Ultra-wideband Technology-based Localization Platform with Real-Time Signal Processing

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I. INTRODUCTION

The ultra-wideband (UWB) technology provides an opportunity for highly accurate (up to the millimeter range) localization. However, such an accuracy can be obtained at small operating ranges, which may be equal to just several centimeters [1]. Moreover, UWB localization systems often use field-programmable gate arrays which results in high power consumption of at least several Watts [1]. Research results on the accuracy of simple architecture UWB localization systems that do not involve highly complicated signal processing are scarce. In this paper, the UWB localization platform with real-time 3D localization based on the time difference of arrival (TDoA) method and the energy detection (ED) receiver is presented. The localization platform constitutes the next development stage of the UWB ranging platform [2]. The measurement results with the 0.5 ns integration window size (equivalent of a 2 GS/s sampling rate) show the mean location error in 3D, ε_{3D}, being lower than 2 cm with standard deviation of the absolute location error in 3D, σ_{3D}, being lower than 1.5 cm.

II. LOCALIZATION PLATFORM ARCHITECTURE

A Picosecond 3500D pulse generator which produces a pulse of a full width at half the maximum of 65 ps with an amplitude of 8 V is used as a transmitter. A LeCroy SDA 816Zi real-time oscilloscope with the 16 GHz analog bandwidth is used as a receiver. A developed UWB omnidirectional antenna operating in 2-11 GHz band plays the role of a transmit antenna. The UWB signals are received by UWB SMT-3TO10M-A SkyCross antennas operating in 3-10 GHz - see Fig. 1. The graphical user interface (GUI) developed in Visual Basic and running on the oscilloscope executes the ED receiver algorithms and position calculation functions. The GUI also provides real-time visualization in 2D. The considered ED receiver makes use of the shifting algorithm which enables highly accurate ranging at relatively low (1-2 GS/s) sampling rates [3]. In order to enable localization without synchronization between the transmitter and a receiver, an algorithm based on the TDoA method has been implemented [4]. With multiple anchors, a set of TDoAs hyperboloids is formed and their intersection provides information about the location of the transmitter. The anchors are placed in the corners of the measurement site at three different heights - see Fig. 4. To assess the impact of the anchor spatial distribution on the location accuracy, a dilution of precision (DOP) analysis has been performed [5].

III. MEASUREMENT RESULTS

Fig. 2 and 5 show the accuracy of the localization platform given by the mean localization error and standard deviation of the absolute error. Measurements were performed at a 50 cm x 50 cm site with 27 measurement points at three heights: 7 cm, 10.5 cm and 13.5 cm, and with line-of-sight conditions. For each measurement point, 20 samples were taken. The integration window size and number of acquisitions were equal to 0.5 ns and 20, respectively [3]. Fig. 3 presents the obtained results at a height of 10.5 cm with horizontal DOP (HDOP). As can be observed, for the considered anchor distribution, HDOP influences the localization accuracy to a small extent taking values from 1.1 to 1.8. For all the considered measurement points, the mean location error in 2D remains below 1 cm, although for 3D, for most cases, it is larger than 1 cm - see Fig. 2. The increased value of the location error in 3D over 2D is related to poor vertical DOP (VDOP) that, at a height of 10.5 cm, takes values from the 3.6-4.2 range - see Fig. 6. Other sources of this increase are related to the considered localization algorithm and antenna propagation characteristics.

IV. CONCLUSIONS

In this paper, we have presented the UWB localization platform with real-time signal processing. Our results show that it is possible to achieve localization accuracy being better than 2 cm in 3D with a 2 GS/s sampling rate.

REFERENCES

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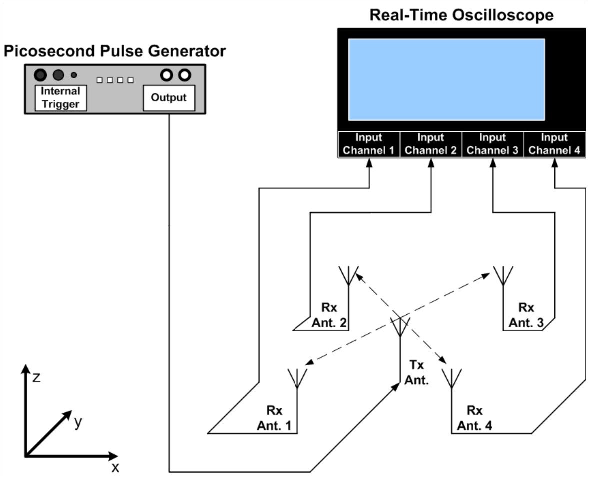

Fig. 1. The high level block diagram of the considered UWB localization platform.

POSITION	ε_X (cm)	ε_Y (cm)	ε_Z (cm)	ε_{2D} (cm)	ε_{3D} (cm)
X=10cm; Y=10cm; Z=7cm	0,29	0,26	0,74	0,39	0,83
X=10cm; Y=25cm; Z=7cm	0,25	0,17	2,45	0,30	2,47
X=10cm; Y=40cm; Z=7cm	0,21	0,31	1,99	0,37	2,03
X=25cm; Y=10cm; Z=7cm	0,19	0,25	0,76	0,31	0,82
X=25cm; Y=25cm; Z=7cm	0,34	0,27	1,17	0,43	1,24
X=25cm; Y=40cm; Z=7cm	0,34	0,41	1,42	0,53	1,52
X=40cm; Y=10cm; Z=7cm	0,04	0,30	0,45	0,31	0,55
X=40cm; Y=25cm; Z=7cm	0,64	0,29	1,58	0,70	1,73
X=40cm; Y=40cm; Z=7cm	0,24	0,36	1,32	0,44	1,39
MEAN:	**0,28**	**0,29**	**1,32**	**0,42**	**1,40**

POSITION	ε_X (cm)	ε_Y (cm)	ε_Z (cm)	ε_{2D} (cm)	ε_{3D} (cm)
X=10cm; Y=10cm; Z=10.5cm	0,68	0,18	0,93	0,70	1,17
X=10cm; Y=25cm; Z=10.5cm	0,32	0,18	1,30	0,37	1,35
X=10cm; Y=40cm; Z=10.5cm	0,40	0,34	2,47	0,53	2,52
X=25cm; Y=10cm; Z=10.5cm	0,20	0,73	1,48	0,76	1,66
X=25cm; Y=25cm; Z=10.5cm	0,43	0,31	1,70	0,53	1,78
X=25cm; Y=40cm; Z=10.5cm	0,23	0,48	1,11	0,53	1,23
X=40cm; Y=10cm; Z=10.5cm	0,22	0,75	1,20	0,78	1,43
X=40cm; Y=25cm; Z=10.5cm	0,28	0,22	0,90	0,36	0,97
X=40cm; Y=40cm; Z=10.5cm	0,49	0,41	1,38	0,64	1,52
MEAN:	**0,36**	**0,40**	**1,39**	**0,58**	**1,51**

POSITION	ε_X (cm)	ε_Y (cm)	ε_Z (cm)	ε_{2D} (cm)	ε_{3D} (cm)
X=10cm; Y=10cm; Z=13.5cm	0,29	0,31	1,37	0,43	1,43
X=10cm; Y=25cm; Z=13.5cm	0,44	0,44	1,17	0,62	1,32
X=10cm; Y=40cm; Z=13.5cm	0,42	0,54	1,15	0,68	1,34
X=25cm; Y=10cm; Z=13.5cm	0,24	0,50	1,57	0,55	1,66
X=25cm; Y=25cm; Z=13.5cm	0,27	0,25	0,84	0,37	0,92
X=25cm; Y=40cm; Z=13.5cm	0,49	0,16	1,91	0,52	1,98
X=40cm; Y=10cm; Z=13.5cm	0,62	0,57	2,07	0,84	2,23
X=40cm; Y=25cm; Z=13.5cm	0,27	0,24	0,97	0,36	1,03
X=40cm; Y=40cm; Z=13.5cm	0,41	0,26	1,44	0,49	1,52
MEAN:	**0,38**	**0,36**	**1,39**	**0,54**	**1,49**

Fig. 2. Mean location errors for the considered measurement points.

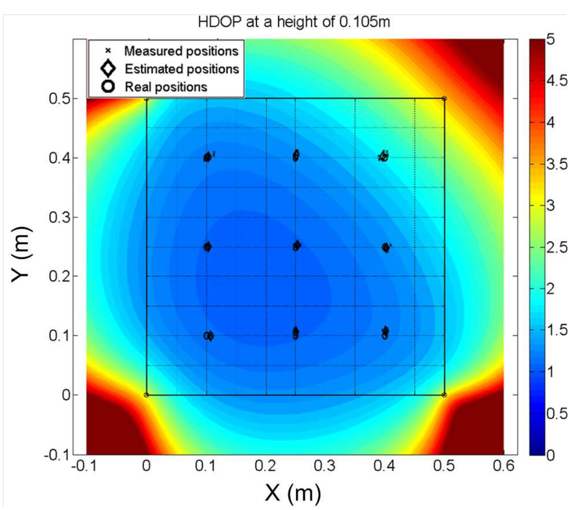

Fig. 3. The x-y position results with HDOP visualization.

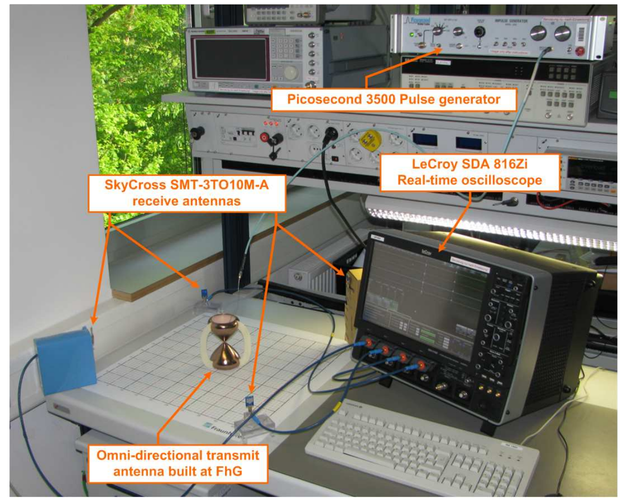

Fig. 4. A photo of the measurement setup.

POSITION	σ_X (cm)	σ_Y (cm)	σ_Z (cm)	σ_{2D} (cm)	σ_{3D} (cm)
X=10cm; Y=10cm; Z=7cm	0,22	0,21	0,66	0,30	0,72
X=10cm; Y=25cm; Z=7cm	0,17	0,10	1,46	0,20	1,48
X=10cm; Y=40cm; Z=7cm	0,14	0,25	1,63	0,29	1,65
X=25cm; Y=10cm; Z=7cm	0,13	0,15	0,47	0,20	0,51
X=25cm; Y=25cm; Z=7cm	0,25	0,24	1,09	0,35	1,15
X=25cm; Y=40cm; Z=7cm	0,23	0,27	0,99	0,36	1,05
X=40cm; Y=10cm; Z=7cm	0,05	0,09	0,35	0,10	0,37
X=40cm; Y=25cm; Z=7cm	0,35	0,16	1,02	0,38	1,09
X=40cm; Y=40cm; Z=7cm	0,33	0,34	0,87	0,47	0,99
MEAN:	**0,21**	**0,20**	**0,95**	**0,29**	**1,00**

POSITION	σ_X (cm)	σ_Y (cm)	σ_Z (cm)	σ_{2D} (cm)	σ_{3D} (cm)
X=10cm; Y=10cm; Z=10.5cm	0,20	0,13	0,84	0,24	0,87
X=10cm; Y=25cm; Z=10.5cm	0,19	0,13	1,16	0,23	1,19
X=10cm; Y=40cm; Z=10.5cm	0,35	0,18	1,95	0,40	1,99
X=25cm; Y=10cm; Z=10.5cm	0,12	0,24	0,82	0,27	0,86
X=25cm; Y=25cm; Z=10.5cm	0,25	0,14	1,45	0,29	1,48
X=25cm; Y=40cm; Z=10.5cm	0,20	0,38	0,82	0,43	0,92
X=40cm; Y=10cm; Z=10.5cm	0,18	0,29	0,74	0,34	0,82
X=40cm; Y=25cm; Z=10.5cm	0,29	0,23	0,87	0,37	0,94
X=40cm; Y=40cm; Z=10.5cm	0,32	0,24	0,96	0,40	1,04
MEAN:	**0,23**	**0,22**	**1,07**	**0,33**	**1,12**

POSITION	σ_X (cm)	σ_Y (cm)	σ_Z (cm)	σ_{2D} (cm)	σ_{3D} (cm)
X=10cm; Y=10cm; Z=13.5cm	0,20	0,25	1,04	0,32	1,09
X=10cm; Y=25cm; Z=13.5cm	0,28	0,23	0,77	0,37	0,85
X=10cm; Y=40cm; Z=13.5cm	0,21	0,27	0,87	0,34	0,94
X=25cm; Y=10cm; Z=13.5cm	0,12	0,27	1,18	0,30	1,22
X=25cm; Y=25cm; Z=13.5cm	0,14	0,14	0,49	0,20	0,53
X=25cm; Y=40cm; Z=13.5cm	0,30	0,13	1,10	0,33	1,15
X=40cm; Y=10cm; Z=13.5cm	0,26	0,23	1,27	0,35	1,31
X=40cm; Y=25cm; Z=13.5cm	0,17	0,08	0,77	0,19	0,79
X=40cm; Y=40cm; Z=13.5cm	0,38	0,27	1,04	0,47	1,14
MEAN:	**0,23**	**0,21**	**0,95**	**0,32**	**1,00**

Fig. 5. Standard deviation of the absolute errors for the considered measurement points.

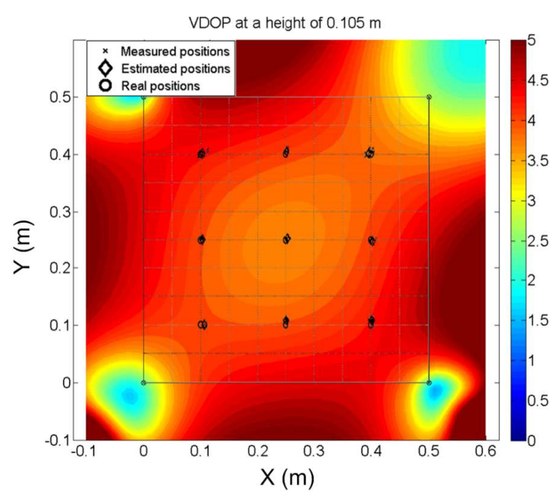

Fig. 6. The x-y position results with VDOP visualization.