Near Field *vs*. UWB Ranging

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Near-Field Ranging Versus Ultra-Wideband Ranging

Ultra-wideband (UWB) systems have the potential to achieve high precision spatial resolution. Their performance, however, can be severely limited by multipath interference, low actual utilized bandwidth, and low SNR.

But, the time-of-arrival or time-difference-of-arrival approach to real-time location systems (RTLS) are not the only answer.

Spatial precision can also result from precise *phase* measurement of narrowband or CW signals. Furthermore, near-field electromagnetic ranging operates at frequencies too low for multipath to be relevant.

This paper compares near-field electromagnetic ranging with UWB and simple RSSI technology for RTLS.

Methods for Location or Position Determination

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- Time Difference Of Arrival (TDOA)
- Received Signal Strength Indication (RSSI)
- Near Field EM Ranging (NFER™)
- Angle Of Arrival (AOA)

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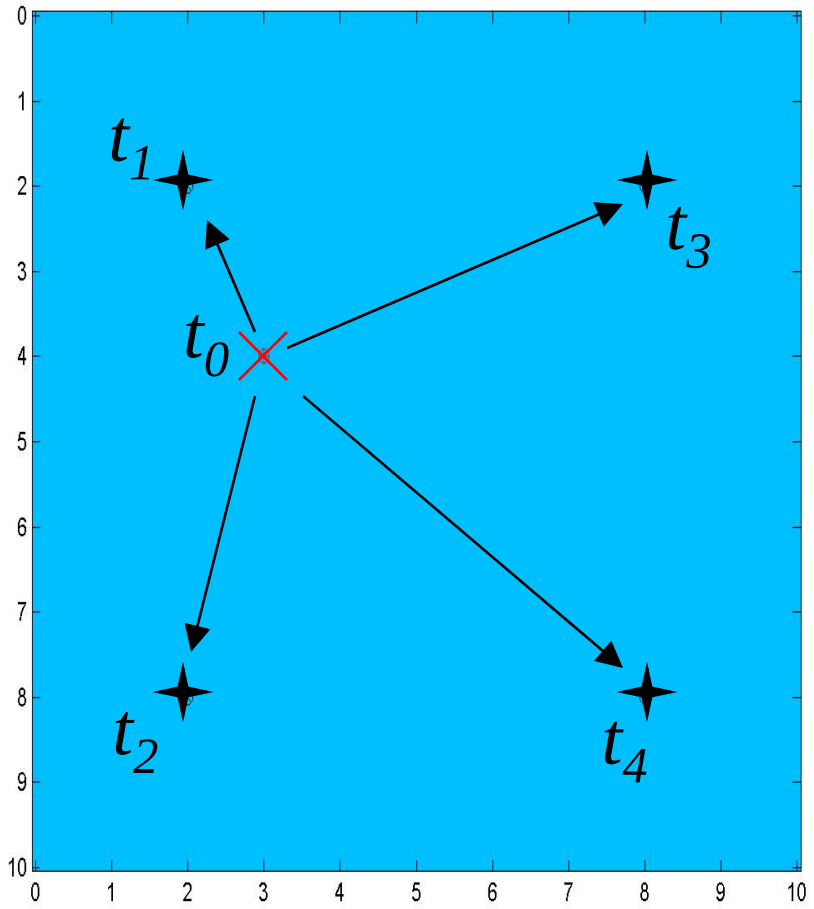
Time Difference or Arrival

Ranging by use of
“precision time” measurement

TDOA

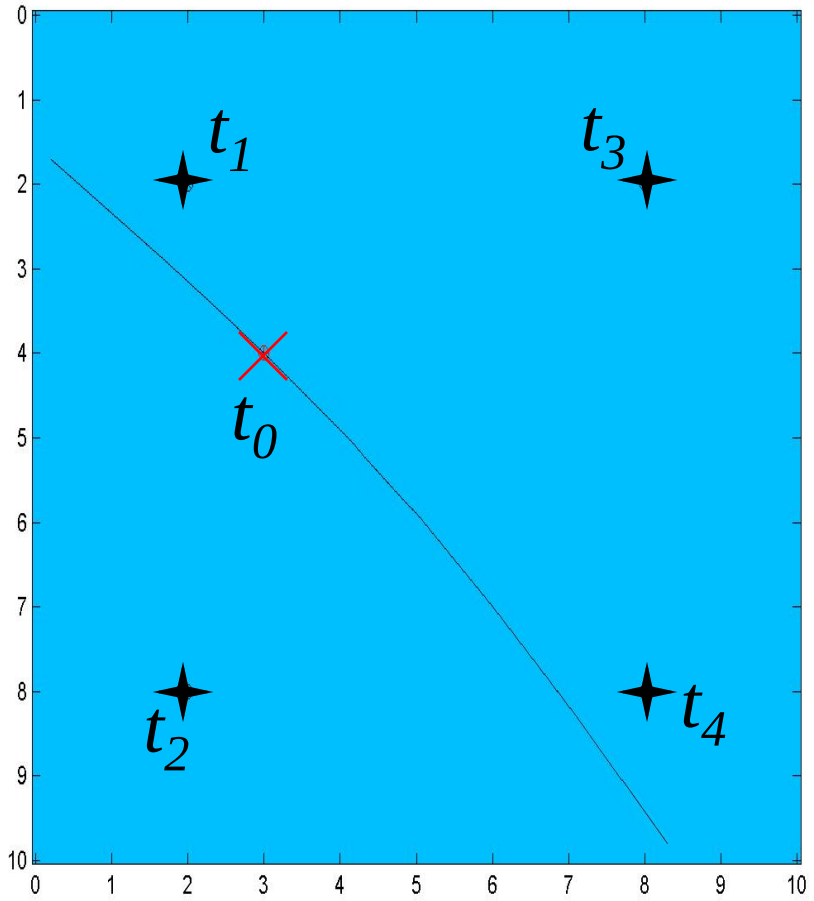
- Node transmits at t_0 received by other nodes at t_1, t_2, t_3, t_4



TDOA

- Node transmits at t_0 received by other nodes at t_1, t_2, t_3, t_4
- Distance difference:

$$d_m - d_n = (t_m - t_n)/c$$



TDOA

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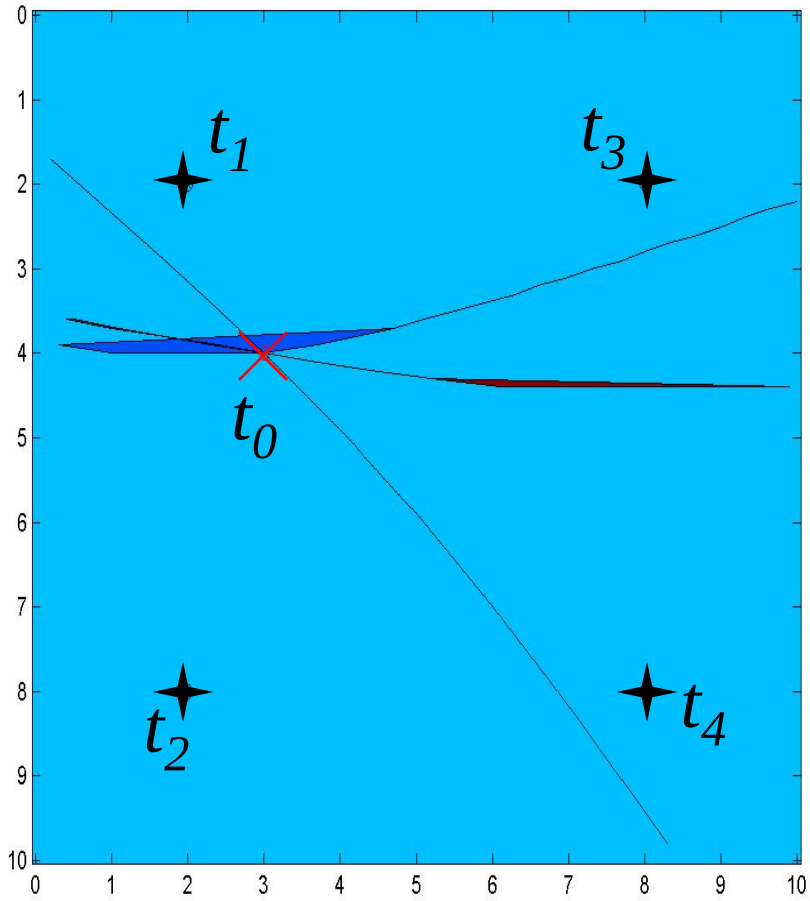
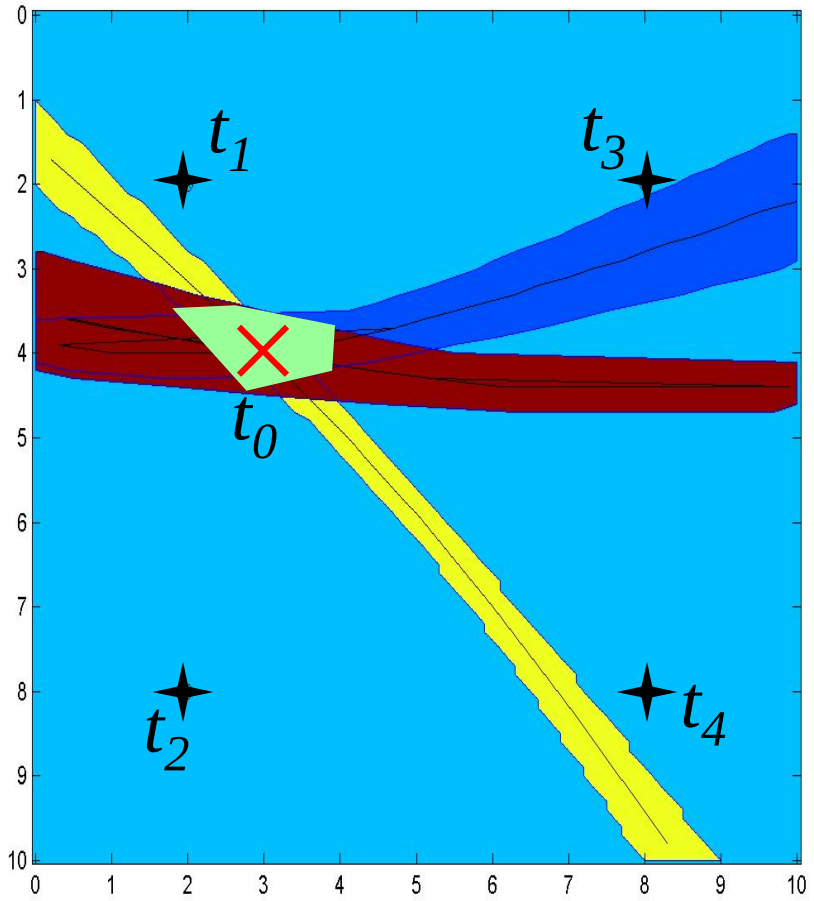
- Distance difference:

  d_m-d_n=(t_m-t_n)/c
- Location determined by intersection



TDOA

- Node transmits at t_0 received by other nodes at t_1, t_2, t_3, t_4
- Distance difference: d_m-d_n=(t_m-t_n)/c
- Location determined by intersection
- **SNR, Bandwidth, and multipath determine accuracy**

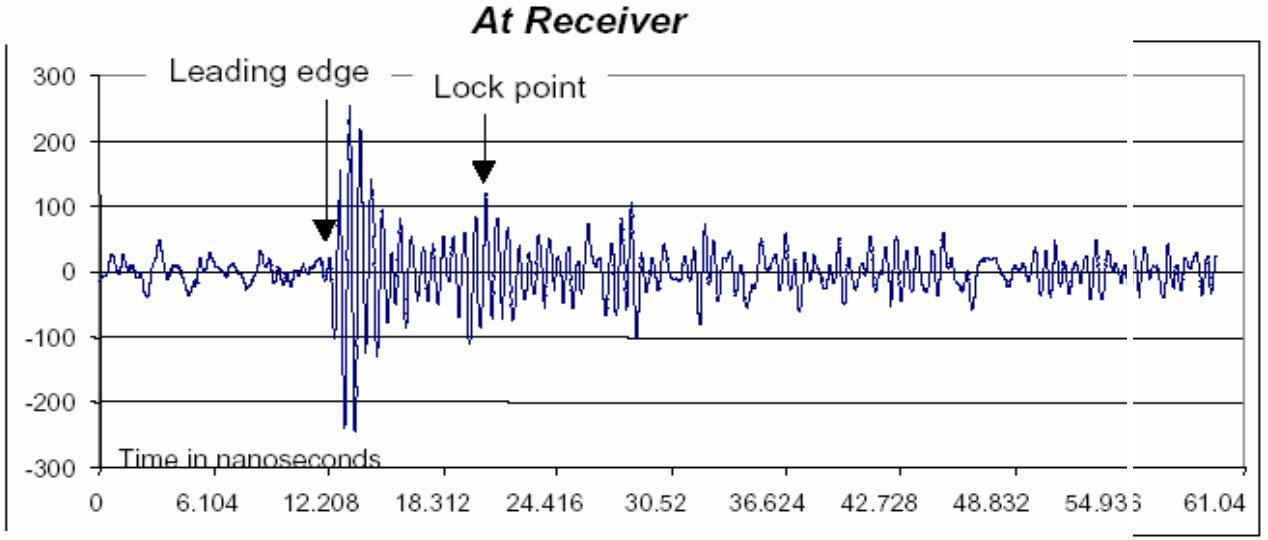


TDOA Waveform Processing

- Time measured precisely, to within ~ 100 ps
- *But* signal can be ambiguous due to multipath
- Indoors, all high frequency signals are spread by multipath which dilutes the range measurement accuracy

at transmitter:

radiated:



Courtesy of Time Domain Corp.

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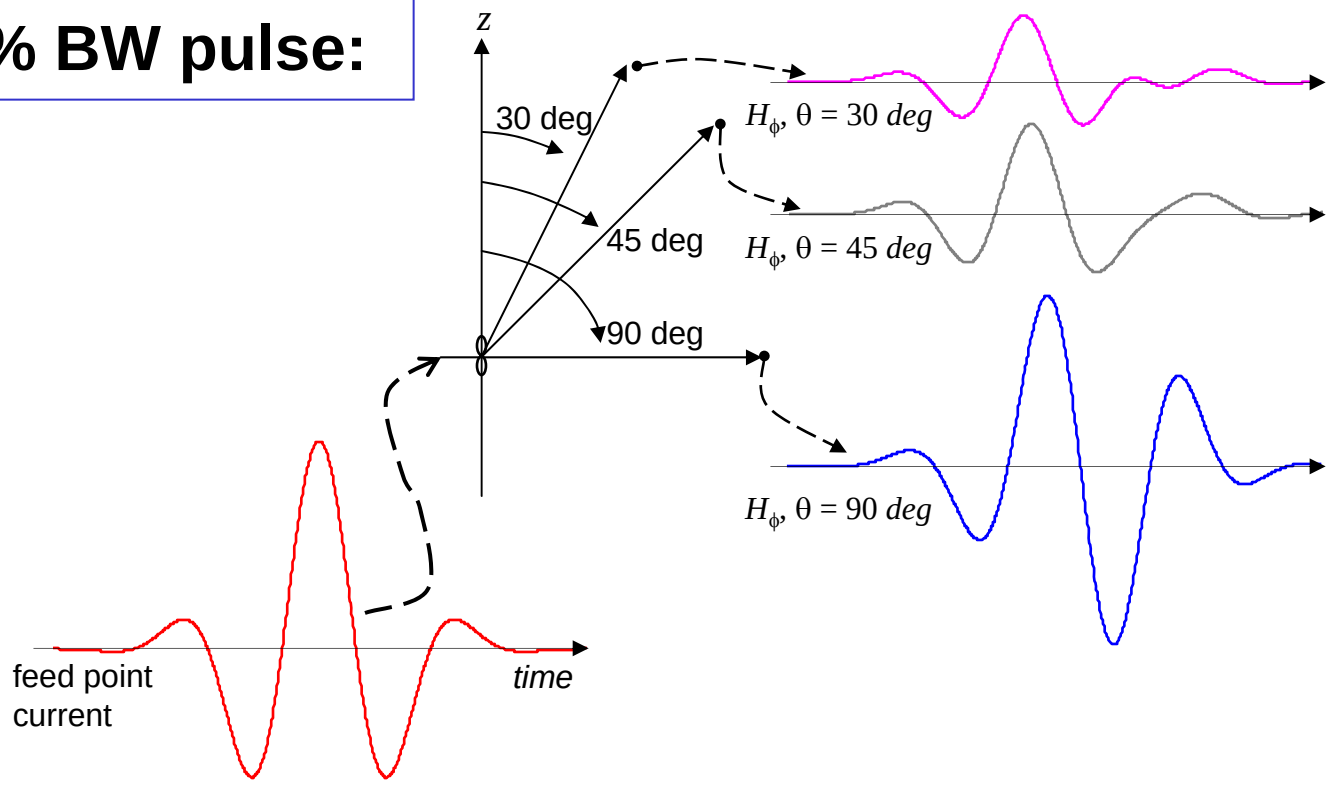
But: UWB signal distorted even by the act of radiation

100% BW pulse:



Typical UWB bandwidth much narrower than 100%

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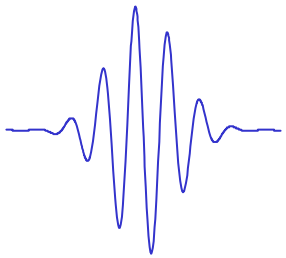
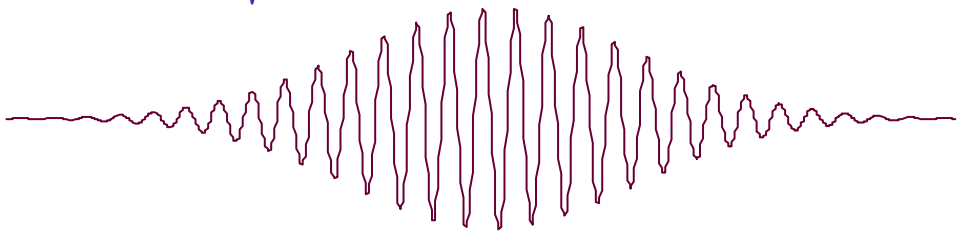
Narrower pulse would spell less accuracy ...

100% BW UWB signal:

50% BW UWB signal:



11% BW; A 500 MHz wide signal at 4.5 GHz:



UWB pulse leading edge indistinct in non-line-of-sight (NLOS)

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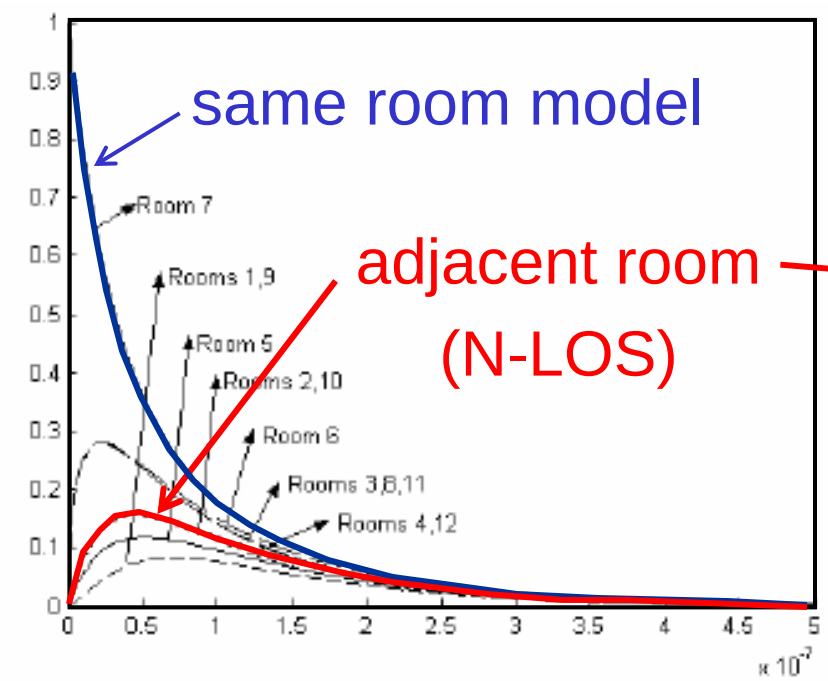


Figure 5. Average received signal envelope for the model with 12 rooms.

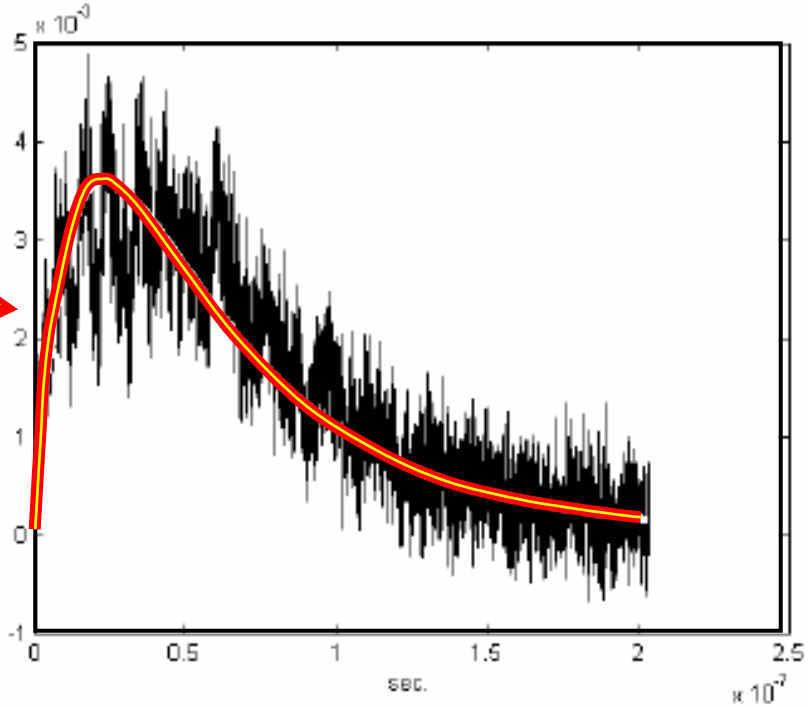
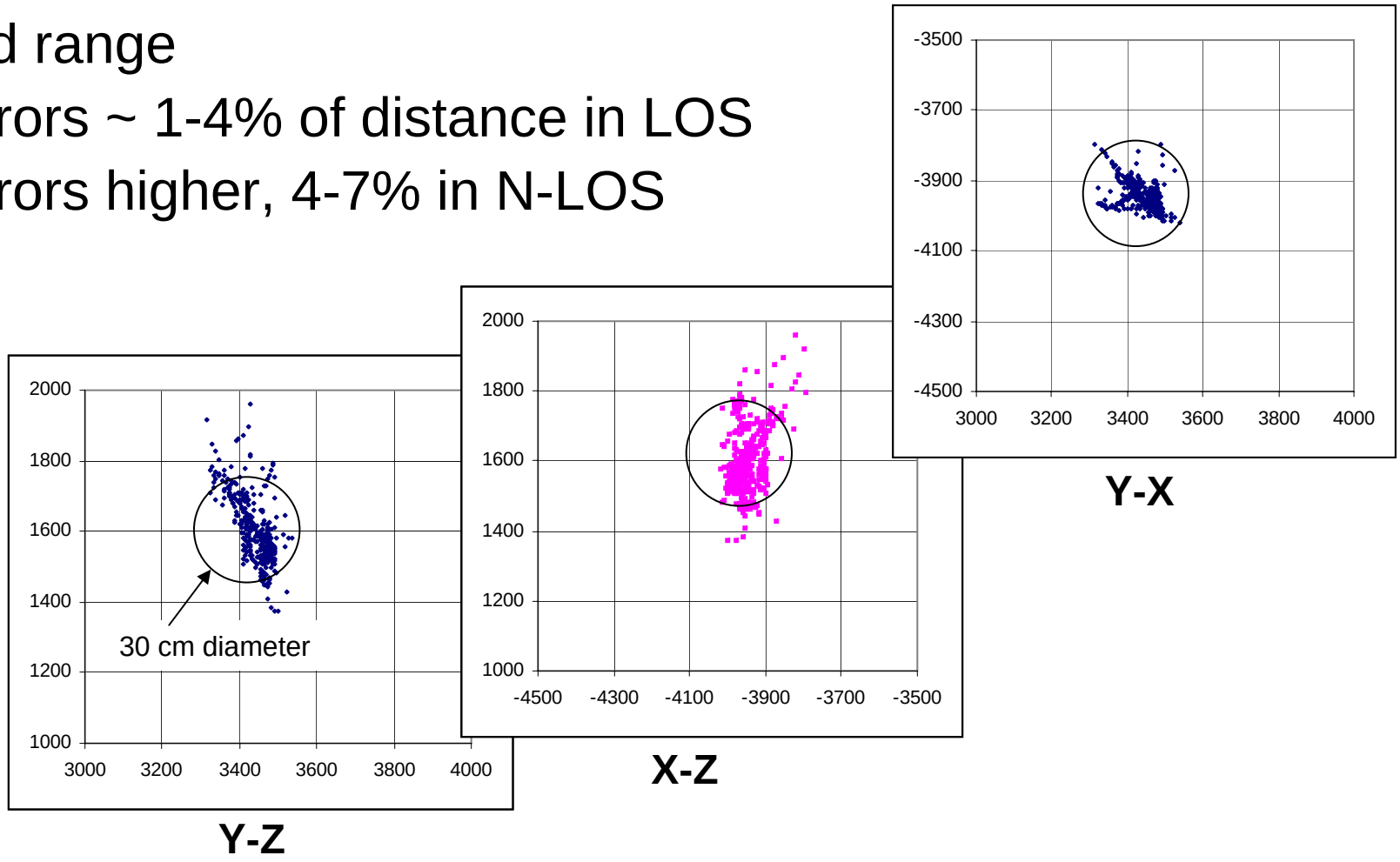


Figure 11. Averaged envelope of the 49 sample spatial points and fitted curve for room E.

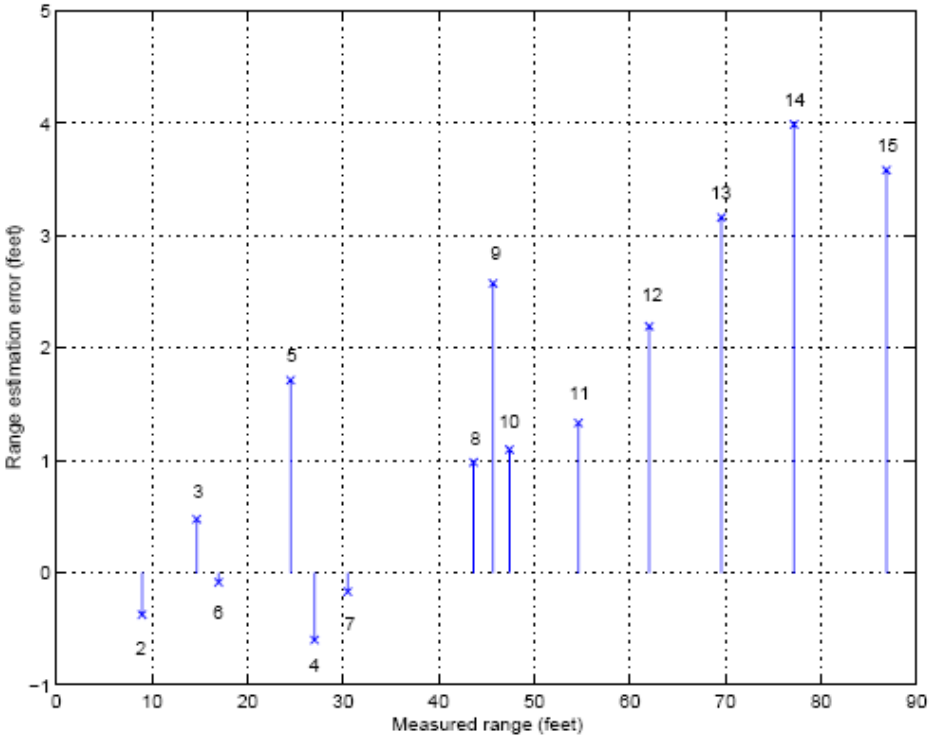
Source: "A Diffusion Model for UWB Indoor Propagation," by M. Nemati and R. Scholtz, IEEE Military Communications Conference, Monterey CA, November 2004.

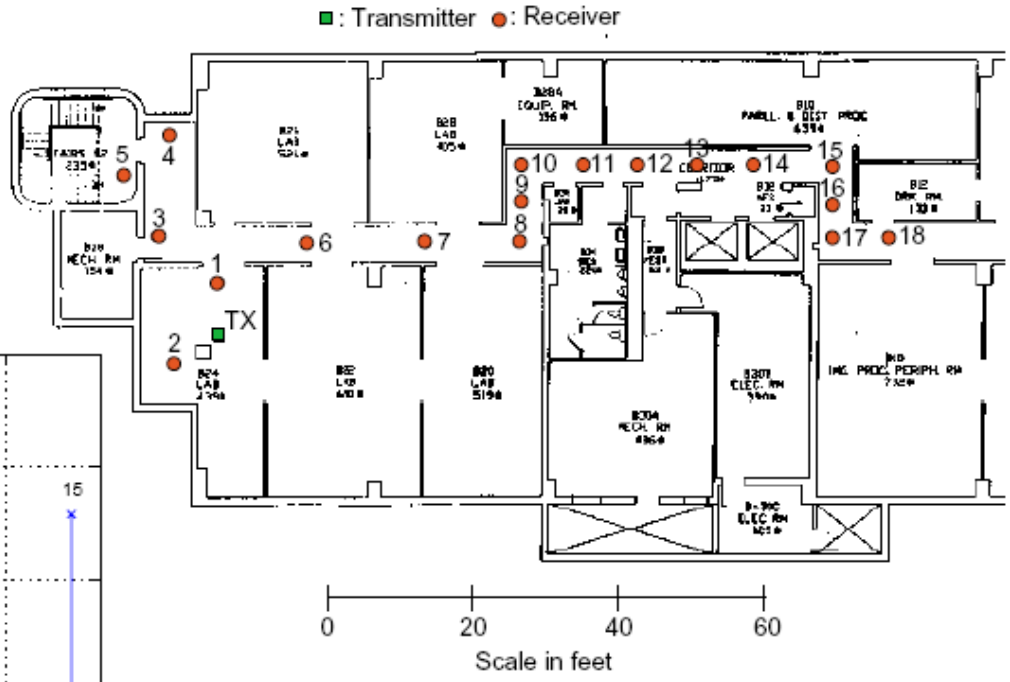
Measured Scatter Plots 3-d Ranging in 10m² room

- 3-d range
- Errors ~ 1-4% of distance in LOS
- Errors higher, 4-7% in N-LOS



UWB in offices





Errors ~ 4 - 7% of distance

Source: Joon-Yong Lee, "Ultra-wideband ranging in dense multipath environments", Ph.D. Dissertation Univ. of Southern California, May 2002.

Location using UWB

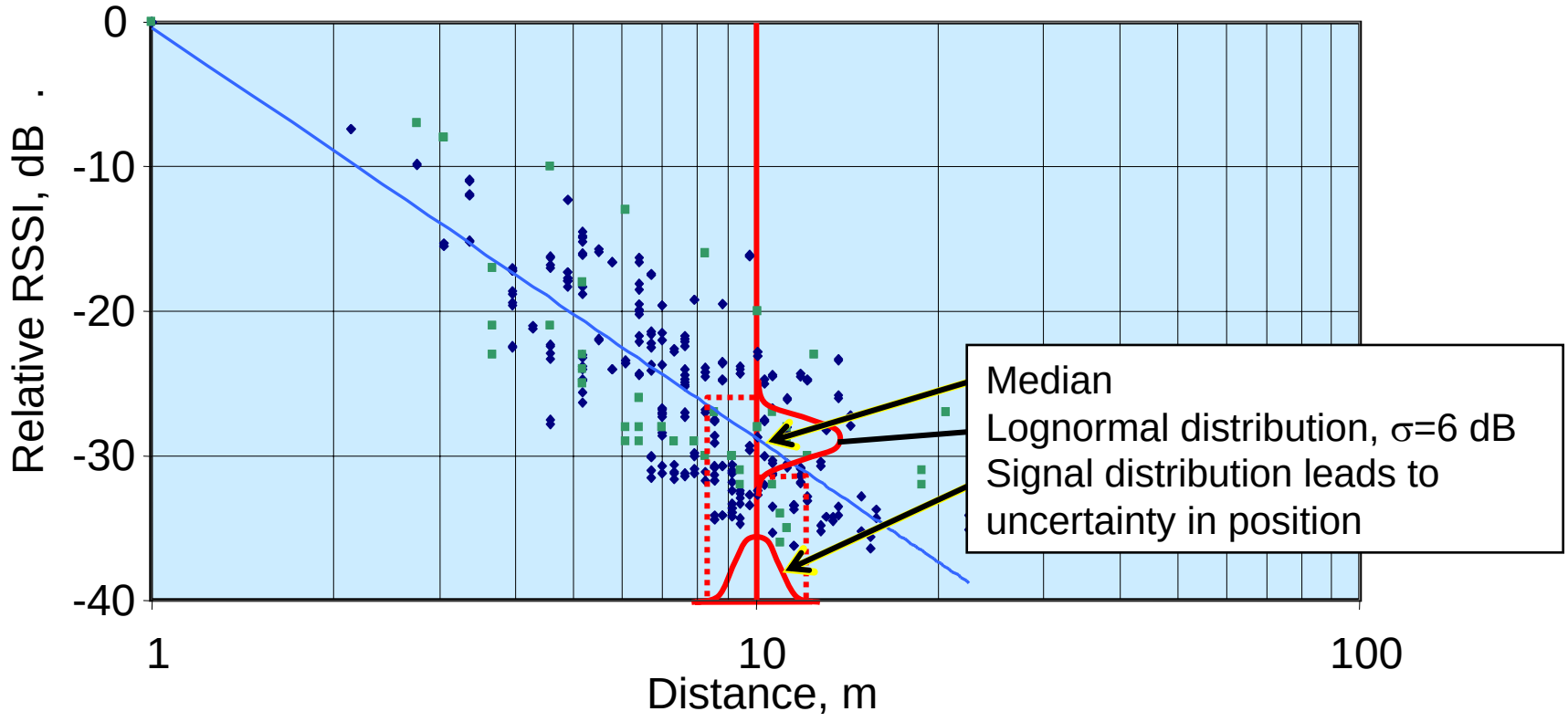
- UWB has precision location potential by virtue of a short, well defined impulse at transmitter
- Radiation process and multipath distort the signal and dilute the precision
- Typical results indoors:

  error is 1 – 7% of range in multipath

RSSI: Propagation Attenuation Ranging

Signal strength and distance are inversely related

RSSI vs. Range



Relative Location Simulation

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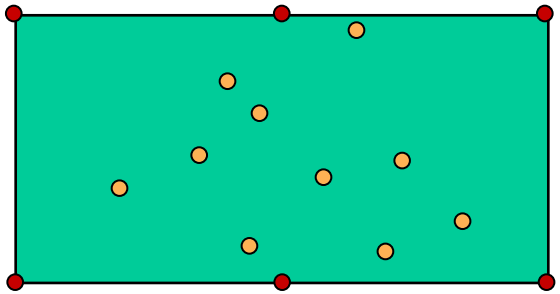
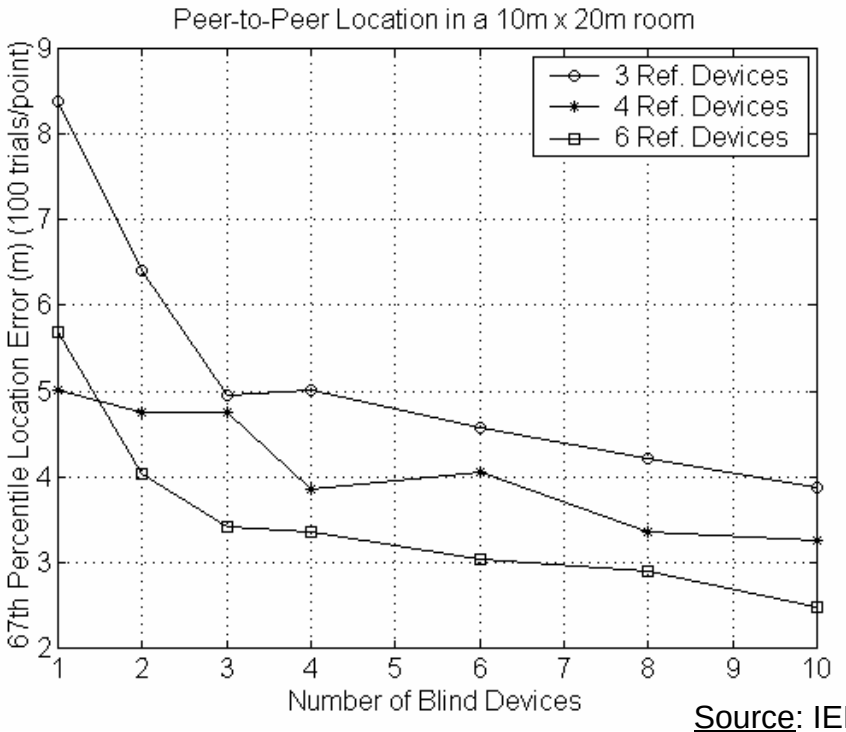
Path Loss Uncertainty: σ = 6 dB
Single room, 20 m by 10 m
3, 4, or 6 Reference devices
1 to 10 Blindfolded devices
Reference devices located in corners
Other devices placed randomly





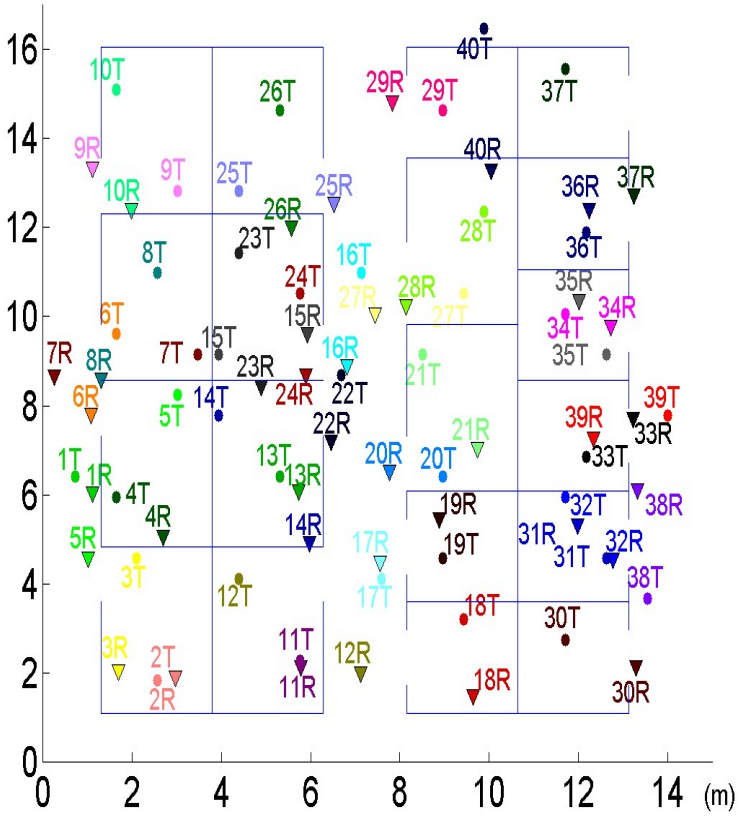
- Simulation of Indoor Relative Location
  - Signal Strength as a Ranging Technology
- Location Accuracy improves with either:
  - More Reference devices
  - More Blindfolded devices

Source: IEEE 802.15.4 document "15-04-0228-01-004A" Relative Location.

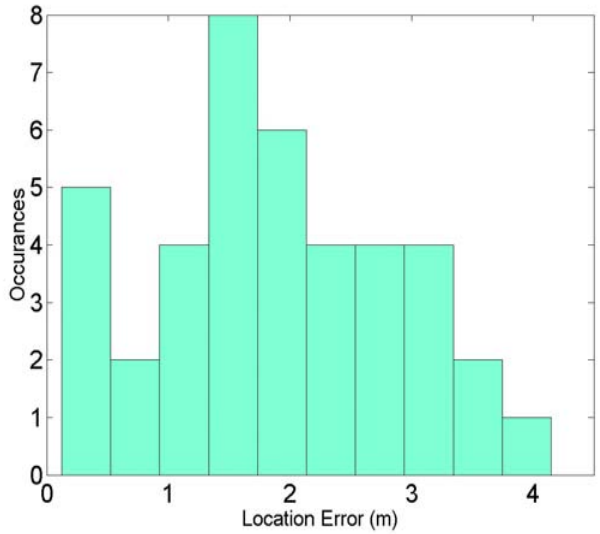
Relative Location Experiment Set-up

∂/∂t TimeDerivative

Key: #T ● ***True Location***
#R ▼ ***Relative Location Estimate***



- RMS Location Error of 2.14 m
- RMS error is 15% of reference device separation



After: IEEE 802.15.4 document "15-04-0228-01-004A" Relative Location.

Distance Measurement using RSSI

∂/∂t TimeDerivative

- Received Signal Strength Indication (RSSI) is proportional to distance
- With multiple devices, distance measurement error decreases
- Simple to implement in conventional narrow band radios – like for 802.15.4

After: IEEE 802.15.4 document "15-04-0228-01-004A" Relative Location.

Ref: N. Patwari, A. O. Hero, III, M. Perkins, N. Correal, R. J. O'Dea, "Relative location estimation in wireless sensor networks," IEEE Trans. On Signal Processing, vol. 51, no. 8, August, 2003, pp. 2137-2148.

Near Field Electromagnetic Ranging

Accurate ranging with

“zero bandwidth”

Location Doesn't Need Bandwidth

∂/∂t TimeDerivative

- Distance measurements do not "need" large bandwidths
- "Time" is not the only parameter to carry "distance" information, "phase" works too
- Near Field EM Ranging (NFER™) techniques may be employed
- Excellent accuracies possible in cluttered region and areas not accessible to UWB

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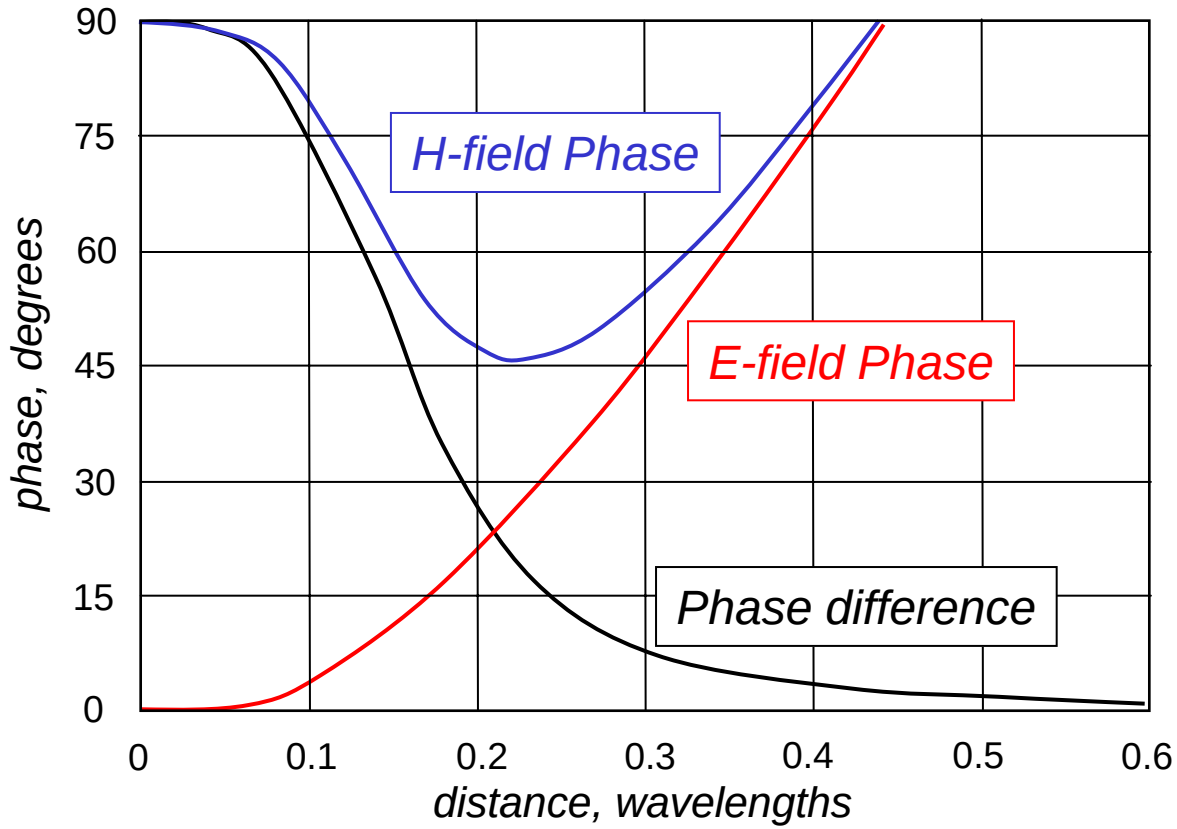
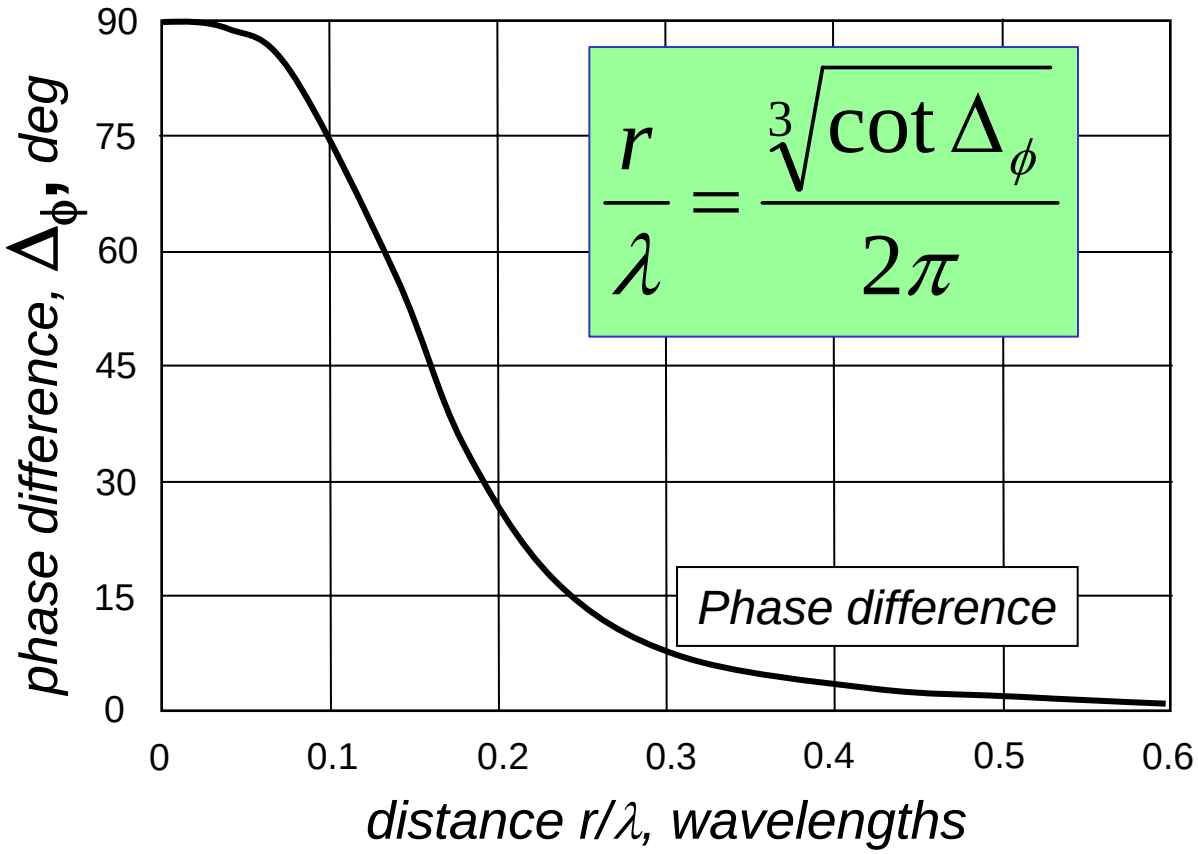
Near-Field Tracking: Electric and Magnetic near field phases



After: "Technical Introduction to Near Field Tracking," (Online): <http://www.q-track.com> Q-Track Corp., 2003.

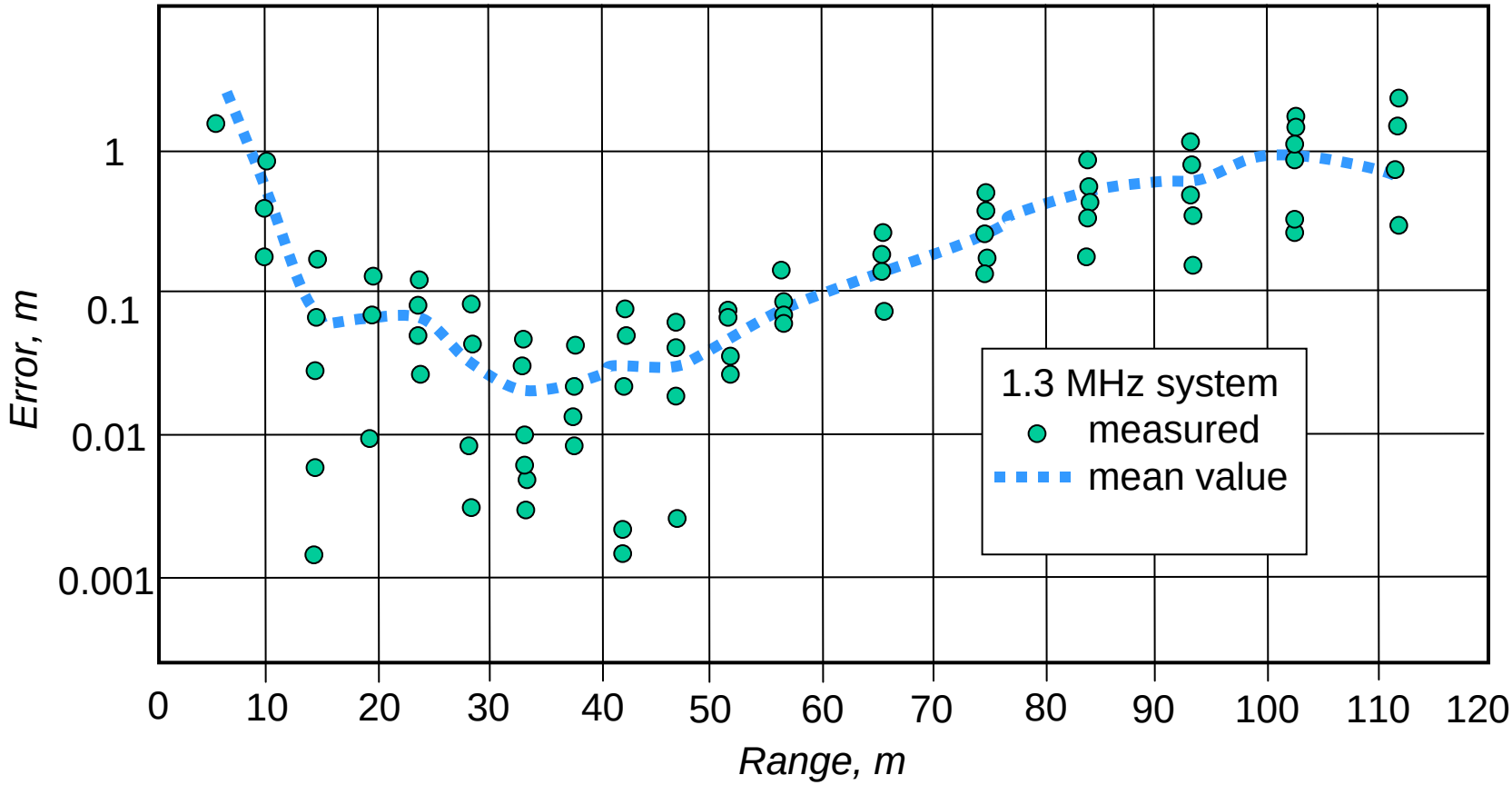
Near-Field Phase Difference gives Distance

∂/∂t TimeDerivative



Near Field Tracking Typical Accuracy

∂/∂t TimeDerivative



Data Courtesy of: Q-Track Corporation

Comparisons

	UWB	NFER	RSSI
profile:	***50–100% BW***	***1 MHz band***	***no add'l cost***
LOS clear area	10-30m ±0.3m **1-4% of range**	**30-60m ±0.3-1m** 3-5% of range	10-15% of PAN range
NLOS	10-20m ±0.3-1m 4-7% of range	**30-60m ±0.3-1m** **3-5% of range**	10-15% of PAN range
indoors cluttered	30m ±1.5-2 m 4-7% of range	**30-60m ±0.3-1m** **3-5% of range**	10-15% of PAN range
outdoor cluttered	–	**75m ±2-3m** **4-5% of range**	10-15% of PAN range
mines and shafts	–	**150m ±3m** **4-5% of range**	–

Phase Monopulse Positioning

- adds accurate angle information to range with “zero bandwidth”
- natural extension to NFER

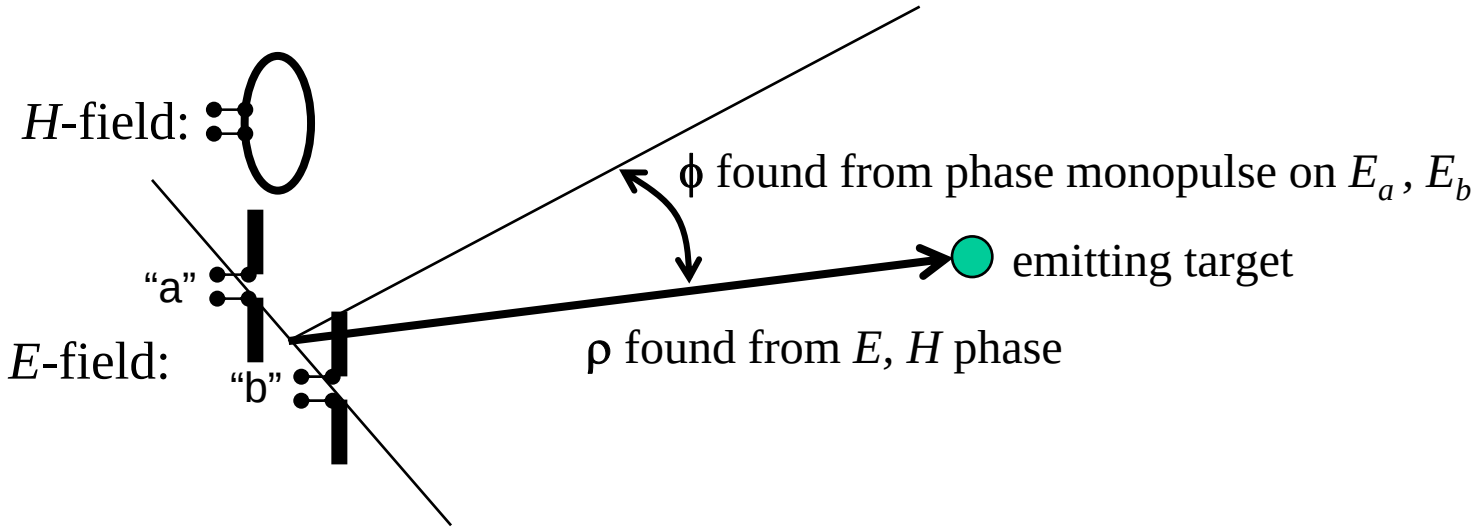
Phase Monopulse Technique adds angle information

∂/∂t TimeDerivative

- The relative angle ϕ to a signal can be found by signals “a” and “b” from two closely spaced antennas “A” and “B”
- Arithmetic network used to form “a+b” and “a-b” signals
- The ratio (a-b)/(a+b) is proportional to angle ϕ
- Technique is called “phase monopulse”, is associated with missile seekers over the past 40 years or so
- Four antennas (elevation and azimuth phase monopulse gives angle in two dimensions!

Azimuth Monopulse Tracking with Near Field Ranging

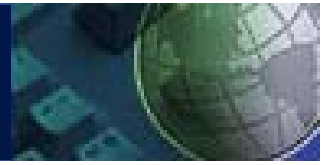
∂/∂t TimeDerivative



NFER range plus phase monopulse azimuth and elevation angles give full three dimensional LOCATION from a single measurement

Summary / Conclusions

- UWB has best accuracy in LOS at short range
- NFER has best range in all environments
- NFER has better accuracy in challenging multipath environments
- Monopulse technique can add angle info
- Other cheaper but far less accurate methods (RSSI) available



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