Microwave Imaging

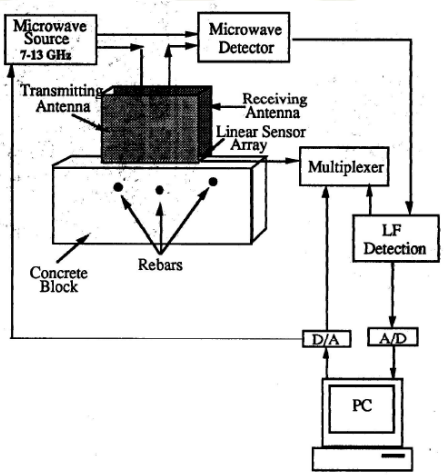
- Microwave imaging gets a lot of information about what the object is made of and what is inside it
- Microwave imaging is safer than the traditional X-rays
- Microwave imaging is low cost

Applications

- Medical diagnosis (e.g. breast cancer detection) The EM waves are sensitive to
  - type of tissue
  - several physical and physiological factors like
    - temperature, solute concentration, blood flew rate
- Nondestructive detecting of the internal damage in concrete structures
- Security screening at transportation terminals (railways, airports, bus stations and subways)
- …

EM Camera for Detecting the Damage at Concrete

- Microwave source(frequency rang from 7 GHz to 13 GHz)
- Transmitting antenna radiates an electromagnetic incident field into the concrete
- The incident field excites the rebars inducing a surface current on it. This current generates a microwave scattered field
- The backscattered field is measured with a sensor array placed in the aperture of a receiving antenna



[K. Belkebir et al., 24th European Microwave Conference, 1994]

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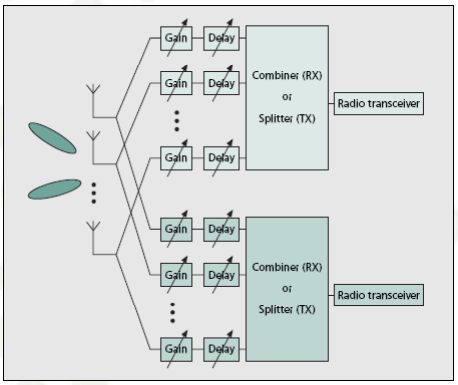
- UWB Camera is :
  - UWB transmitting/receiving antenna arrays
  - Based on the time delay & sum beam forming



[H. Hashemi, T. Chu and J. Roderick,IEEE Communications Magazine, September 2008]

UWB Beamforming

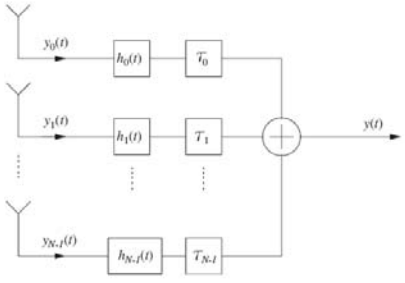
- Delay & sum beamforming
  - s(t) is the impulse signal
  - ϕ_0 is the steering angle
  - h_n weighting coefficient
  - d is antenna spacing
  - c is propagation speed

$$\tau_\phi = \frac{d}{c}.\sin(\phi)$$

$$\tau_{\phi_0} = \frac{d}{c}.\sin(\phi_0)$$

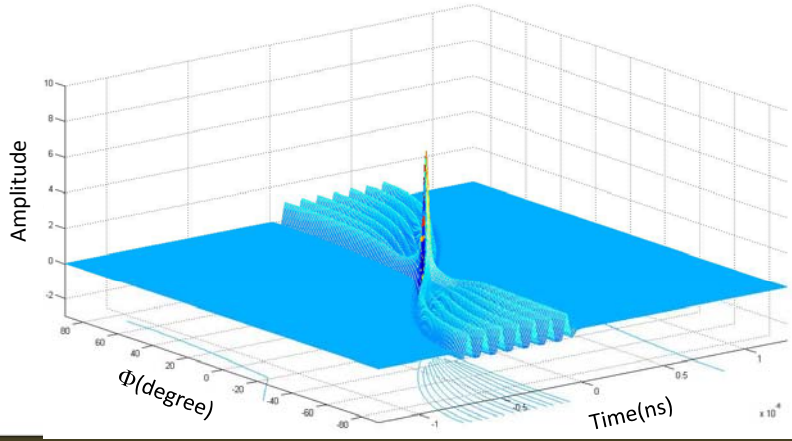
$$y_n(t) = s(t + n\tau_\phi)$$

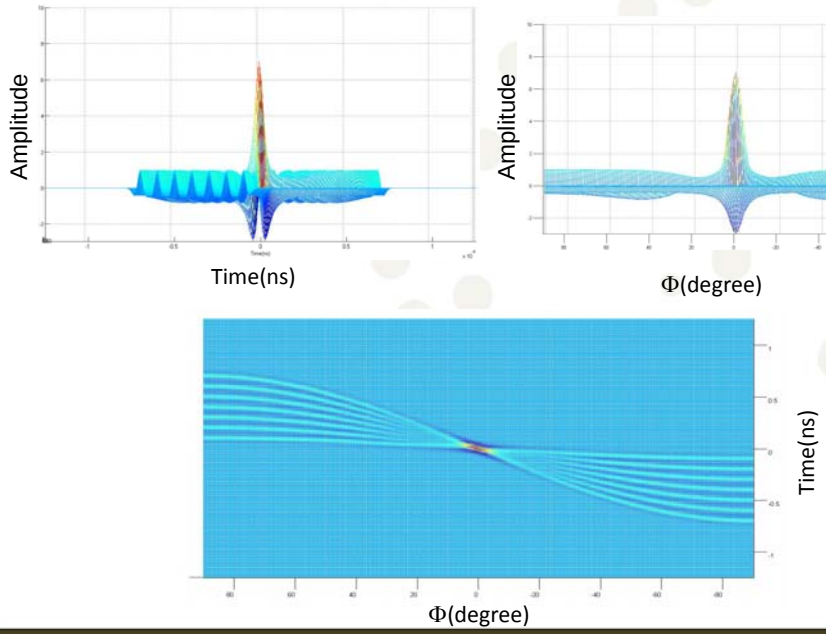
$$y(\phi, \phi_0, t) = \frac{1}{\sum h_n} \sum_{n=0}^{N-1} h_n s(t + n(\tau_\phi - \tau_{\phi_0}))$$

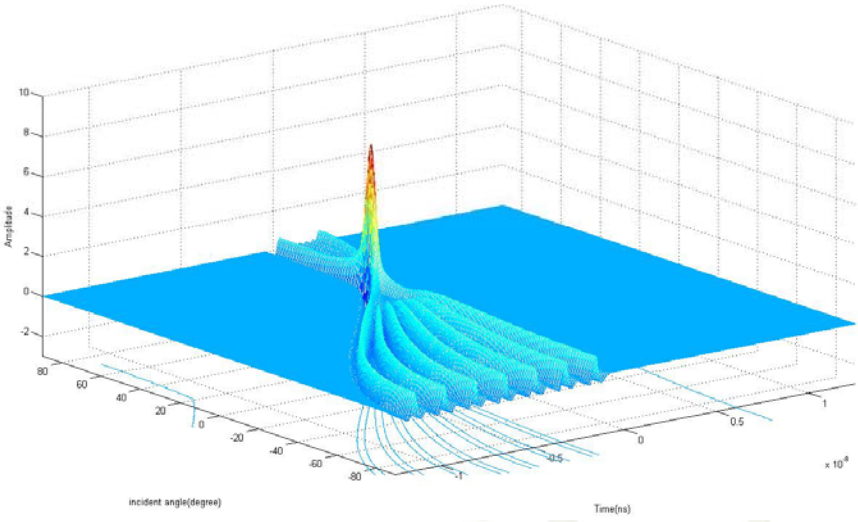


[S. Ries, T. Kaiser , Signal Processing, Volume 86, Issue 9,September 2006]

- 7 elements linear array
- h_n =1 n=0…6
- Steering angle=0^o
- d=λ/2 (λ=c.T and T is the duration time of impulse signal)







Steering angle=40º
d=λ/2

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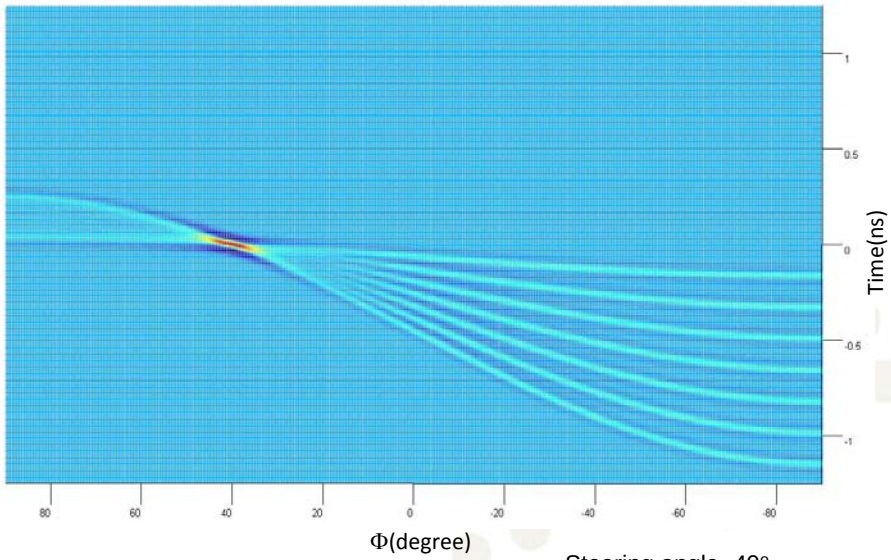

Steering angle=40º
d=λ/2

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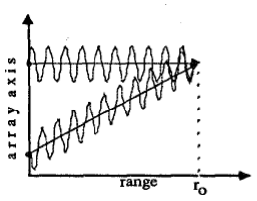
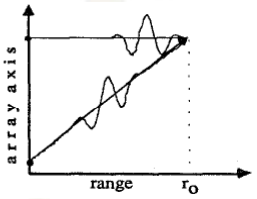
UWB Beampattern

- Pulses do not exist simultaneously➔ no interference and spatial aliasing➔ Lack of grating lobes
  - Antenna spacing larger than λ/2
    - » better resolution & beam focusing

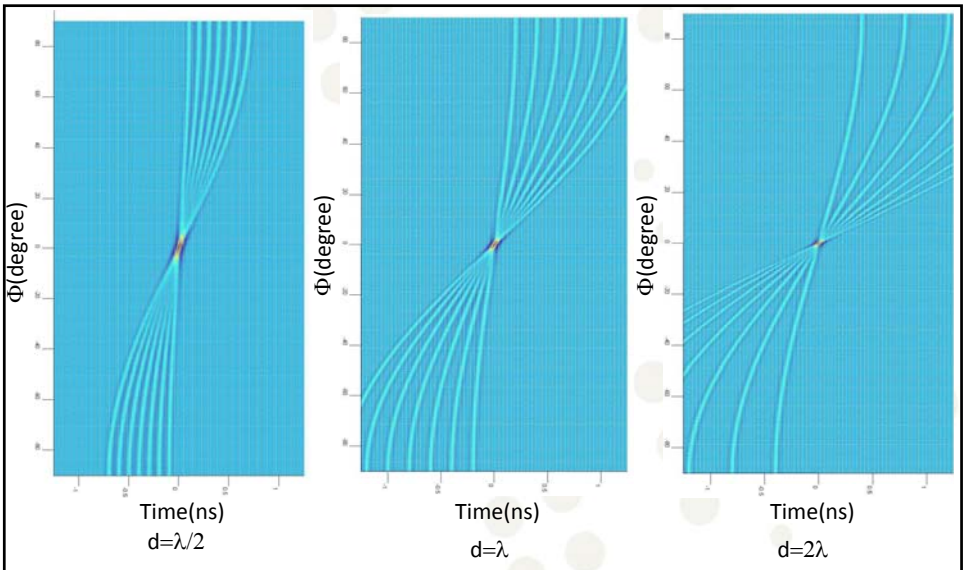


Narrow band



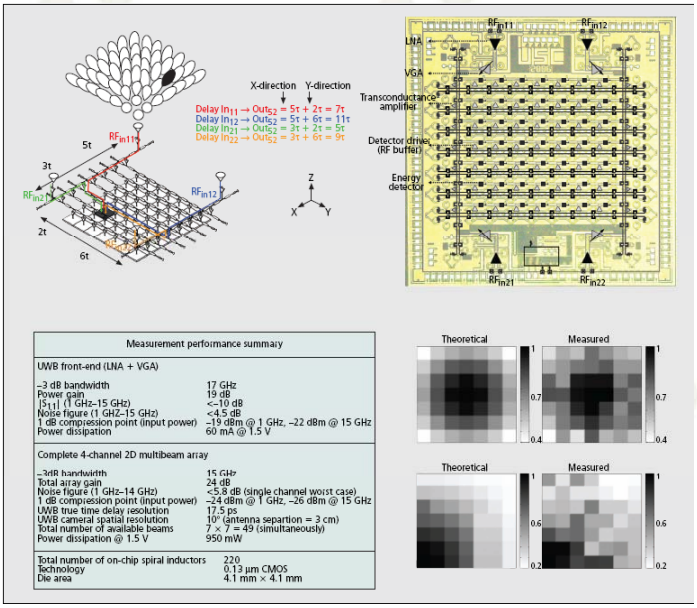
UWB

[J. L. Schwartz and B. D. Steinberg, Antennas and Propagation Society International Symposium, 1996]



•The larger antenna spacing, the better beam focusing

Receiving UWB Camera based on delay & sum beamforming with 2×2 antennas and 7×7 simultaneous active pixels



Measurement performance summary	
UWB front-end (LNA + VGA)	
–3 dB bandwidth	17 GHz
Power gain	19 dB
$\|S_{11}\|$ (1 GHz–15 GHz)	<–10 dB
Noise figure (1 GHz–15 GHz)	<4.5 dB
1 dB compression point (input power)	–19 dBm @ 1 GHz, –22 dBm @ 15 GHz
Power dissipation	60 mA @ 1.5 V
Complete 4-channel 2D multibeam array	
–3dB bandwidth	15 GHz
Total array gain	24 dB
Noise figure (1 GHz–14 GHz)	<5.8 dB (single channel worst case)
1 dB compression point (input power)	–24 dBm @ 1 GHz, –26 dBm @ 15 GHz
UWB true time delay resolution	17.5 ps
UWB cameral spatial resolution	10° (antenna separtion = 3 cm)
Total number of available beams	7 × 7 = 49 (simultaneously)
Power dissipation @ 1.5 V	950 mW
Total number of on-chip spiral inductors	220
Technology	0.13 μm CMOS
Die area	4.1 mm × 4.1 mm

[T. Chu and H. Hashemi, ISSCC 2008]

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Future works

- Near field UWB beamforming
- Transmitting arrays
- Irregular or sparse arrays
- UWB antenna
- …

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References

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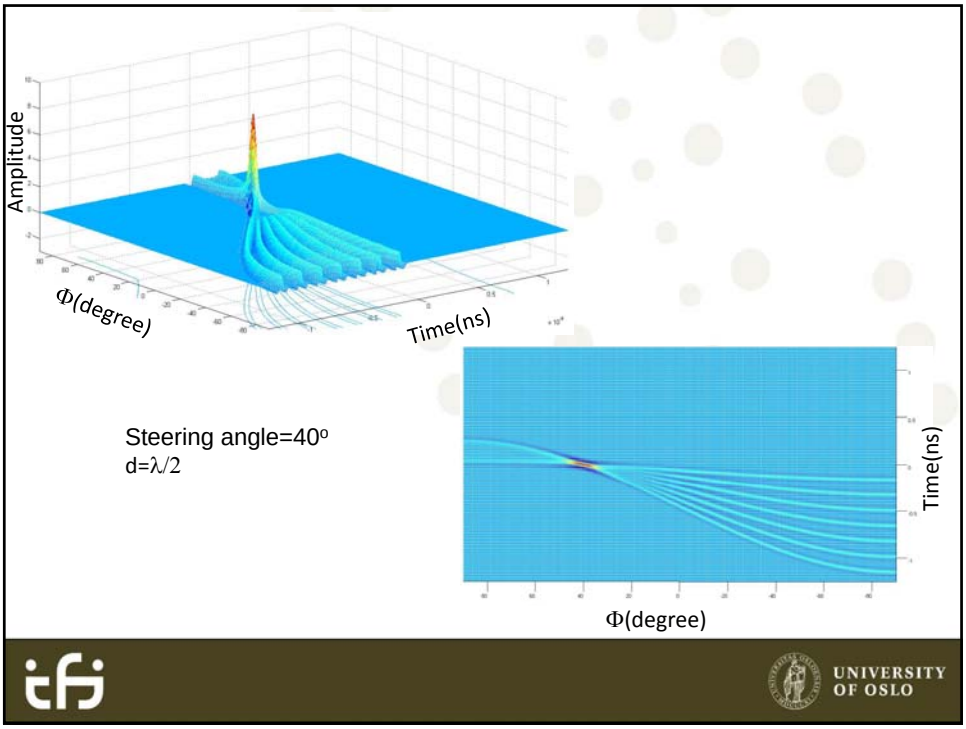
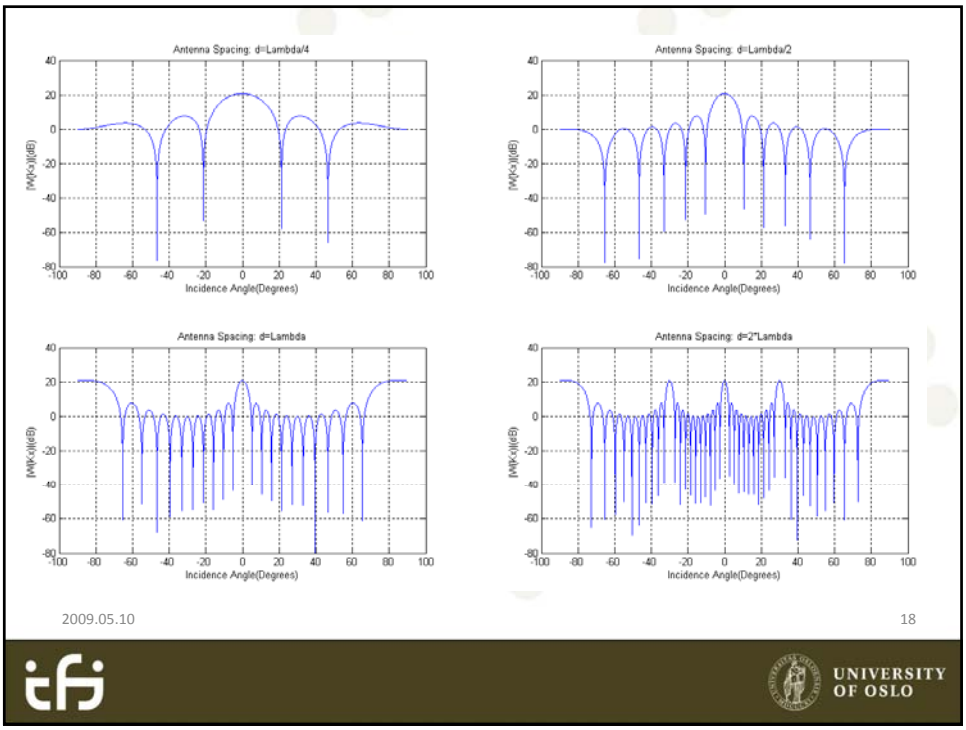
- H. Hashemi, T. Chu and J. Roderick, “Integrated True-time-Delay-Based Ultra-Wideband Array Processing,” IEEE Communications Magazine, September 2008, pp. 162-172.
- J. L. Schwartz and B. D. Steinberg , “ Ultrasparse, Ultrawidj33and Phased Arrays ,” Antennas and Propagation Society International Symposium, 1996.
- T. S. Chu and H. Hashemi, “A CMOS UWB Camera with 7×7 Simultaneous Active Pixels”, IEEE International Solid-State Circuits Conference, 2008.
- S. Ries, T. Kaiser , “ UWB impulse beamforming: It is a different world ”, Signal Processing, Volume 86, Issue 9,September 2006, pp. 2198-2207 .
- M. Wang, S. Yang and S. Wu , “ Beamforming of UWB pulse array and its implementation ”, Digital Signal Processing, Volume 16, Issue 4, July 2006, pp. 333-342.

Thank you!


Amplitude
Φ(degree)
Time(ns)
Steering angle=40º
d=λ/2
Time(ns)
Φ(degree)


Antenna Spacing: d=Lambda/4
Antenna Spacing: d=Lambda/2
Antenna Spacing: d=Lambda
Antenna Spacing: d=2*Lambda
Incidence Angle(Degrees)