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CLUTTER REMOVAL TECHNIQUE USING VIRTUAL REFERENCE TAGS FOR INTRUDER LOCALIZATION ULTRA WIDE BAND RADAR NETWORK

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Abstract—

This paper presents an extension in our previous research on Ultra Wide Band (UWB) radar using Virtual reference tags (VRTs). VRTs are virtual tags that are mapped over a particular surveillance area. Each tag has its own stored information which is used by radar as a reference point to track the target. In multistatic radar scenario with one transmitter and three receivers UWB pulses are used to locate and track the intruder. These pulses when reflected by intruder are received at three receivers. A hybrid of Time Of Arrival (TOA) and Received Signal Strength (RSS) techniques are used to process the received signal. VRTs not only provide solution to synchronization problems in TOA and RSS techniques but also provide a platform where clutters can be easily removed. In UWB radar for localization of intruder VRTs provide a promising solution of clutter removal by adding information in specific tags. These specific tags can indicate themselves as clutters, which can be identified by the radar. Lastly we use Network Simulator 2 (NS2) to simulate and conclude the use of VRTs as clutter removal technique.

Index Terms— Radar, Surveillance area, Virtual Reference Tags (VRTs), Time Of Arrival (TOA), Received Signal Strength (RSS).

INTRODUCTION

Clutters have always been a hurdle in radar designs which limit their use to specific regions. Many complex methods are present for clutter removal in different cases[1],[2]. Due to their complexity and inefficiency these techniques have less accuracy when applied in UWB radar sensor network. Our design is multistatic radar comprising of one transmitter (TX) and three receivers (RX). These four nodes (one TX and three RX) are placed at the edges of surveillance of surveillance area. Ultra wide band (UWB) [3] pulses are transmitted and received by three receivers. The received signal is processed by applying the hybrid of Time Of Arrival (TOA) and Received Signal Strength (RSS) localization techniques[4],[5]. In TOA positioning technique the time signal took to be reflected by the object or target is measured at each receiver. When the propagation time of the signal is known, the measured time provides the distance between the target and respective receiver [6]. Considering three receivers as center of circles and their respective distance from target as radius of circle we get three circles that intersect on a single point. This intersecting point of three circles is the position of target. In RSS technique the strength of the signal which is reflected from the target is measured at all corresponding receivers. If we consider an ideal case each measurement of the signal strength at receivers will give the distance of receiver from the target, same like in case of TOA. But in RSS the accuracy decreases in case of multi path fading environment and shape of circle gets distorted and it becomes difficult to get an exact intersection of distorted circles. This can produce a considerable amount of error in target positioning [7].

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2 VIRTUAL REFERENCE TAGS (VRTS)

To overcome drawbacks in TOA and RSS techniques our design uses a hybrid of TOA and RSS along with VRTs[4]. These VRTs contain information about the characteristics of target reflected received signal in respective three receivers. Each VRT has its own information. Table 1 shows the information stored at that each VRT.

TABLE 1
Information or data stored in each VRT

Information	*Receiver 1*	*Receiver 2*	*Receiver 3*
Distance from VRT	*Distance of VRT from RX1*	*Distance of VRT from RX2*	*Distance of VRT from RX3*
RSS from VRT	*RSS at RX1 considering target location at VRT*	*RSS at RX2 considering target location at VRT*	*RSS at RX3 considering target location at VRT*

These VRTs are designed virtually and mapped on the surveillance area. Figure 1 shows a scenario in which twenty five VRTs are designed over the surveillance area.

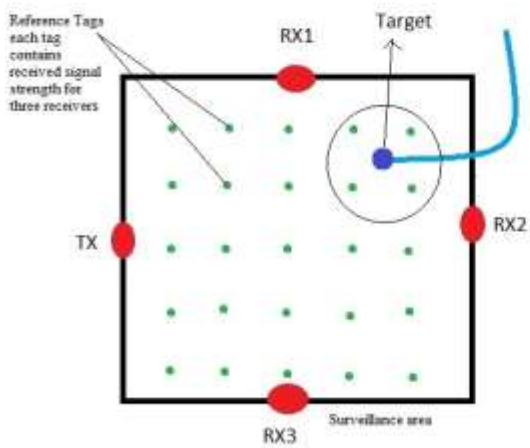

Figure 1. VRTs positioning in surveillance area.

Whenever target enters, the actual reflected signal properties are compared with the nearest VRT properties, providing reference points to radar which reduce TX-RX synchronization problem and increase accuracy[4].

2.1 Radar clutters

The term clutter is used for unwanted echoes in radar systems. For different types of radar clutter type can be different. In our case these echoes occur due to reflection from any object (car, building, animal, pole etc) other then the target present in surveillance area. Figure 2 shows how clutter occurs due to objects.

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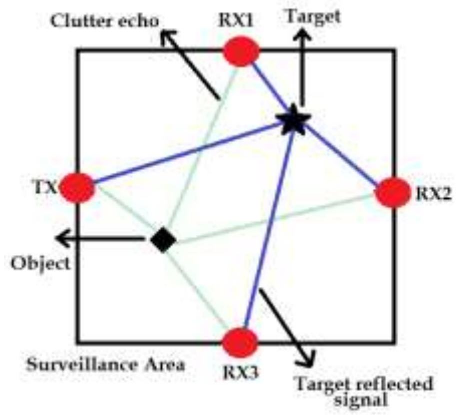

Figure 2. Clutter effect in radar systems.

2.2 Clutter removal with VRTs

To overcome clutter problem VRTs can be used. Since VRTs are virtually mapped over the surveillance area so while mapping, VRTs that overlap object or VRTs closest to objects are given additional flags in their information. Figure 3 shows the situation of objects with their closest VRTs.

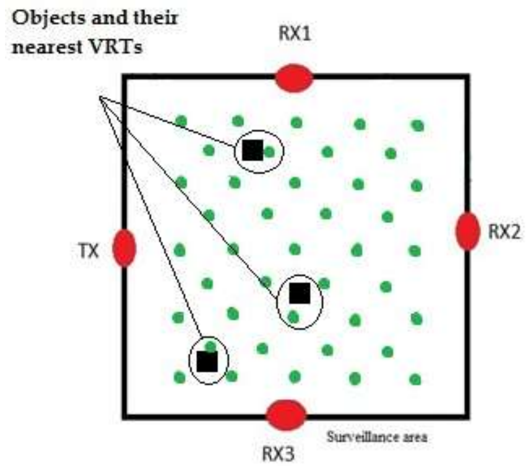

Figure 3. Objects in the surveillance area mapped with VRTs.

The VRTs with flags in their information can now indicate the presence of an object clutter. Once objects are identified their echo can be matched and ignored by the receivers. VRTs mapping for different surveillance area can be done while installing the radar system or VRTs can be reprogrammed when some part of surveillance area is changed.

3 Radar Design

Once TX-RXs are placed at their location, virtual reference tags are planned at different positions within the surveillance area. The number of VRTs can vary in different configurations depending on radar design and characteristics of surveillance area. The system parameters for the radar design are shown in table 2.

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TABLE 2
System Parameters

Parameter	Symbol	Value
Surveillance area	A	*90x90 m*
Lower frequency	f_L	*5 GHz*
Upper frequency	f_U	*5.5 GHz*
Signal bandwidth	B	*500 MHz*
Transmitted antenna gain	G_t	*0 dB*
Receiver antenna gain	G_r	*0 dB*
Radar cross-section	σ	$1\ m^2$
Pulse repetition frequency	*PRF*	*1.5 MHz*

After setting the parameters of system, we design radar in Network Simulator 2(NS2). Figure 4 shows the simulation start of the radar design.

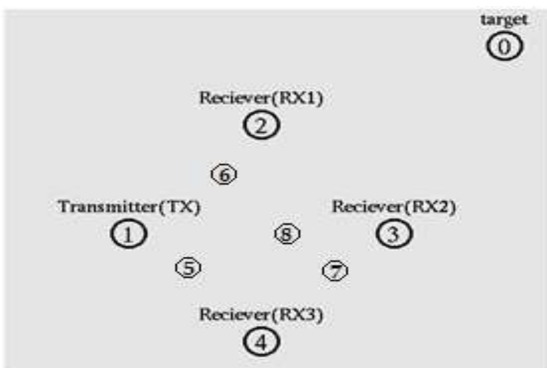

Figure 4. Radar simulation in NS2

The surveillance area is set as 90X90 meters. TX-RXs area placed at the edges of surveillance area represented by node 1, 2, 3 and 4. Node 0 represents target which will move in the surveillance area. Nodes 5, 6, 7 and 8 represent objects in the surveillance area which produce clutters. The number of VRTs will vary keeping the path of target and location objects same.

4 Experimental Results

The actual path and detected path of target using 29, 105 and 1681 VRTs are shown in table3.

TABLE 3
Actual and calculated target path with 29, 105 and 1681 VRTs

Time	Actual Path	Calculated path with 29 VRTs	Calculated path with 105 VRTs	Calculated path with 1681 VRTs
At time: 0.1s	*Not in area*	*Not in area*	*Not in area*	*Not in area*
At time: 0.2s	*X: 67.517; Y: 61.988*	*X: 70.000; Y: 55.000*	*X: 66.000; Y: 58.000*	*X: 68.000; Y: 62.000*

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At time: 0.3s	*X: 56.000; Y: 58.000*	*X: 55.000; Y: 55.000*	*X: 58.000; Y: 58.000*	*X: 56.000; Y: 58.000*
At time: 0.4s	*X: 27.000; Y: 49.000*	*X: 25.000; Y: 55.000*	*X: 26.000; Y: 50.000*	*X: 26.000; Y: 48.000*
At time: 0.5s	*X: 83.000; Y: 89.000*	*X: 85.000; Y: 85.000*	*X: 82.000; Y: 90.000*	*X: 82.000; Y: 88.000*
At time: 0.6s	*Not in area*	*Not in area*	*Not in area*	*Not in area*
At time: 0.7s	*X: 23.130; Y: 54.036*	*X: 25.000; Y: 55.000*	*X: 26.000; Y: 58.000*	*X: 24.000; Y: 54.000*
At time: 0.8s	*X: 89.000; Y: 82.000*	*X: 85.000; Y: 85.000*	*X: 90.000; Y: 82.000*	*X: 88.000; Y: 82.000*
At time: 0.9s	*X: 60.000; Y: 50.000*	*X: 55.000; Y: 55.000*	*X: 58.000; Y: 50.000*	*X: 60.000; Y: 50.000*
At time: 1.0s	*X: 22.000; Y:43.000*	*X: 25.000; Y:40.000*	*X: 18.000; Y:42.000*	*X: 22.000; Y:42.000*
At time: 1.1s	*X: 14.000; Y: 87.000*	*X: 10.000; Y: 85.000*	*X: 10.000; Y: 90.000*	*X: 14.000; Y: 86.000*
At time: 1.2s	*X: 14.000; Y: 87.000*	*X: 10.000; Y: 85.000*	*X: 10.000; Y: 90.000*	*X: 14.000; Y: 86.000*
At time: 1.3s	*X: 12.000; Y: 13.000*	*X: 10.000; Y: 10.000*	*X: 10.000; Y: 10.000*	*X: 12.000; Y: 12.000*
At time: 1.4s	*X: 25.000; Y: 43.000*	*X: 25.000; Y: 40.000*	*X: 26.000; Y: 42.000*	*X: 24.000; Y: 42.000*
At time: 1.5s	*X: 83.000; Y: 12.000*	*X: 85.000; Y: 10.000*	*X: 82.000; Y: 10.000*	*X: 82.000; Y: 12.000*
At time: 1.6s	*Not in area*	*Not in area*	*Not in area*	*Not in area*
At time: 1.7s	*Not in area*	*Not in area*	*Not in area*	*Not in area*
At time: 1.8s	*Not in area*	*Not in area*	*Not in area*	*Not in area*
At time: 1.9s	*Not in area*	*Not in area*	*Not in area*	*Not in area*
At time: 2.0s	*Not in area*	*Not in area*	*Not in area*	*Not in area*
At time: 2.1s	*Not in area*	*Not in area*	*Not in area*	*Not in area*
At time: 2.2s	*Not in area*	*Not in area*	*Not in area*	*Not in area*
At time: 2.3s	*Not in area*	*Not in area*	*Not in area*	*Not in area*
At time: 2.4s	*Not in area*	*Not in area*	*Not in area*	*Not in area*
At time: 2.5s	*Not in area*	*Not in area*	*Not in area*	*Not in area*
At time: 2.6s	*Not in area*	*Not in area*	*Not in area*	*Not in area*
At time: 2.7s	*Not in area*	*Not in area*	*Not in area*	*Not in area*
At time: 2.8s	*X: 37.355; Y: 37.355*	*X: 40.000; Y: 40.000*	*X: 34.000; Y: 34.000*	*X: 38.000; Y: 38.000*

Figure 5 shows the graphical comparison of the actual and three detected path in different VRTs. Also in three different cases objects detection is shown in table 4.

TABLE 4
Actual and detected locations of objects.

Object number	*Actual location of objects*	*Calculated Location of objects with 29 VRTs*	*Calculated Location of objects with 105 VRTs*	*Calculated Location of objects with 1681 VRTs*
1	*X: 19.000; Y:37.000*	*X: 20.000; Y:40.000*	*X: 18.000; Y:34.000*	*X: 20.000; Y:36.000*
2	*X: 36.000; Y:69.000*	*X: 35.000; Y:70.000*	*X: 34.000; Y:66.000*	*X: 36.000; Y:70.000*
3	*X: 53.000; Y:46.000*	*X: 50.000; Y:45.000*	*X: 50.000; Y:42.000*	*X: 54.000; Y:46.000*
4	*X: 78.000; Y:36.000*	*X: 80.000; Y:35.000*	*X: 76.000; Y:34.000*	*X: 78.000; Y:36.000*

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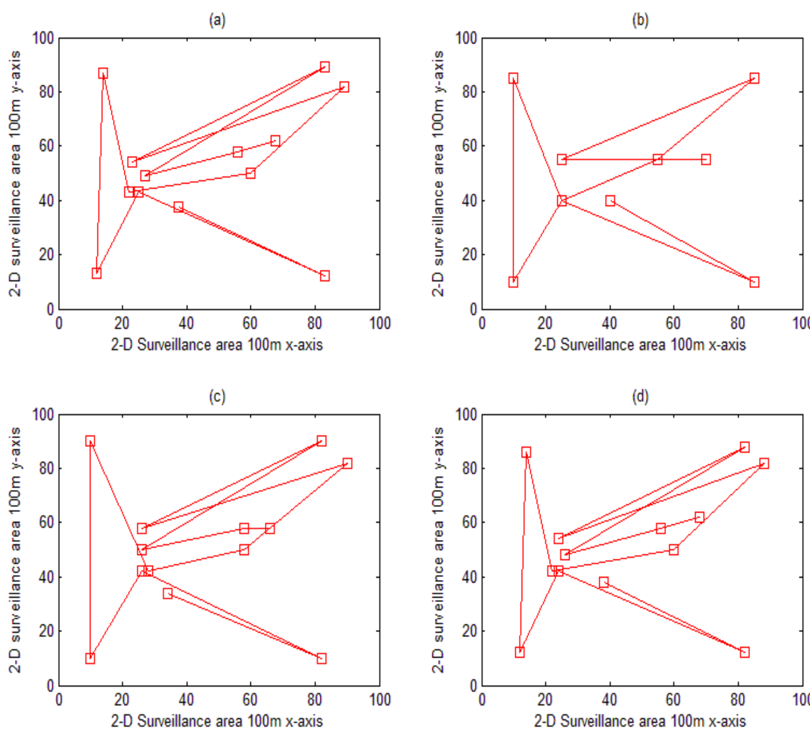
From table 3 and 4 we came to know that increasing number of VRTs also increases accuracy of the system and for a surveillance area of 100x100 meters if we make 2500 VRTs we can monitor target path with 0.2 meter accuracy. By increasing VRTs from 2500 we can get even more accurate results and also their vast application made them improve radars application in vehicles[8]. These VRTs not only help us in giving reference to target but also helps identifying objects in surveillance hence decreases clutter effects.

Figure 5. Target movement in 2-D surveillance area of 90x90 meters, (a) Actual path of target, (b) Calculated target path with 29 VRTs, (c) Calculated target path with 105 VRTs, (d) Calculated target path with 1681 VRTs.



4 CONCLUSION

This paper focuses on clutter removal in a specific field of UWB radar. The properties of radar in which VRTs are used as clutter removal are:

- Multistatic radar with one transmitter and three receivers placed at the edges of surveillance area.
- The radar uses UWB pulses which when reflect by the target are processed.
- The radar uses TOA and RSS hybrid technique to process the reflected signal.
- VRTs are mapped over the surveillance area to provide references to the location of target overcoming the drawback of synchronization in TOA and RSS techniques.

Clutters in our case are defined to be objects of any nature which can reflect the signal with some specific strength to receivers. These reflected signals can be identified by using VRTs. When VRTs are mapped on surveillance they have information given in table 1 which provides reference to three receivers about target and receivers consider target location to be the nearest VRT. Similarly these VRTs while mapping also contain a flag which can identify presence of object other than target. The nearest VRT to the object contains a flag that identifies receivers the location of object.

The application of VRTs in clutter removal does not limit their use in radars. With little modification they can be implemented in many other radar fields like road safety in vehicles, under water radar systems of submarines, radars in battle tanks to identify location of enemy tank etc.

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