International Committee on Global Navigation Satellite Systems

The TC-OFDM System for Seamless Outdoor & Indoor Positioning in Wide Area

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Outline

1. Background
2. TC-OFDM
3. Research Progress
4. Conclusions

1.1 Requirement Analysis

Emergency Rescue

Public Security

Community Services

Social Communication

How to save more people?

The Applications of Seamless Outdoor & Indoor Positioning in Wide Area

Benefit both People and Society

1.2 Limitation of GNSS in indoor positioning

- The strength of GNSS signal is about -130dBm on the ground (without sheltering).

Receiver Sensitivity

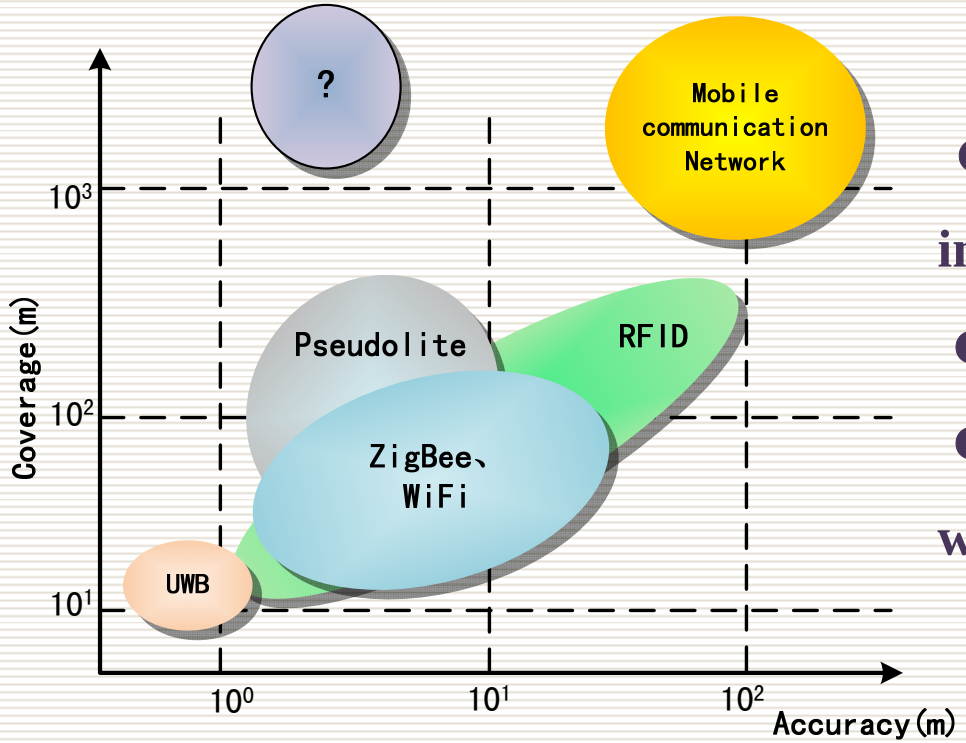
Year	Acquisition Sensitivity（dBm）	Tracking Sensitivity（dBm）
1997	-142	-150
2004	-142	-159
2012	-148	-162

Signal Attenuation(L-Band)

	Window	Wall	Mental	Ceiling
Attenuation	3dB	18dB	25dB	23dB

Conclusion：GNSS can not provide stable positioning services in urban canyon or indoor environments.

1.3 The Current Situation of Indoor Positioning



- More than one million mobile BS in China;
- Nearly 4.7 million BS worldwide;
- BS is a low cost carrier to realize wide indoor signal coverage.

Conclusion: The research on Indoor & Outdoor Positioning based on the integration of mobile BS & GNSS is promising and meaningful.

1.4 Problems to resolve

1.NLOS(Non Line of Sight)
2.The Ranging Accuracy affected by Terrestrial Channel
3.The Accuracy of Time Synchronization

Positioning Error comes to **more than 100m**

Since 2008, we have researched and developed TC-OFDM（**Time & Code Division-Orthogonal Frequency Division Multiplexing**） system for Seamless Outdoor & Indoor Positioning in Wide Area

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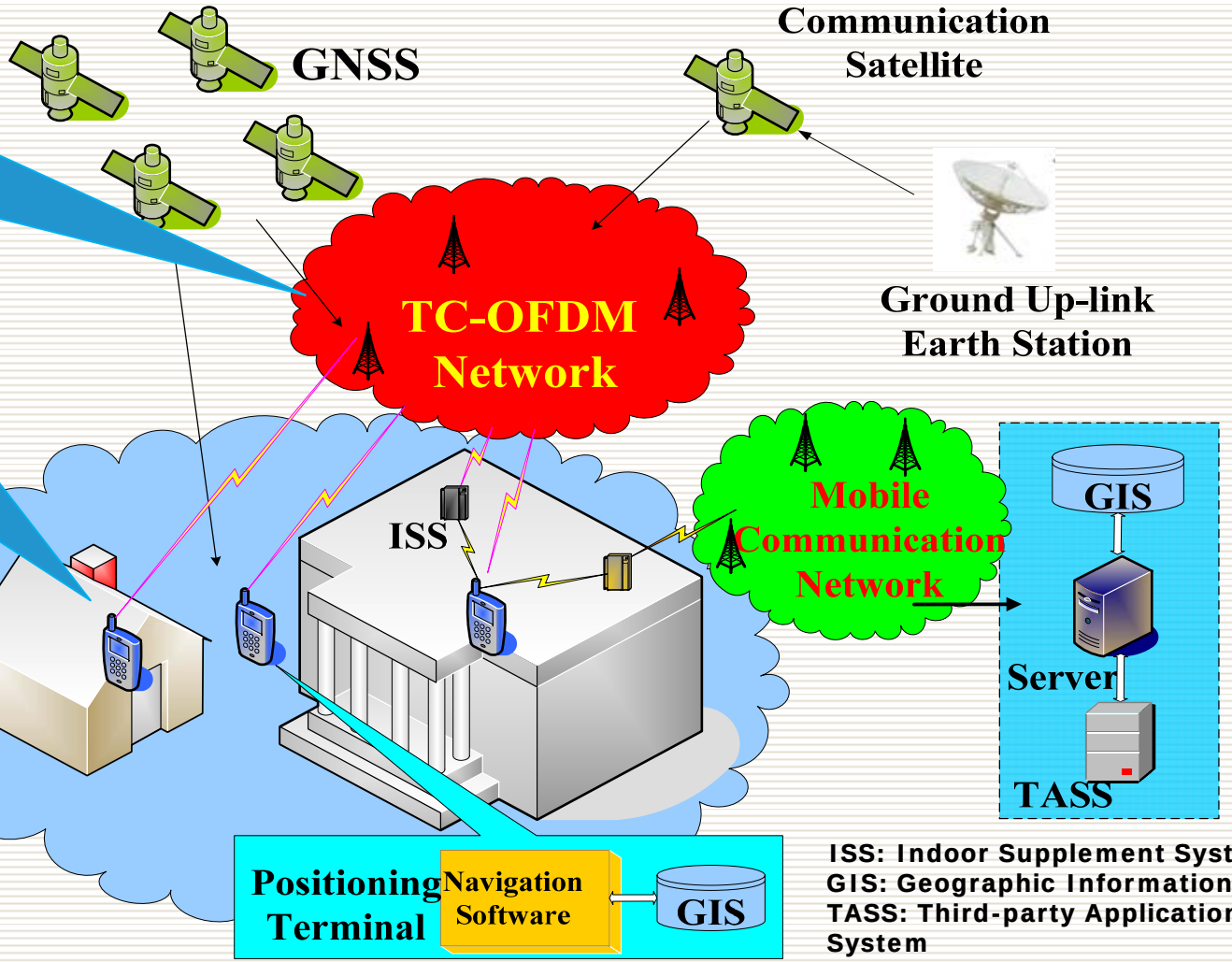
2.1 The Architecture of TC-OFDM System

BS:
data signal from satellites multiplexed with positioning signal

Terminal:
demodulates the navigation signal and sends the result to service platform



ISS: Indoor Supplement System
GIS: Geographic Information System
TASS: Third-party Application Service System

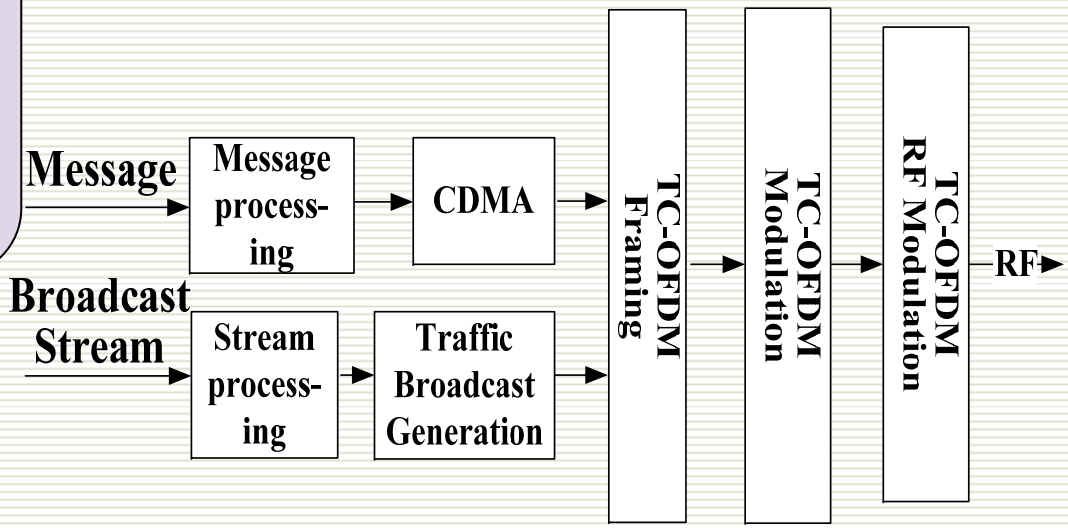
2.2 Signal Design

Communication signals OFDM:
- Anti-multipath
- Anti-interference of Narrowband

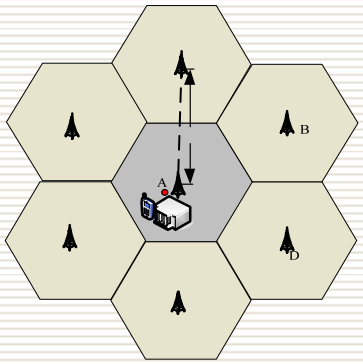
Navigation signals CDMA:
- High Spreading Gains
- Good Ranging Performance

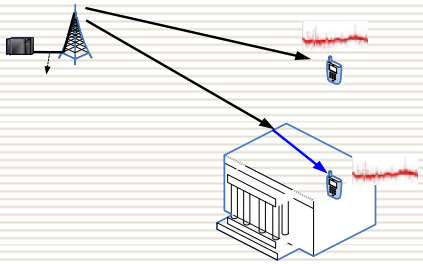
TC-OFDM:
Multi-signals for Communication and Navigation in One Frequency

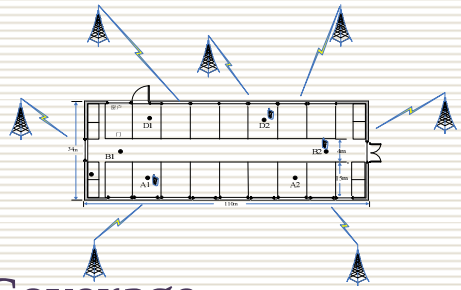
TC-OFDM Signal Generation &Modulation



2.3 Signal Coverage

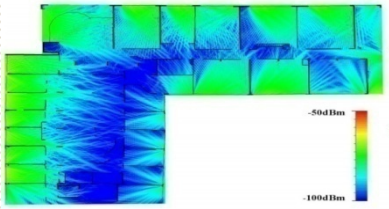






Stimulation with COST231Model

A few complex buildings (yellow parts) require signal supplement based on the existed wire system.



Stimulation of Signal Coverage

Strength of Signal Coverage

Points	BS1（Service BS）	BS2	BS3	BS4	BS5	BS6	BS7
A1、A2	-92dBm	-127dBm	uncertain	-91 dBm	-91dbm	uncertain	-127dBm
B1、B2	-72dBm	-109dBm	-91dBm	-109 dBm	-109 dBm	-91 dBm	-109dBm
D1、D2	-56 dBm	-91dBm	uncertain	-127dBm	-127dbm	uncertain	-91dBm

2.3.3 Differential Positioning with TDOA

NLOS, cause an error from 10 to 500m

Difference Positioning

TDOA

Differential Message

Indoor GIS

NLOS Distribution Estimating

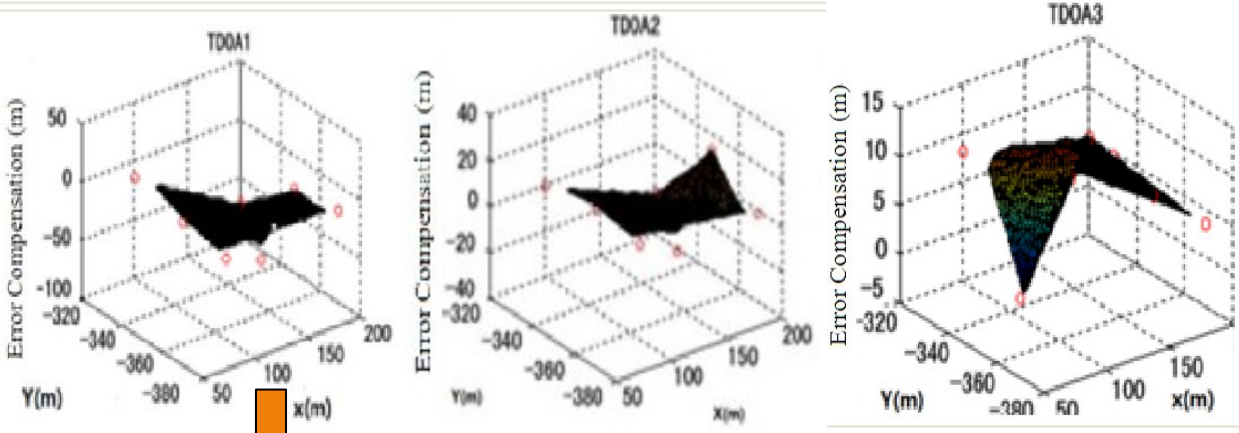
Differential Correction

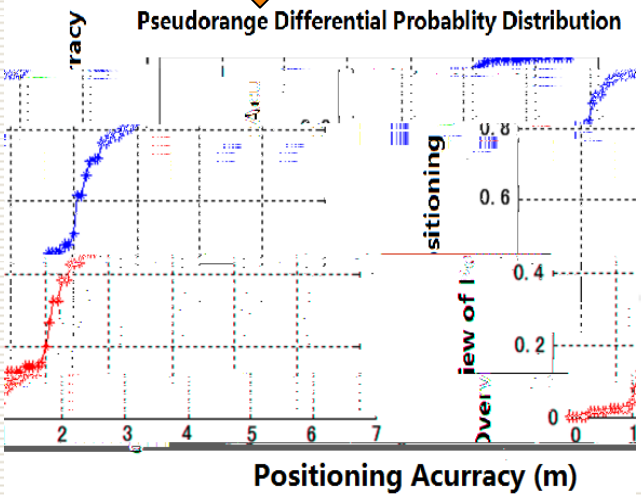
Differential Correction

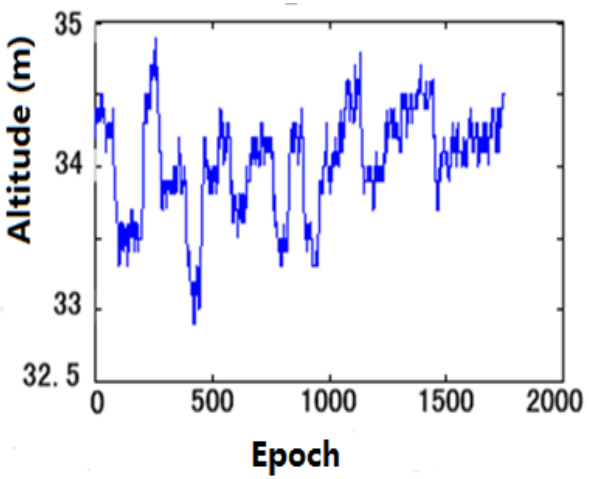
Differential Position Resolution

3 Dimensional Positioning

NLOS Compensation







Horizontal Positioning Accuracy < 3m （1σ）

Vertical Positioning Accuracy < 1 m （1σ）

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U3 User, 15/10/2012

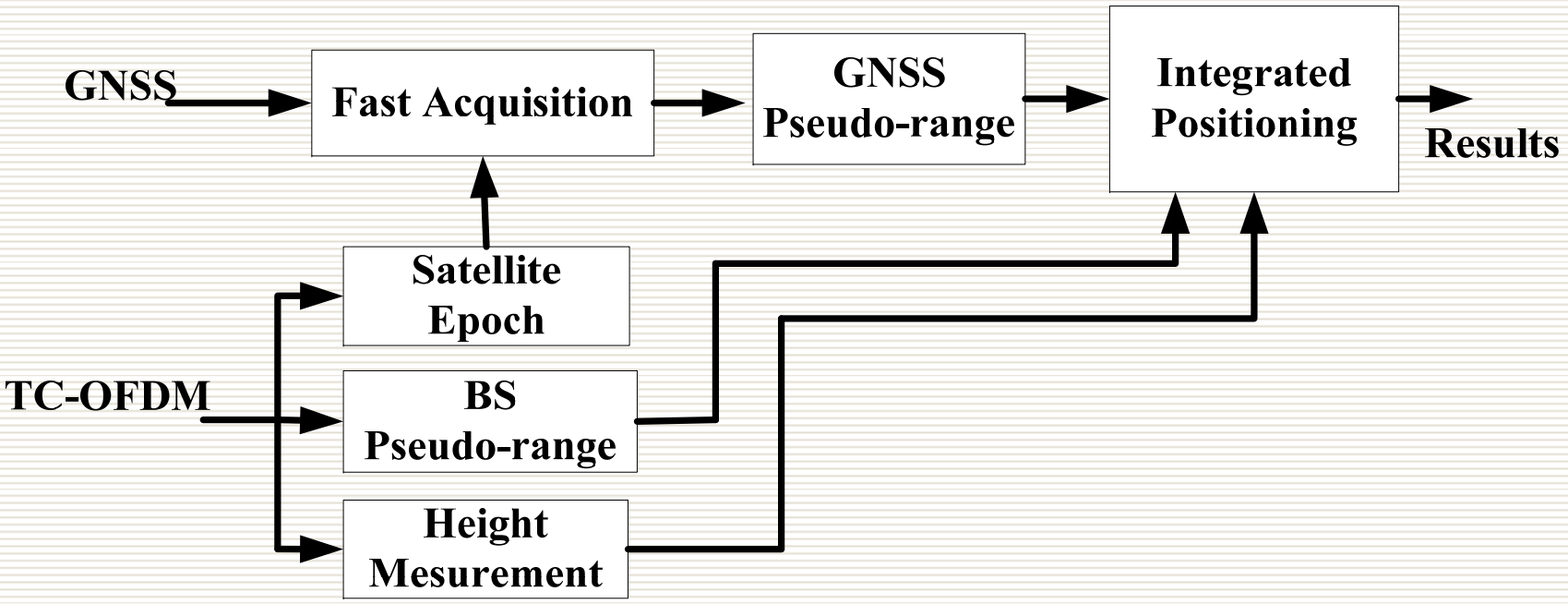
2.3.4 TC-OFDM & GNSS Integration

The function of TC-OFDM System:

1. Sending GNSS differential signal through communication channel;

2. Combined Positioning Solution;

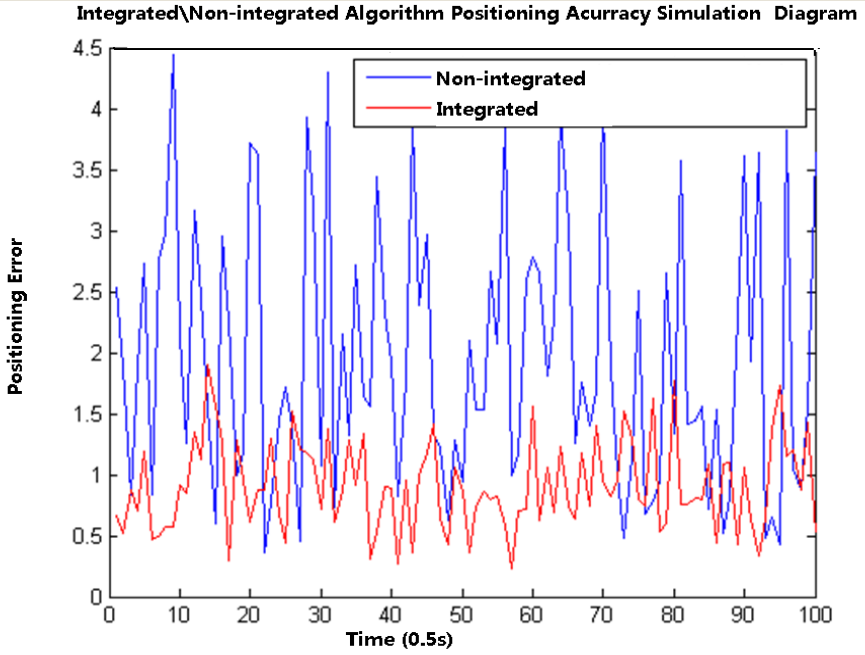
3. Providing assisted information for shortening TTFF.



2.4 TC-OFDM & GNSS Integration

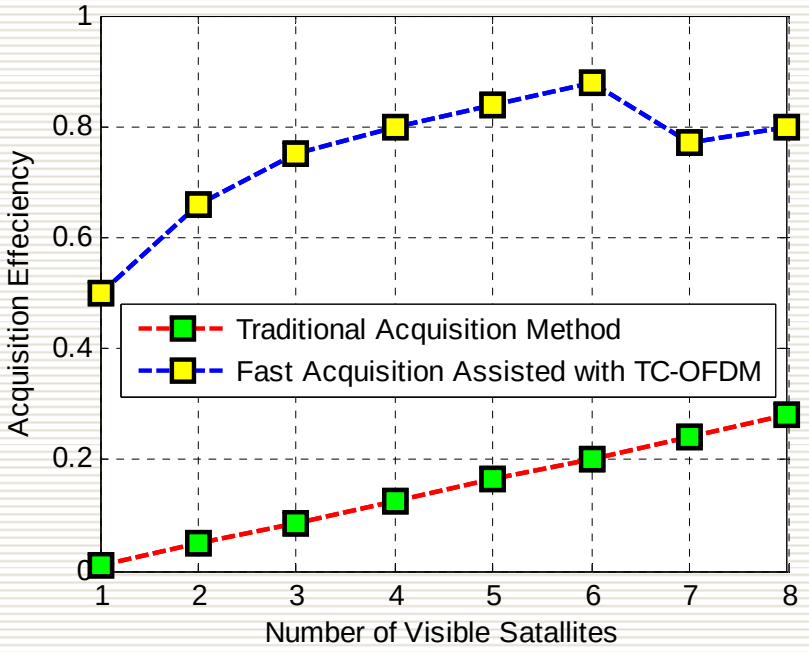
Promoting the Accuracy of Positioning in 3D:

- **Optimizing the DOP of satellite positioning system;**
- **Providing 1m vertical accuracy positioning result.**



Integrated positioning： improve the accuracy up to 60%

Fast Satellite Acquisition Assisted with TC-OFDM



5 times faster for acquisition

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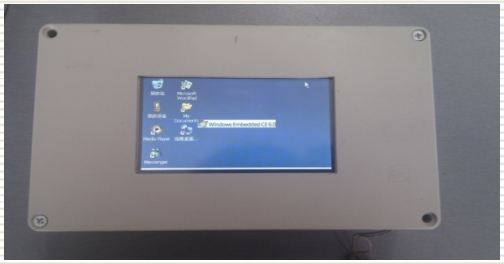
3.1 Prototype of TC-OFDM System

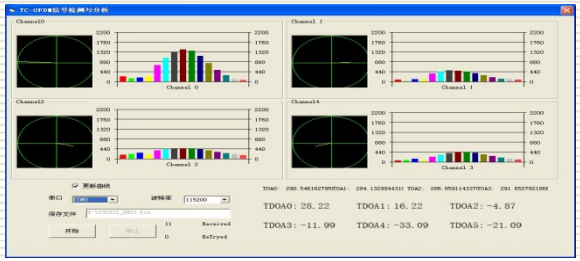
Base Station Placement

Equipments in Base Station

Principle Terminal



Signal Monitor



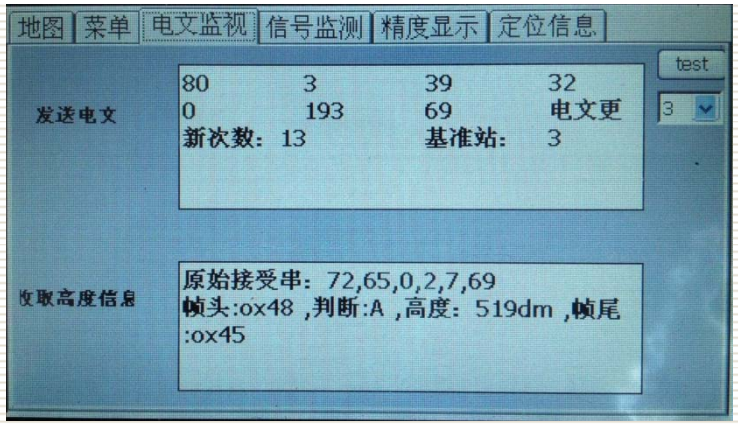
Antennas

3.2 Positioning Test of TC-OFDM Terminals

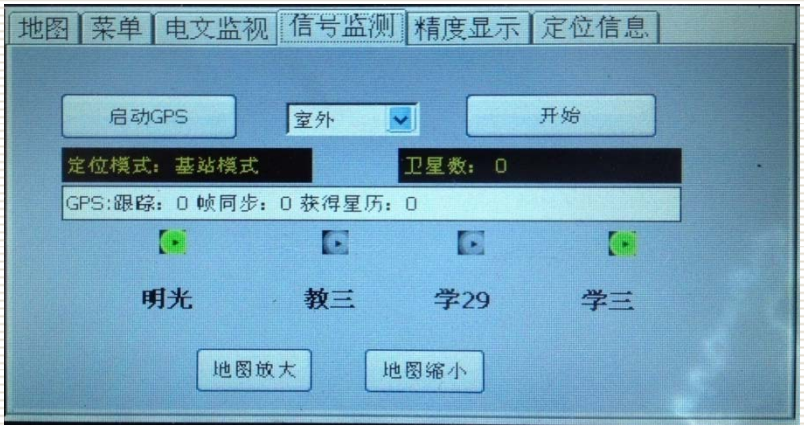
Indoor Positioning

Outdoor Positioning

Messages Monitoring



Signal Monitoring



3.3 Results of Outdoor Positioning Test

Testing the positioning accuracy of the integrated system at 8 points in urban canyon

Standard Deviation of the Result ≤ 1m

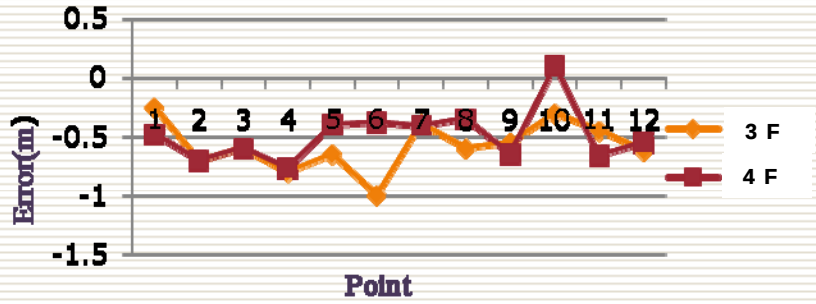
No.	RMS（X）	RMS（Y）	RMS（Z）
G9	0.39	0.65	0.62
G10	0.37	0.71	0.68
G11	0.33	0.55	0.53
G6	0.52	0.46	0.55
G7	0.4	0.4	0.44

Absolute Precision of the Result < 3m

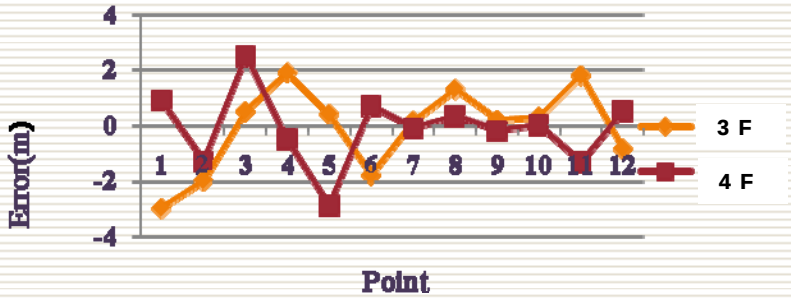
No.	X	Y	Z
G9	-0.36	2.17	-1.1
G10	-0.25	1.69	-1.4
G11	-0.66	1.58	-1.02

3.4 Results of Indoor Positioning Test

- The standard deviation (Inner average precision) is almost less than 1.5m;
- The error of point-to-point distance measurement is less than 3m;
- The error of height measurement is less than 1m.



Vertical Accuracy



Horizontal Accuracy

Standard Deviation of the Result

No.	RMS（X）	RMS（Y）	RMS（Z）
T0	0.64	0.57	0.45
T1	0.65	0.39	0.63
T2	0.76	0.74	0.36
T3	0.64	1.07	0.3
T4	0.05	0.04	0.44
T5	0.75	0.7	0.52
T6	2.98	0.72	0.43
T7	0.79	0.74	0.6
T8	0.34	0.16	0.51
T9	0.23	0.16	0.57
T10	0.15	0.48	0.58
T11	0.94	0.58	0.33
T12	0.29	0.84	0.59

3.5 Comparison with Other Technique

Positioning Methods	Network	Accuracy	Feature
CELL-ID (Cell- Identity)	All Mobile Network	250m-20km	Low cost positioning signal covering; Lack of accuracy to meet the demand of indoor positioning service.
EFLT (Enhanced Forward Link Trilateration)	CDMA	250-350m	
AFLT (Advanced Forward Link Trilateration)	CDMA	50-200m	
E-OTD (Enhanced Observed Time Difference)	GSM	50-200m	
TOA/TDOA (Time of Arrival/Time Difference Of Arrival)	All Mobile Network	40-150m	
AOA(Arrival Of Angle)	All Mobile Network	50-150m	
TC-OFDM （Time & Code Division-Orthogonal Frequency Division Multiplexing）	Mobile Communication Network	3-5m	Multi-signal: the positioning signal and the service signal; Low cost of signal covering; High accuracy.

3.6 Demonstration & Application of TC-OFDM System

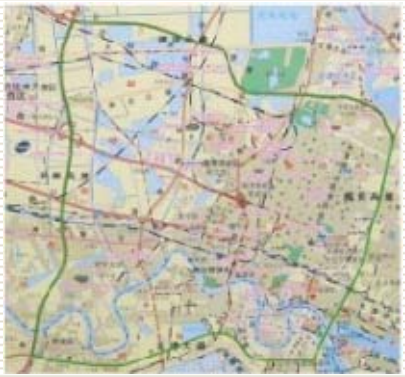
Plan for TC-OFDM

2013：Demonstrated in a large scale in Tianjin

2015：Applied domestically in 339 cities

The experimental and commercial frequency band has been authorized.

Tianjin, China



Tianjin Binhai New Area For Demonstration

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The TC-OFDM System:

- **Offers a navigation and communication integration scheme with low cost.**
- **Promotes the continuity, stability and accuracy of indoor & outdoor positioning.**
- **Achieves 1m vertical accuracy and 3-5m horizontal accuracy .**

Thank you

for your attention!