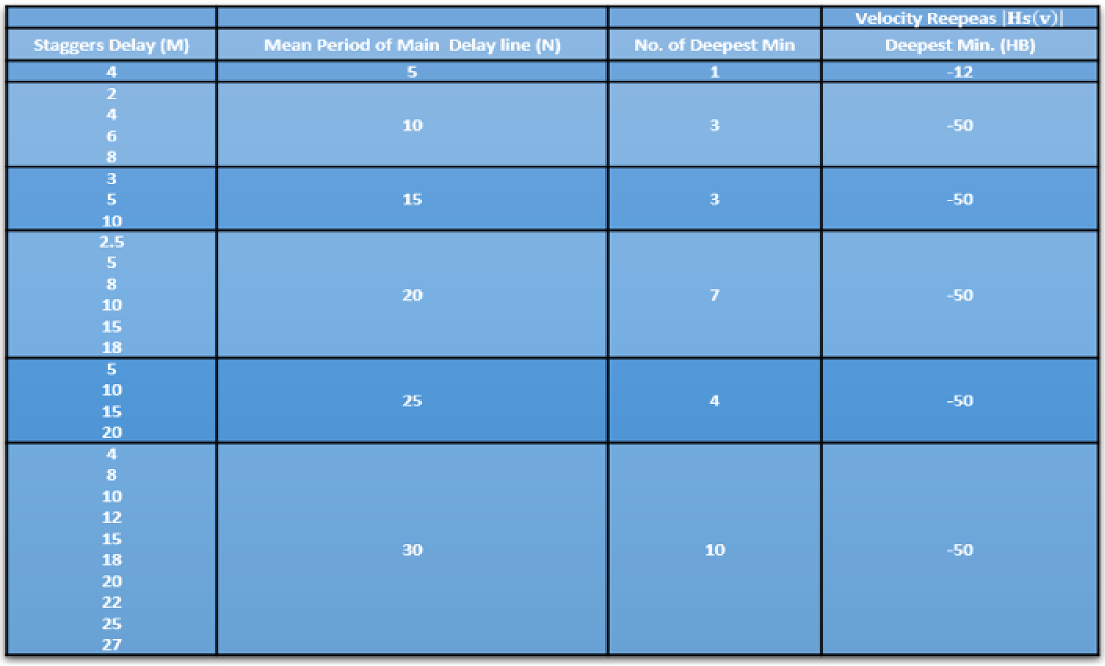
Figure 27: Velocity Response at Stagger Ratio 1:25:49

Table 3: Velocity Response |Hs (v)| Vs staggered Delay



				Velocity Reepeas $|Hs(v)|$
Staggers Delay (M)	Mean Period of Main Delay line (N)	No. of Deepest Min	No Deepes	Deepest Min. (HB)
1	5	4:5:6	3	-8
2	5	3:5:7	2	-9
3	5	2:5:8	2	-10
4	5	1:5:9	2	-12
1	10	9:10:11	2	-13
5	10	25:10:15	4	-50
6	10	4:10:15	1	-50
9	10	4:10:19	2	-20
1	15	14:15:16	2	-26
13	15	2:15:28	2	-28
1	20	19:20:21	2	-18
2	20	18:20:22	1	-50
19	20	1:20:39	2	-30
1	25	24:25:26	2	-22
23	25	2:25:48	2	-30
24	25	1:25:49	2	-30
29	30	1:30:59	2	-30

Table 4: Velocity Response |Hs (v)| Vs staggered Delay



			Velocity Reepeas $|Hs(v)|$
Staggers Delay (M)	Mean Period of Main Delay line (N)	No. of Deepest Min	Deepest Min. (HB)
4	5	1	-12
2 4 6 8	10	3	-50
3 5 10	15	3	-50
2.5 5 8 10 15 18	20	7	-50
5 10 15 20	25	4	-50
4 8 10 12 15 18 20 22 25 27	30	10	-50

This is a feature of any PRF system that does not use frequency hopping. Doppler frequencies above the system PRF might be necessary if the radar system's needs are particularly demanding. There needs to be a way to lessen or do away with these arbitrary speeds. Frequency agility and the staggered PRF are two ways to lower these blind speeds. The increased blind speed is the only one that can be overcome by frequency agility. To solve the blind speed issue in an MTI radar system, staggered pulse repetition intervals are commonly used. Effect of two and three period staggering upon frequency Coherent MTI radar works via phase comparison of all echoes to see if they are coherent with a reference phase. In the event of a reflection from a moving object, the subtractor will produce an output. "for uniform PRF a Doppler frequency associated with a target speed (V) and wave length (λ) is $\left(\frac{2v}{\lambda}\right)$

Pulse trains modulated by a sinusoidal envelope are the coherent detector's output.

$$E = \sin 2\pi f d t \ldots\ldots\ldots \qquad (19)$$

The amplitude of pulses in a uniform (non-staggered) PRF is calculated by sampling the envelope at specific moments.

$$tn = To + nT \ldots\ldots\ldots \qquad (20)$$

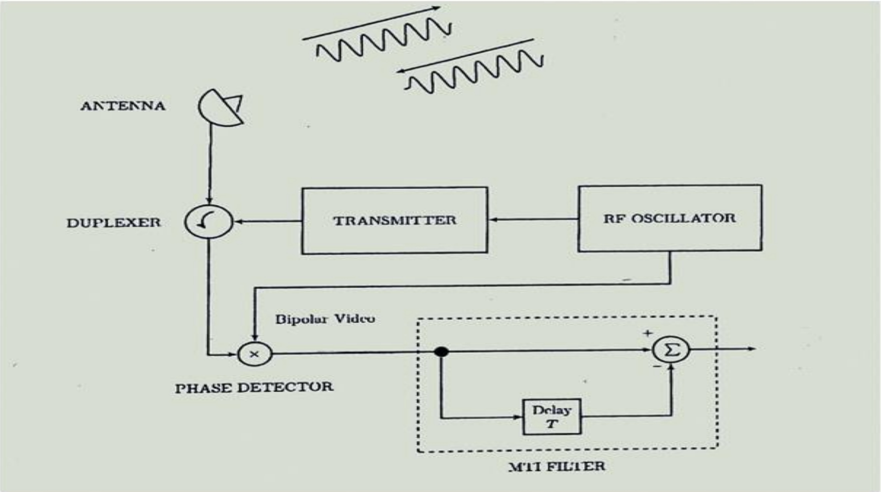


Figure 28: Simplified Block Diagram of a Coherent MTI system

by applying the definition of average gain to get:

$$\pi T = a$$

$$\pi T \frac{M}{N} = b\bar{G} = \frac{T}{N} \int_{0}^{N/T} \left(\sin^4 af - \frac{4}{3} \sin^2 bf \sin^4 af + \frac{1}{2} \sin^2 bf \right) df \ldots\ldots (24)$$

where

a= πT ……… (25)

b= $\pi T \frac{M}{N}$ ……… (26)

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where

M= stagger delay

N = canceller delay (main delay)

By applying the definition of improvement factor

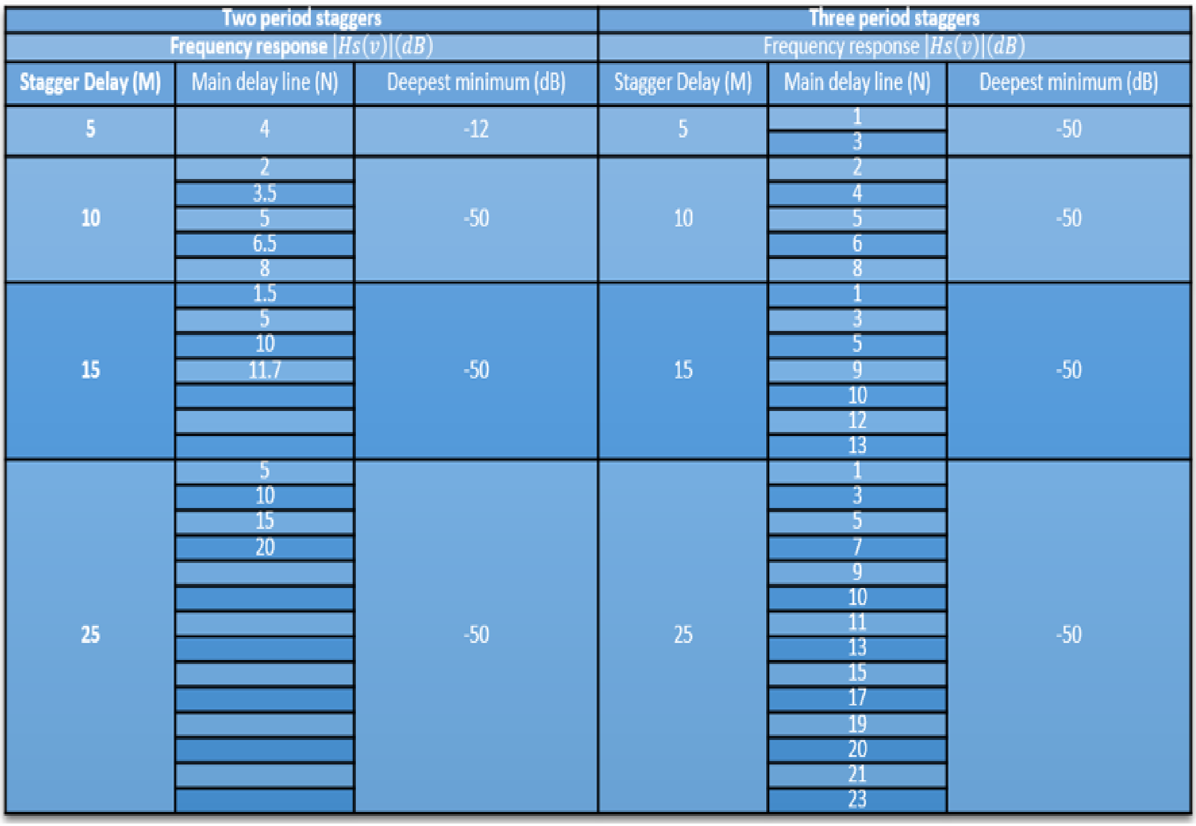
$$I = 3.\frac{\frac{1}{2}\sqrt{2\pi}\delta}{\frac{1}{2}\sqrt{2\pi}\delta\left[\frac{1}{3}e^{-8(\pi T\delta)^2}-\frac{4}{3}e^{-2(\pi T\delta)^2}+3+\frac{2}{3}e^{-2(\pi T\delta)^{2\left(4+\frac{M}{N}\right)}}\cos h8(\pi T\delta)^2\frac{M}{N}-\frac{8}{3}e^{-2(\pi T\delta)^{2\left(1+\frac{M^2}{N^2}\right)}}\cos h4\,(\pi T\delta)^2\frac{M}{N}\right]} \dots\dots\dots (27)$$

Therefore:

$$I = \frac{1}{1+\frac{1}{9}e^{-8(\pi T\delta)^2}-\frac{4}{9}e^{-2(\pi T\delta)^2}+\frac{2}{9}e^{-2(\pi T\delta)^{2\left(4+\frac{M^2}{N^2}\right)}}\cosh 8(\pi T\delta)^2\frac{M}{N}}$$ Finally

$$I = \frac{1}{1+\frac{1}{3}e^{-8(\pi T\delta)^2}-\frac{4}{3}e^{-2(\pi T\delta)^{2\left(1+\frac{M^2}{N^2}\right)}}\cosh 4\,(\pi T\delta)^2\frac{M}{N}} \dots\dots\dots (28)$$

Tables 5: Deepest Minimum for two and three period staggers



Two period staggers			Three period staggers		
Frequency response $\lvert Hs(v)\rvert(dB)$			Frequency response $\lvert Hs(v)\rvert(dB)$		
Stagger Delay (M)	Main delay line (N)	Deepest minimum (dB)	Stagger Delay (M)	Main delay line (N)	Deepest minimum (dB)
5	4	-12	5	1 3	-50
10	2 3.5 5 6.5 8	-50	10	2 4 5 6 8	-50
15	1.5 5 10 11.7	-50	15	1 3 5 9 10 12 13	-50
25	5 10 15 20	-50	25	1 3 5 7 9 10 11 13 15 17 19 20 21 23	-50

Table 6: Frequency Response at two period staggers (Deepest Minimum)

Delay stagger (M)	Main delay line (N)	$\frac{V}{Vbs}$	Deepest minimum $\|Hs(V)\|(dB)$
1	5	0.5	-50
1	10	0.45	-18
		0.51	-18
1	15	0.5	-50
1	20	0.48	-22
		0.52	
1	25	0.5	-50
1	30	0.48	-25
		0.52	

Table 7: Frequency Response at three period staggers (Deepest Minimum)

Delay stagger (M)	Main delay line (N)	$\frac{V}{Vbs}$	Deepest minimum $\|Hs(V)\|(dB)$
1	5	0.5 0.82	-8
1	10	0.1 0.9	-14
1	15	0.08 0.95	-17
1	20	0.05 0.97	-19
1	25	0.04 0.98	-22
1	30	0.03 0.97	-23

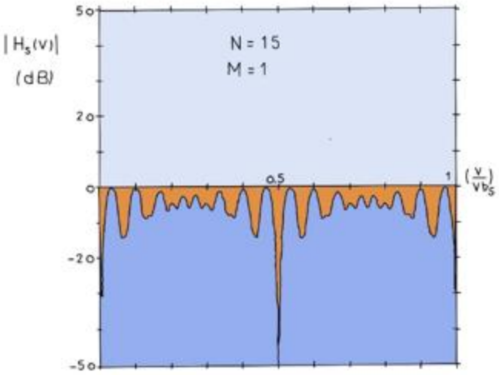


Figure 29: Velocity Response at Stagger Ratio 14:16

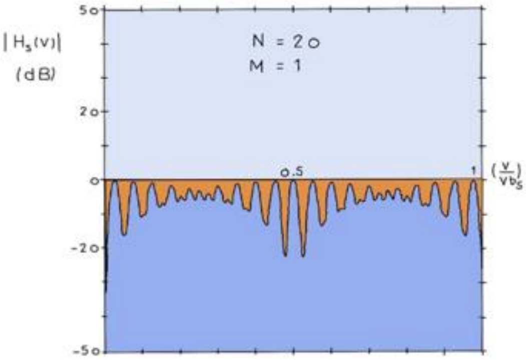


Figure 30: Velocity Response at Stagger Ratio 19:21

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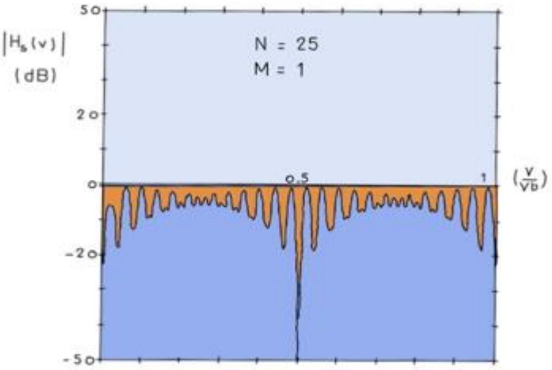

Figure 31: Velocity Response at Stagger Ratio 29:31

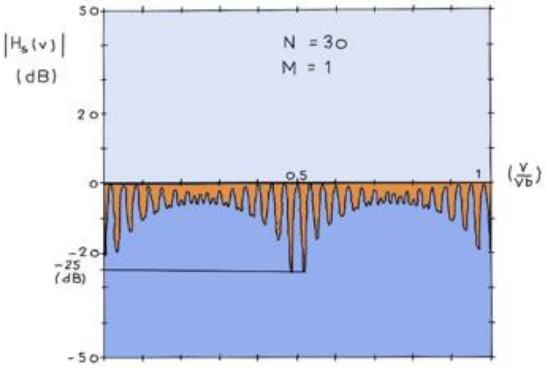

Figure 32: Velocity Response at Stagger Ratio 24:26

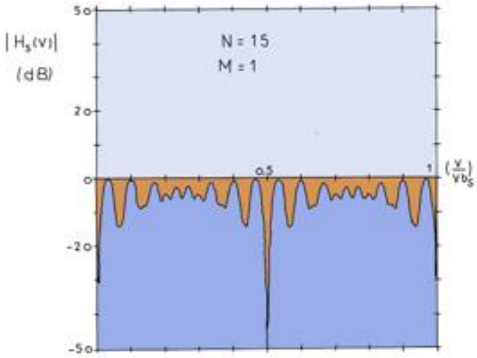

Figure. (33): Velocity Response at Stagger Ratio 4:5:6

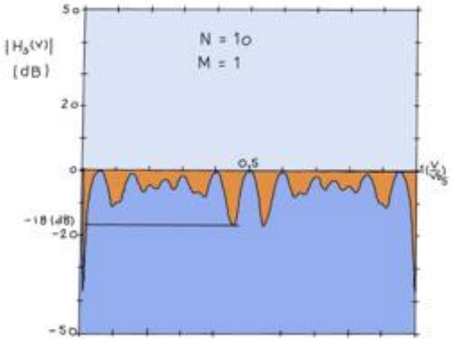

Figure. (34): Velocity Response at Stagger Ratio 9:10:11

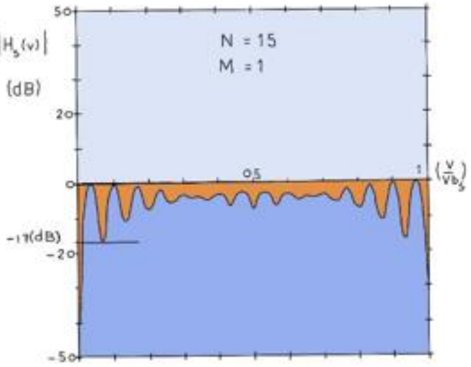

Figure. (35): Velocity Response at Stagger Ratio 14:15:16

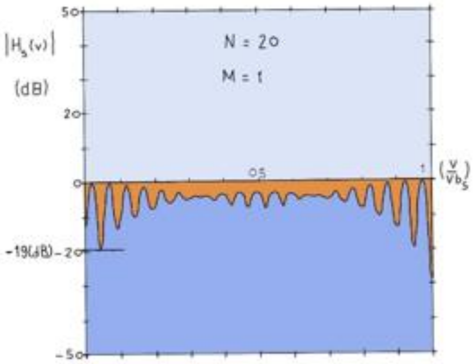

Figure. (36): Velocity Response at Stagger Ratio 19:20:21

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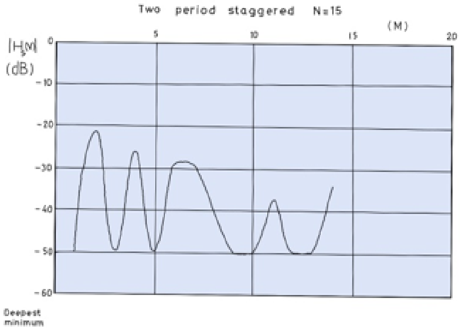

Figure 37: A Deepest Minimum in Response Curve Vs stagger Delay (M)

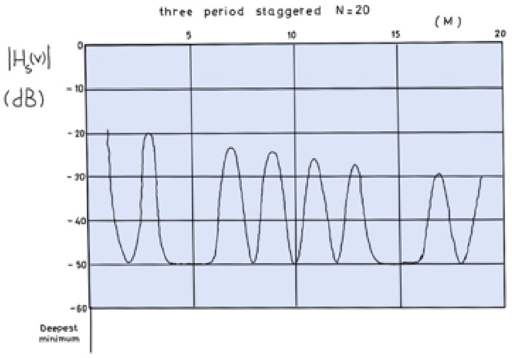

Figure 38: A Deepest Minimum in Response Curve Vs stagger Delay (M)

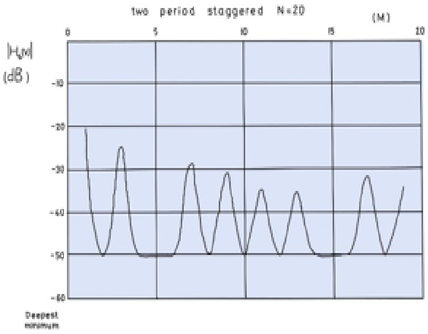

Figure 39: A Deepest Minimum in Response Curve Vs stagger Delay (M)

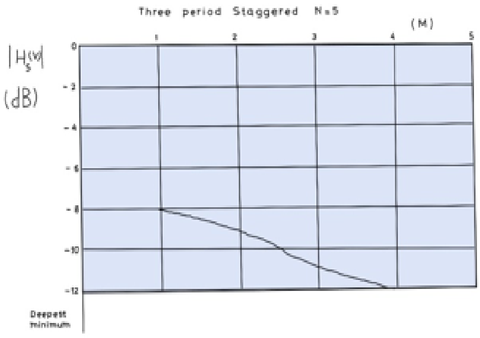

Figure 40: A Deepest Minimum in Response Curve Vs stagger Delay (M)

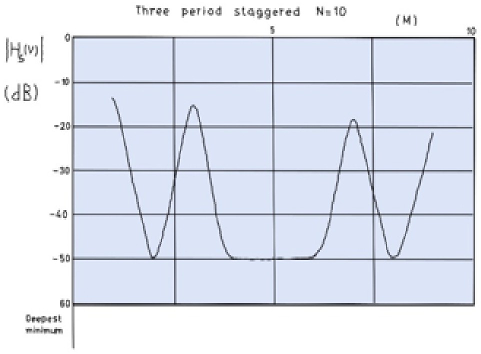

Figure 41: A Deepest Minimum in Response Curve Vs stagger Delay (M)

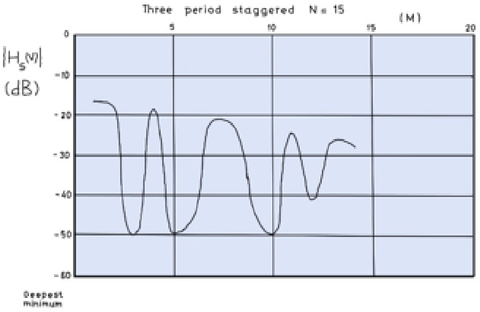

Figure 42: A Deepest Minimum in Response Curve Vs stagger Delay (M)

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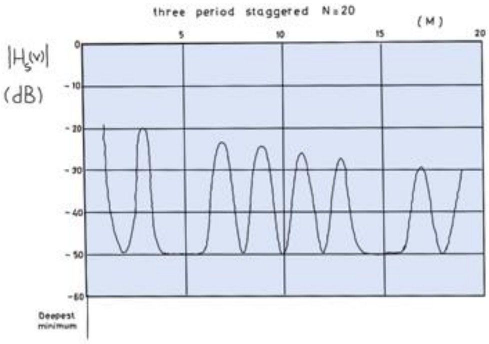

Figure 43: A Deepest Minimum in Response Curve Vs stagger Delay (M)

Figure 44: A Deepest Minimum in Response Curve Vs stagger Delay (M)

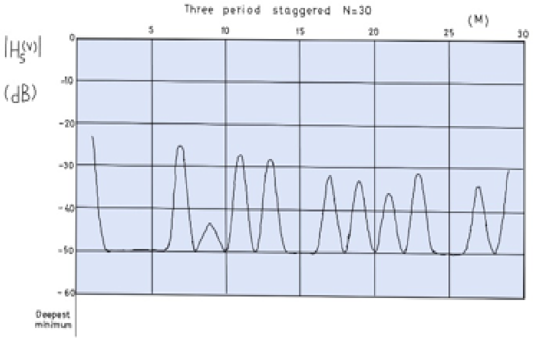

Figure 45: A Deepest Minimum in Response Curve Vs stagger Delay (M)

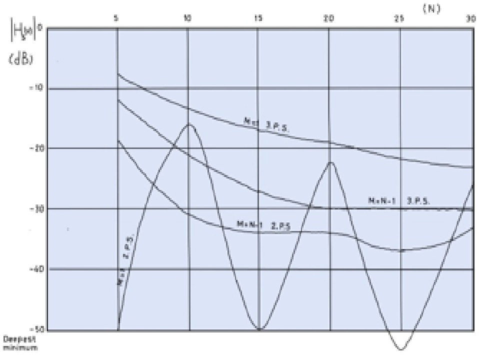

Figure 46: A Comparison between two and three Period staggers at M =1, and M=N-1

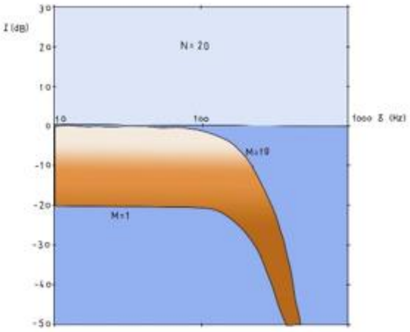

Figure. (47): Improvement Factor for three period stagger

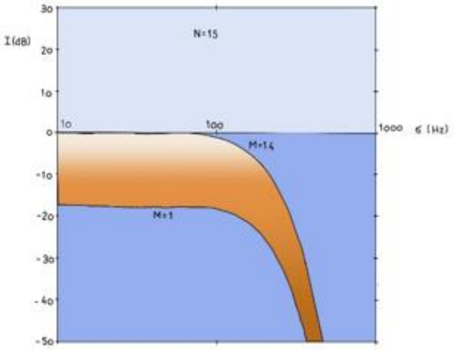

Figure. (48): Improvement Factor for Two period stagger

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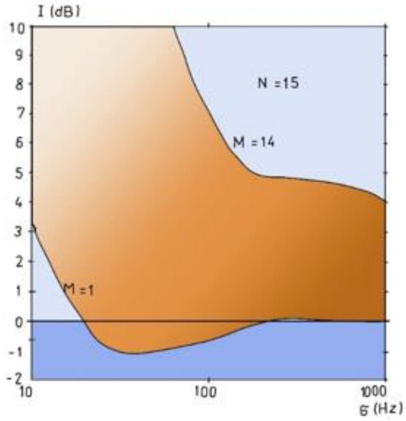

Figure. (49): Improvement Factor for two period stagger

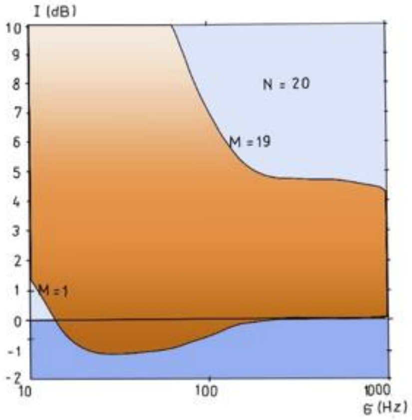

Figure. (50): Improvement Factor for three period stagger

CONCLUSION

Many of the recent sophisticated radar systems are characterized by the fact that they have to acquire and track small targets at large distances and at angles close to the horizon.

In order to meet these requirements, high radiated power levels and increased receiving system sensitivity are frequently required.

As a result, several problems arise which can severely limit radar performance while these problems are different in effect.

By completion the theoretical concept comprise evaluation the staggered optimum ratio useful in MTT 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 Nil seen near both ends of the curve.

By assume, M=I as shown in fig (18-19); 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.

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