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APPLICATION OF THE SPATIAL MTI TECHNIQUE ON THE AIRPORT LANDING RADAR

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ABSTRACT

The two dimensional spatial MTI technique discussed before [1, 2] has the advantages of detecting moving targets which have zero Doppler shift and also improve the probability of detecting target immersed in heavy or fluctuating clutter.

In this paper the application of the spatial MTI is extended to the three-dimensional radar. In this case, the pixel represents a volume element with an elevation coordinate in addition to the range and azimuth. The size of the required memory increase because each memory cell in the two dimensional case is replaced by an array, the length of which depends on the number of cells in the elevation coordinate.

The effect of different radar parameters, namely the pulse repetition frequency, pulse width, the antenna beam-width,..., on the performance of the spatial MTI technique is included.

Application of the spatial MTI on the airport landing radar was discussed. The effect of the limited searching sector and the nearly radial target motion is considered. The considered case study shows the feasibility of using the new technique to improve the landing radar performance without affecting the resolution.

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1- INTRODUCTION

The detection of a moving target in the presence of clutter using the conventional MTI technique is based on the Doppler shift. This technique suffers from the problem of blind speeds and missdetection of the target which moves tangentially with respect to the radar set.

The present state of the art in information technology and signal processing were an incentive to attempt to introduce a totally new concept for MTI radar. This concept is completely independent of the Doppler frequency shift used hitherto in MTI systems. Thus the space, in which the radar is effective, is divided into a large number of units which we shall call pixels. These may be over two, or else three dimensions as the case may be. Thus for ground radar the unit or pixel is effectively a ground area, i.e two dimensional. Reflection from the pixels is caused by either a moving target or by clutter, or from a fixed target. Now the whole space around the radar is scanned in one antenna scan which is taken for the whole number of pixels to make a "Frame". The reflections from the pixels of the frame are stored in a memory array. The same is done for the next frame. Now the two frames will be compared, pixel by corresponding pixel. If the new stored reflection exceeds the previous one by predetermined value (which we call threshold), a moving target is said to be detected in that pixel. Otherwise a clutter (or else no target) is detected in that pixel. This technique permits also the clutter alone to be mapped. The stored reflection of the pixel is in fact the result of several repeated reflections by a number of transmitted pulses. These repeated reflections are added, i.e integrated or averaged. This will contribute to the reduction of noise and clutter fluctuation.

The pixel, which is the unit for the resolution of the existence, or non-existence, of a target in it, is in fact the decisive factor for the resolution of the radar. In a two dimensional radar such as the ground radar, the pixel will be enclosed from an angle θ to $(\theta + \delta\theta)$ ($\delta\theta$ being the antenna beam width) and a radius vectors from R and $(R + \delta R)$. Thus it has the area $R\delta\theta\delta R$ as shown in fig. 1.

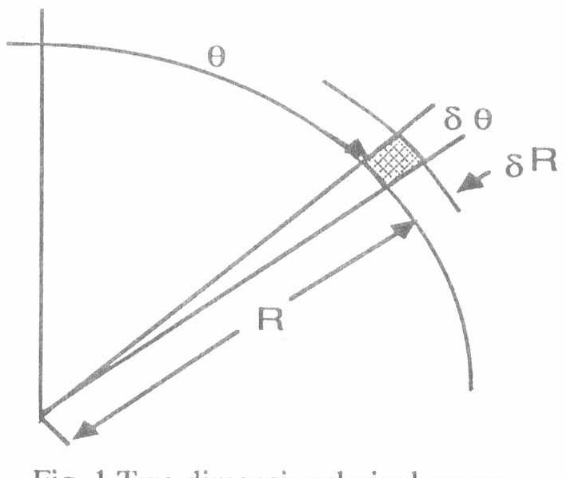

Fig. 1 Two dimensional pixel-space

2. EFFECT OF RADAR PARAMETERS ON SYSTEM PERFORMANCE

Pulse Width (τ)

It is known that transmitting a pulse with narrower width τ results in better range resolution. The pulse width determines the radial dimension of the pixel, according to the relation

$$\delta R = \frac{c\tau}{2}$$

Decreasing the radial dimension of pixels results two side effects; increasing the required speed of processing and increasing the overall number of pixels and consequently the required memory.

Pulse Repetition Frequency (PRF)

For a given incremental angular width of the pixel $\delta\theta$, the number N of integrated pulses within the pixel is practically proportional to the radar pulse repetition frequency (PRF).

The Radar Station I.F Amplifier

The SMTI technique assumes the linearity of the receiver. In most cases, the receiver is linear up to the output of the I.F amplifier. Three exceptions will be discussed; the instantaneous gain control, the logarithmic amplifier, and the automatic gain control. If the instantaneous gain control is used, it reduces the wide variation in the video signal amplitude depending on range. A constant value of the difference threshold ΔV can then be taken.

If the I.F. amplifier obeys a logarithmic law, the existence of heavy clutter will reduce the increase of the video signal amplitude when the target signal is added. This increase may not exceed the detection threshold and miss-detection is expected.

When using the automatic gain control (AGC) circuit, the difference between the ratio of the amplitude of the clutter and the target remains the same at the receiver output. Miss detection occurs when useful target signal becomes smaller than the difference threshold level.

The Antenna Beamwidth

The antenna beam width in the azimuth direction determines that angular width of the pixel. So, the wider the beamwidth, the lower is the resulting angular resolution. But on the other hand, for a fixed repetition frequency, a wider beamwidth will result a greater number of integrated pulses N and consequently better detection probability. Moreover, a wider beam width reduces the necessary memory capacity because of the smaller number of pixels.

Coverage Area

The bigger is the area to be covered by the radar, the higher the number of pixels needed and consequently the bigger memory size required will be. However, there is no advantage in increasing the range beyond the value for which the reflections from target is smaller than the difference threshold value as determined by the noise and clutter situation.

Frame Time

The frame time is the time on which the antenna makes one scan. During this time all the echo reflected from the space surrounding radar are memorized. It is an important factor that determines the classification of the proposed radar to detect a certain target depending on its velocity. The frame time determines the minimum detectable target speed which is inversely proportional to it. If it is small, it may not be sufficient for the slow target to leave the pixel before the next antenna scan and a missdetection in some frames well occur.

A long frame time improves the system performance from another point of view, if all the other parameters are kept constant; increasing this time will result in a corresponding increase in the number of integrated pulses N and consequently a better probability of detection or a smaller rate of false alarms.

3. THREE DIMENSIONAL SPATIAL MTI

The application of spatial MTI can be extended to be used for the three dimensional radar. In this case, the pixel will be a volume element instead of being an area element. It has the range dimension (δR), the azimuth dimension ($\delta\theta$), and the elevation dimension ($\delta\phi$). The size of the required memory increase because each memory cell in the two dimensional case is replaced by an array, the length of which depends on the number of cells in the elevation coordinate. If the scanning time is the same, a higher speed of processing is required.

As the elevation angle, or the height, is the third coordinate required to determine the location of the pixel in space, a part of the corresponding memory cell address is belonging to the elevation coordinate. The generation of the elevation address depends on the used scanning method in radar.

4. APPLICATION OF THE SPATIAL MTI ON LANDING RADAR

The spatial MTI technique can be applied easily on the landing radar. The limited scanning sector and relatively small range are the main factors lead to a small number of pixels. Consequently, the size of the required memory is not so large. The small range of the landing radar leads to an additional advantage; it is the high repetition frequency which results a relatively large number of pulses to be integrated.

In case of landing, the main source of clutter is the fixed targets in the vicinity of the airport. Its large amplitude does not degrade the proposed system performance as long as there is no saturation in the radar amplifier. This is because of the ability of the spatial MTI to cancel fixed targets and the heavy fluctuated clutter [1].

The minimum detectable target radial speeds depends on the radial ccordinate of the pixel. As this type of radar deals with the approaching aircraft, the minimum detectable speed is always exceeded. The main limitation is the required speed of processing if a high resolution in range is required.

Considering the following example of landing radar as a case study.

Maximum range	=	20 Km
Pulse repetition frequency (PRF)	=	2400 HZ
Pulse width	=	o.4 μsec
Scan speed	=	20 r.p.m
Vertical beam width	=	0.7°
Horizontal beam width	=	0.7°
Scan elevation angle	=	-1°→ 8°
Scan azimuth angel	=	20°

The pixel is chosen to be equal to radar resolution cell.

The range dimension (δR)	=	$c\tau/_2$
	=	60m
Total number of pixels	=	(20/0.7) (9/0.7) (20000/$_{60}$)
	≃	120000 pixel
The memory size	=	120 Kbyte

$$\text{The number of integrated pulses (N)} = \frac{\text{Tscan} \cdot \text{PRF}}{\text{No of pivel rays}}$$

$$= \frac{3 \times 2400}{(20/0.7)\,(9/0.7)}$$

$$= 20$$

The required speed of processing depends on the radial dimension of the pixel. In the case under consideration, all the processing related to the reflected pulses within the pixel have to be performed within 0.4 μ sec.

The minimum detectable radial speed $= \delta R/\text{Tscan}$

$= 60/3 = 20$ m / sec

5. CONCLUSION

The spatial MTI can be extended to be used with the three-dimensional radar. In this case the pixel is an element of volume with the range, azimuth, and elevation coordinates. The large size of the required memory is a result of increasing the number of pixels. But the nowadays developments in the digital technology, makes the realization of the three-dimensional MTI feasible.

The considered case study of the 3-dimensional landing radar shows the ability of this technique to improve its performance against clutter without affecting its resolution. The minimum detectable target speed is an additional advantage ; it is too small compared with the practical landing speed.

REFERENCES

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