Signal to noise ratio estimates of ultrasound depth of penetration

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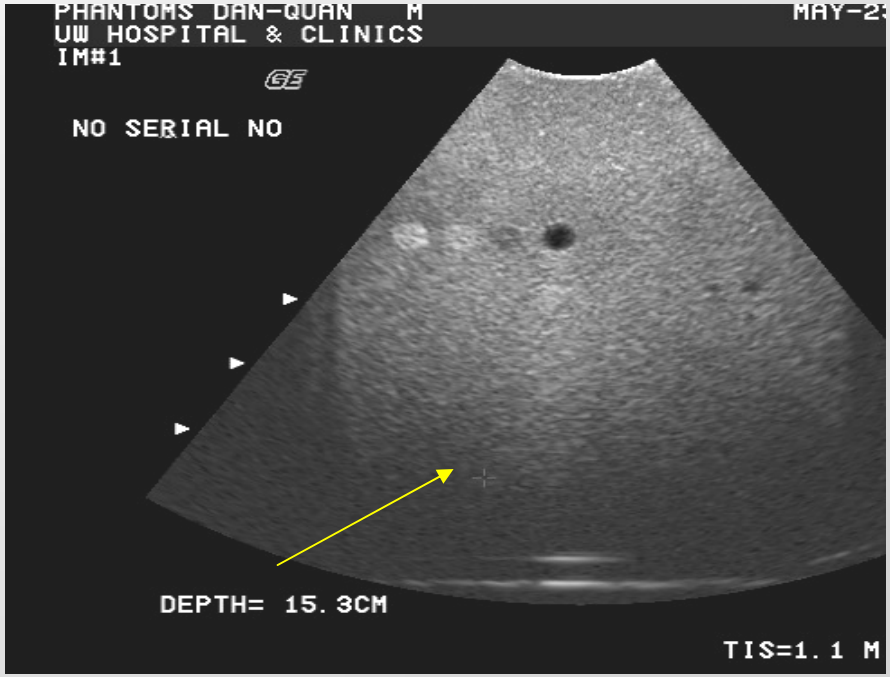
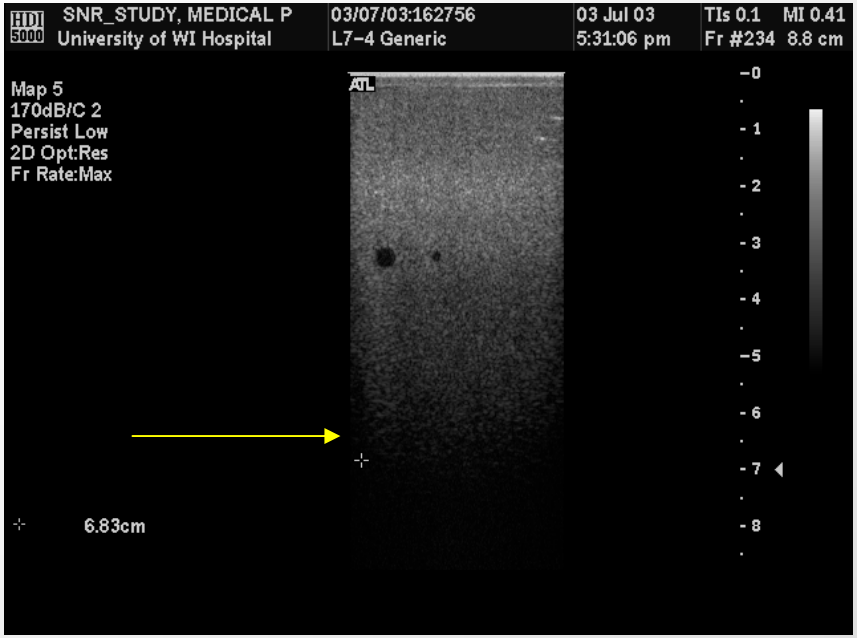
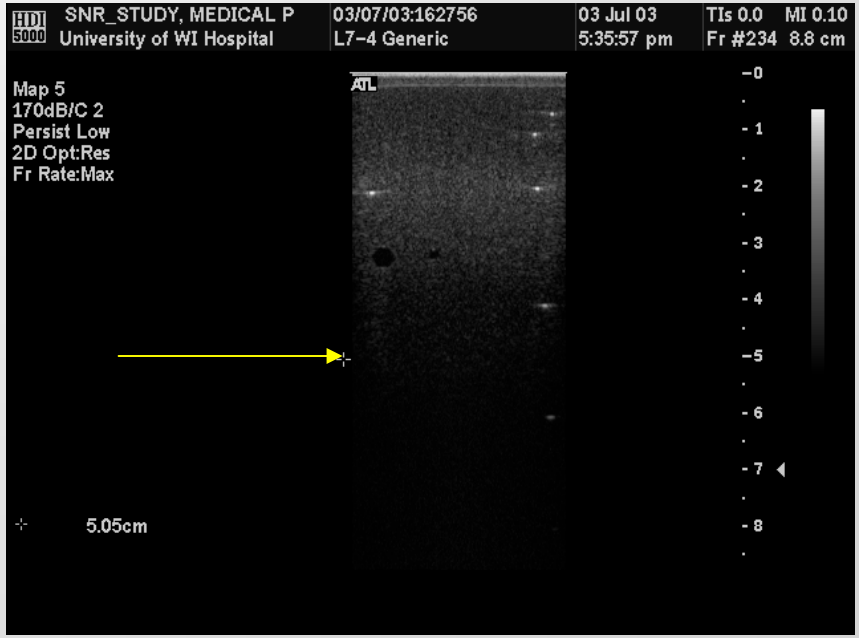
DOP: Depth of Penetration

- Used as a test of system sensitivity
  - Acceptance tests
  - Routine QA tests
- DOP: depth beyond which details in background material of phantom cannot be visualized.



Intensity ↓ DOP ↓ (ATL: L74)

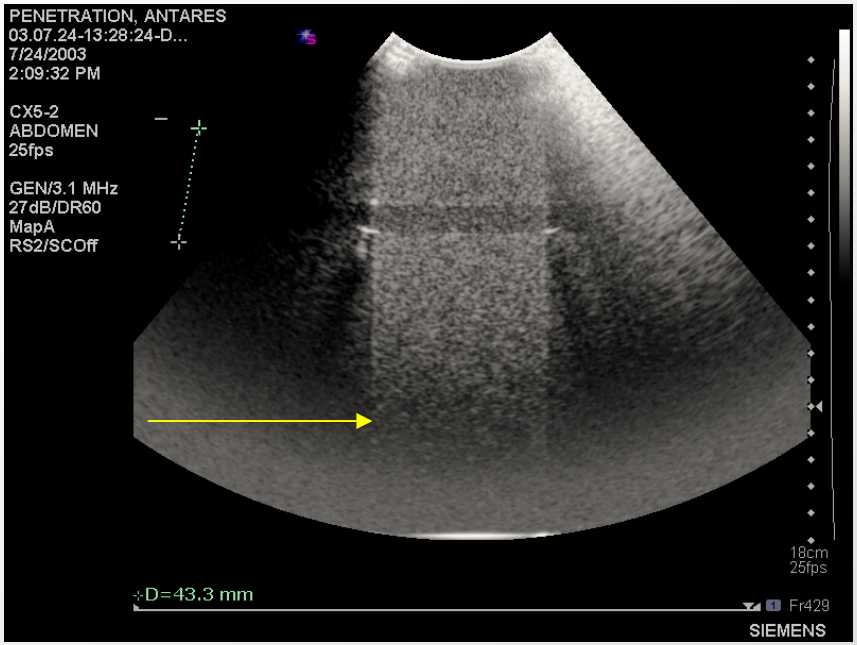


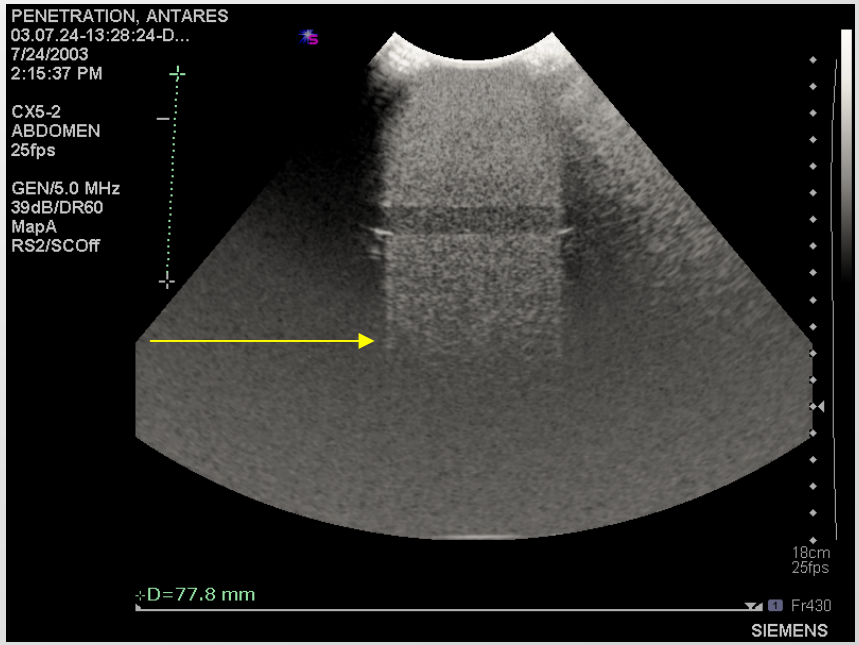


hi: MI 0.41

low: MI 0.10

Frequency↑ DOP↓ (Siemens: C52)





3.08MHz

5.00 MHz

DOP: Depth of Penetration (cont)

- Assessment is ***subjective***

- Not widely accepted by standards groups, such as NEMA, IEC

Goals

- Establish an **objective** measure of maximum depth of visualization
  - Be based on a signal-to-noise ratio SNR' measurement vs. depth
  - Should be *consistent* with user DOP

Experimental Methods

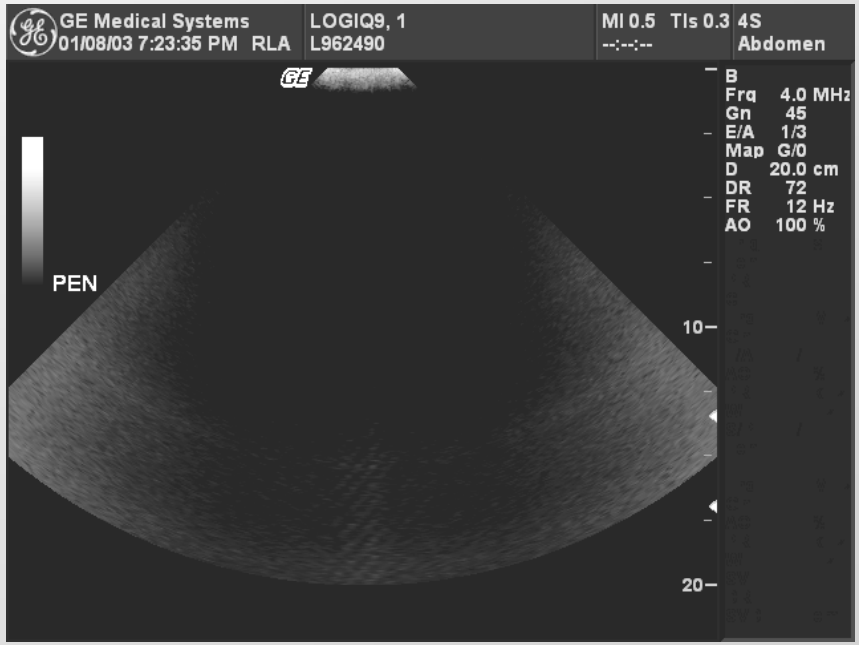
- Phantom: Gammex RMI 403 GS phantom, attenuation is 0.7 dB/cm-MHz
- Transmit focus, receiver gain adjusted for maximum visualization depth of background echoes
- 3 researchers *independently* placed an electronic marker on machine's frozen-image monitor to indicate DOP

Observation process

- observers agreed on criteria,
  - DOP judged to be the depth at which details of background texture are visualized. Isolated texture marks not counted.

- images are frozen, read and saved for both
  - the phantom
  - the noise: free probe

Phantom image & Free probe image
(GE: 4S)



Phantom image

Image of free probe

SNR’-DOP

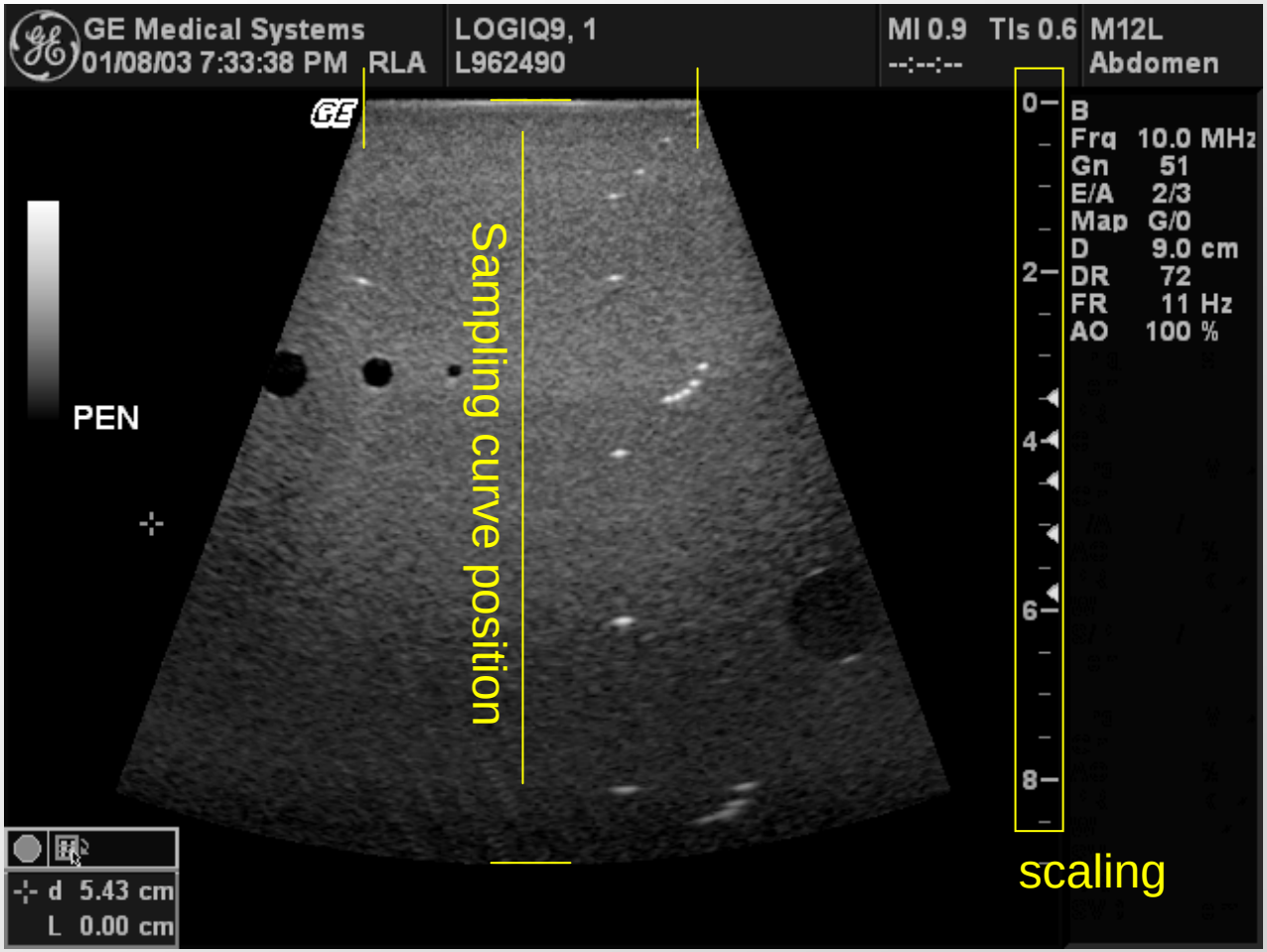
- Define:
  - signal (s’) = mean pixel value of phantom image
  - Noise (n’) = mean pixel value of free probe image
  - SNR’ = s’/ n’
- it is a ***measure*** called ***SNR’***

SNR'-DOP (cont)

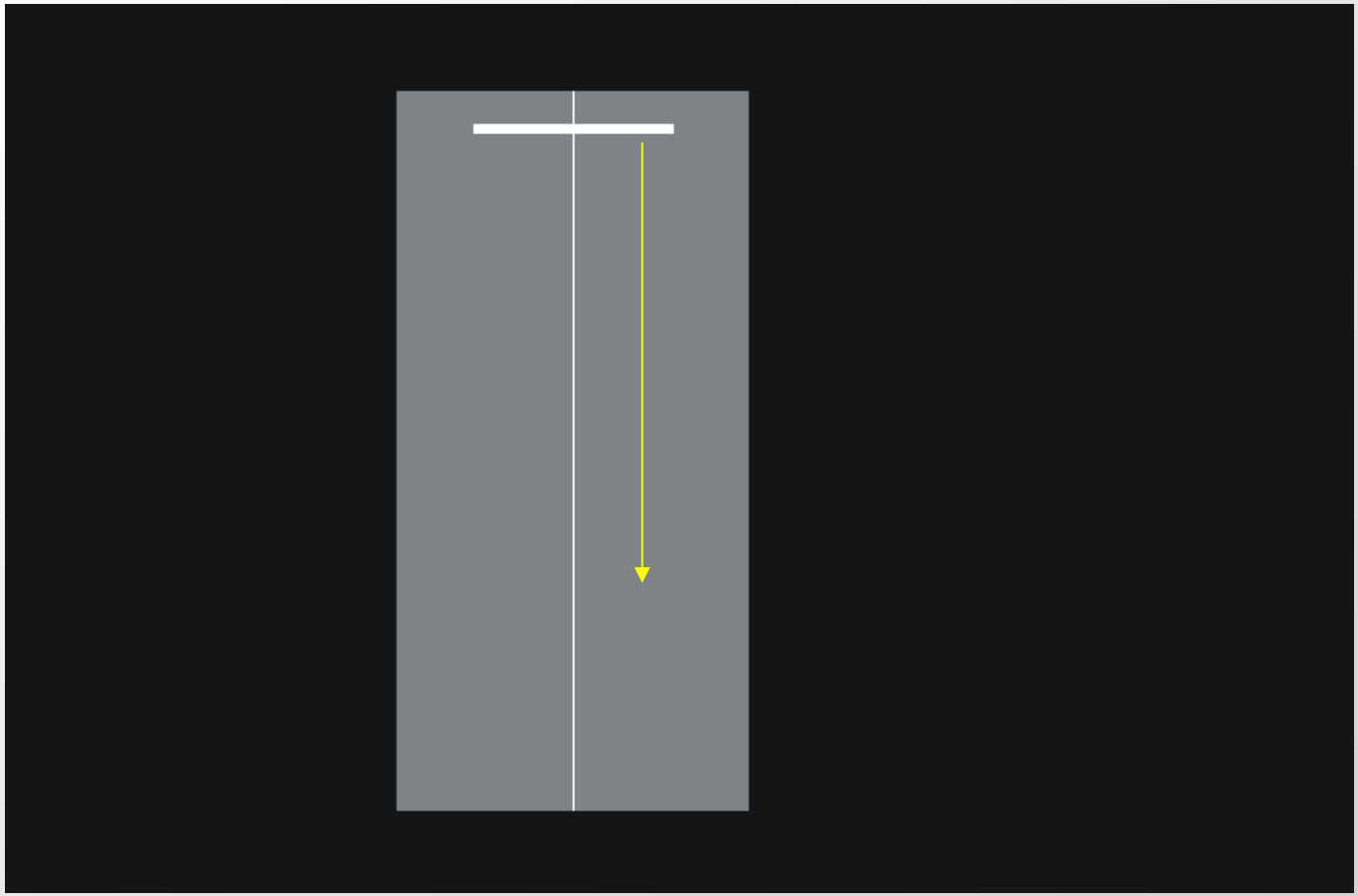
typical image (GE: M12 10MHz)

SNR'-DOP (cont)

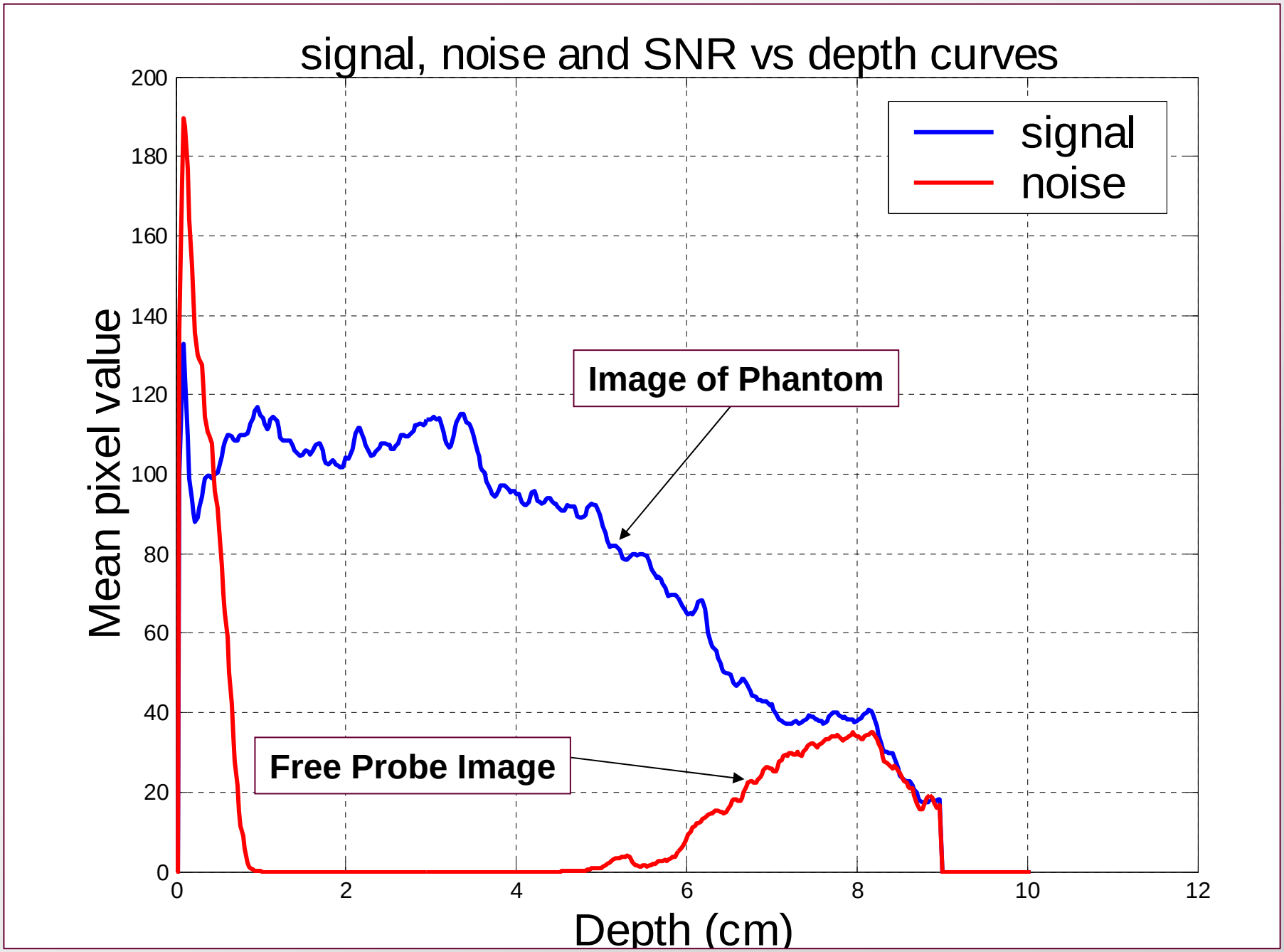
typical image (GE: M12 10MHz)

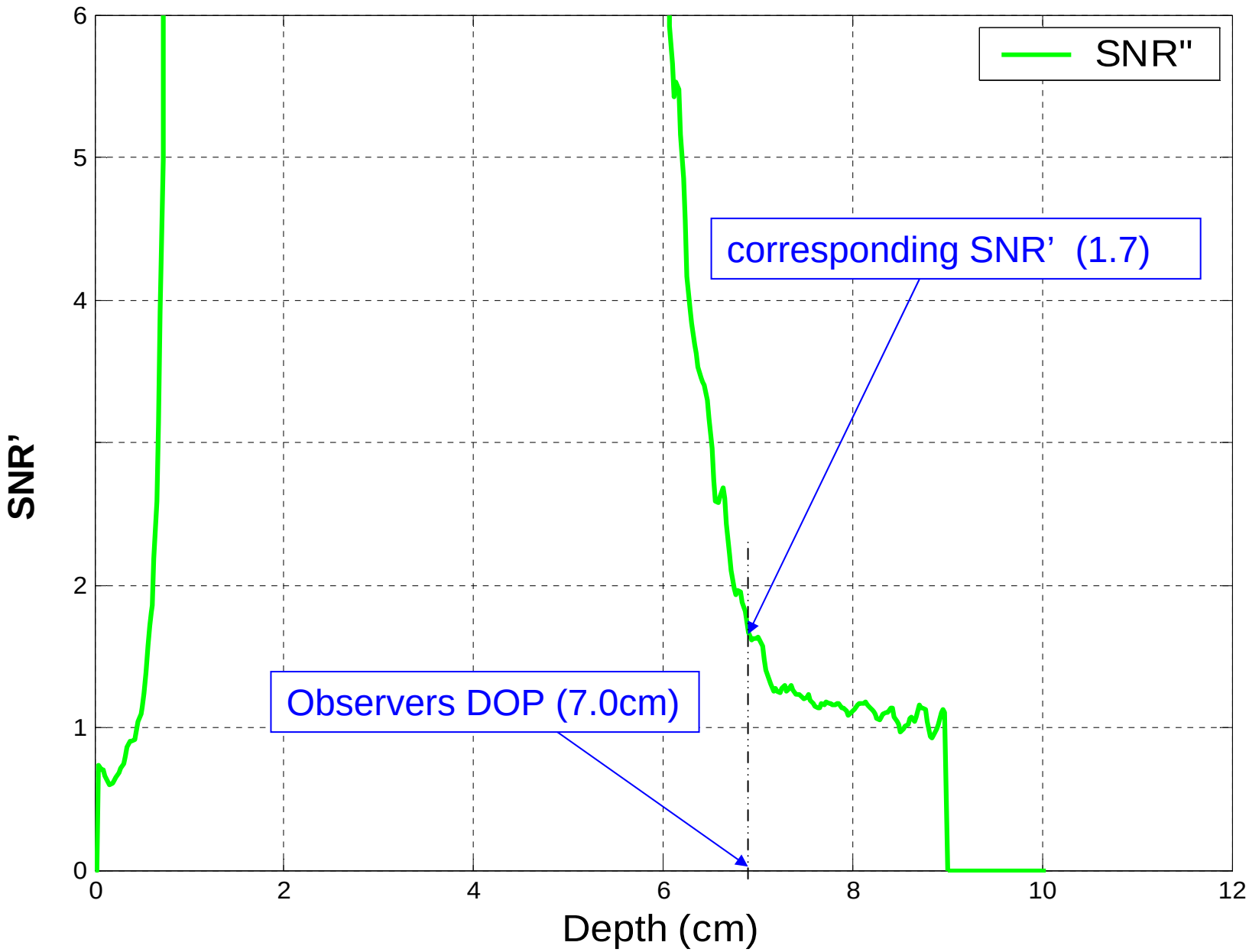


The process of averaging



Run the averaging box over the line in both phantom and free probe images


signal, noise and SNR vs depth curves
signal
noise
Image of Phantom
Free Probe Image
Mean pixel value
Depth (cm)
0
20
40
60
80
100
120
140
160
180
200
0
2
4
6
8
10
12


SNR"
corresponding SNR’ (1.7)
Observers DOP (7.0cm)
SNR’
Depth (cm)
0
1
2
4
5
6
0
2
4
6
8
10
12

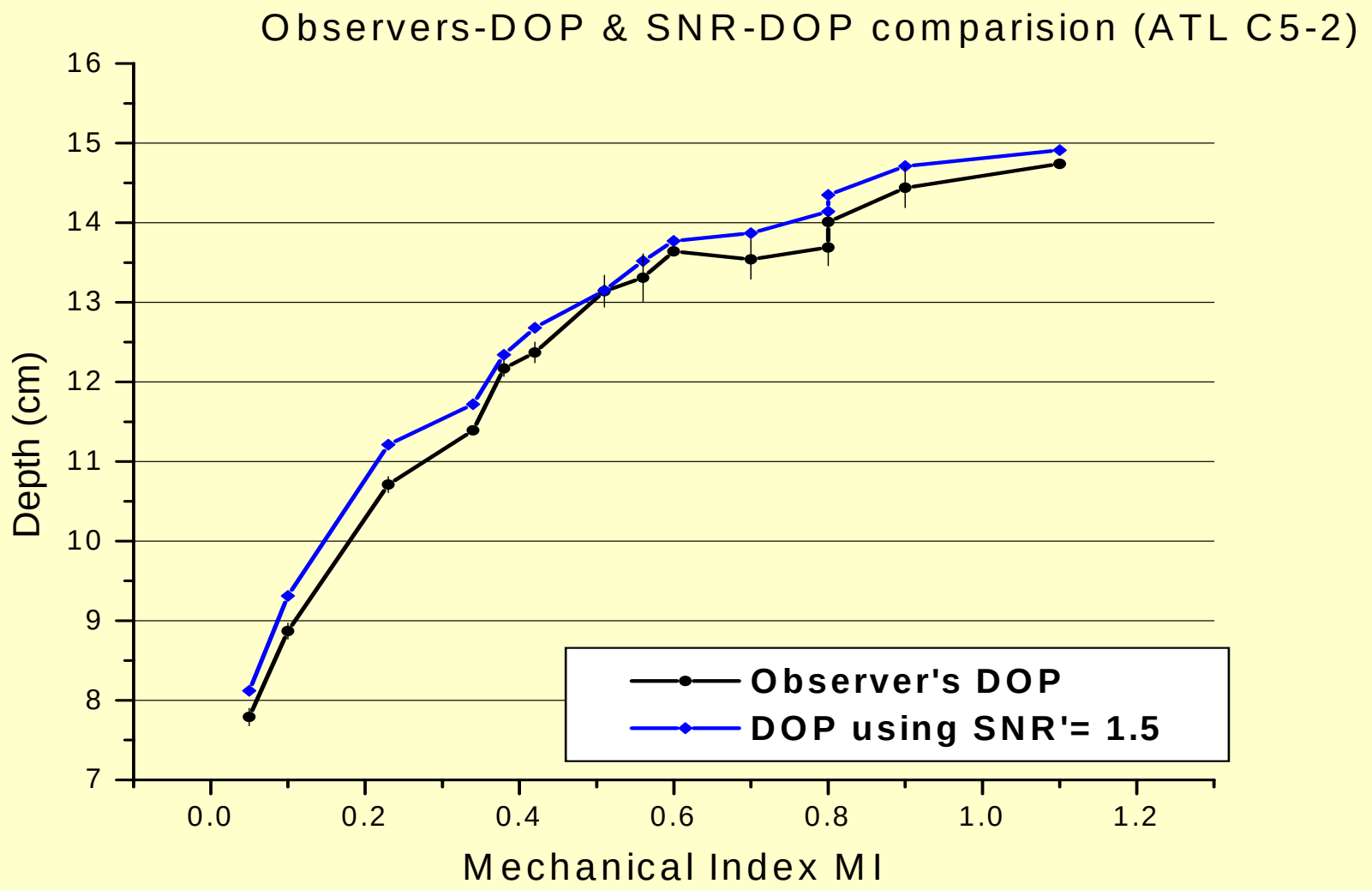
Results & Analysis

Effect of Changing Transmit Level

- If we pick SNR'=1.5
  - Observer-DOP ≅ (SNR'-DOP)
  - difference is comparable to users StDev

SNR'-DOP tracks well Observer-DOP

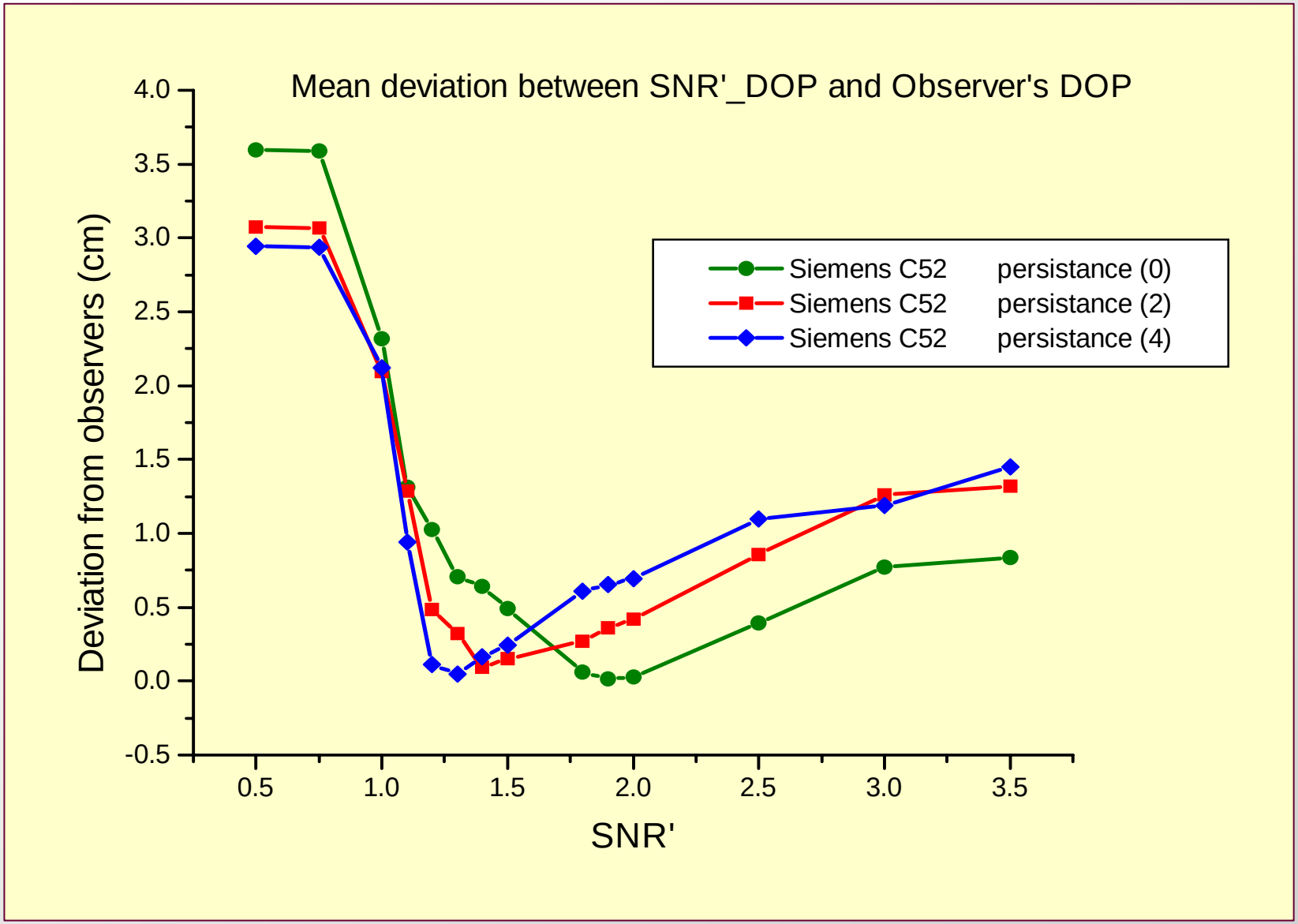
(transmit level study)



- Q. Is this SNR’ =1.5 good for all probes and/or settings? (is it global ?)

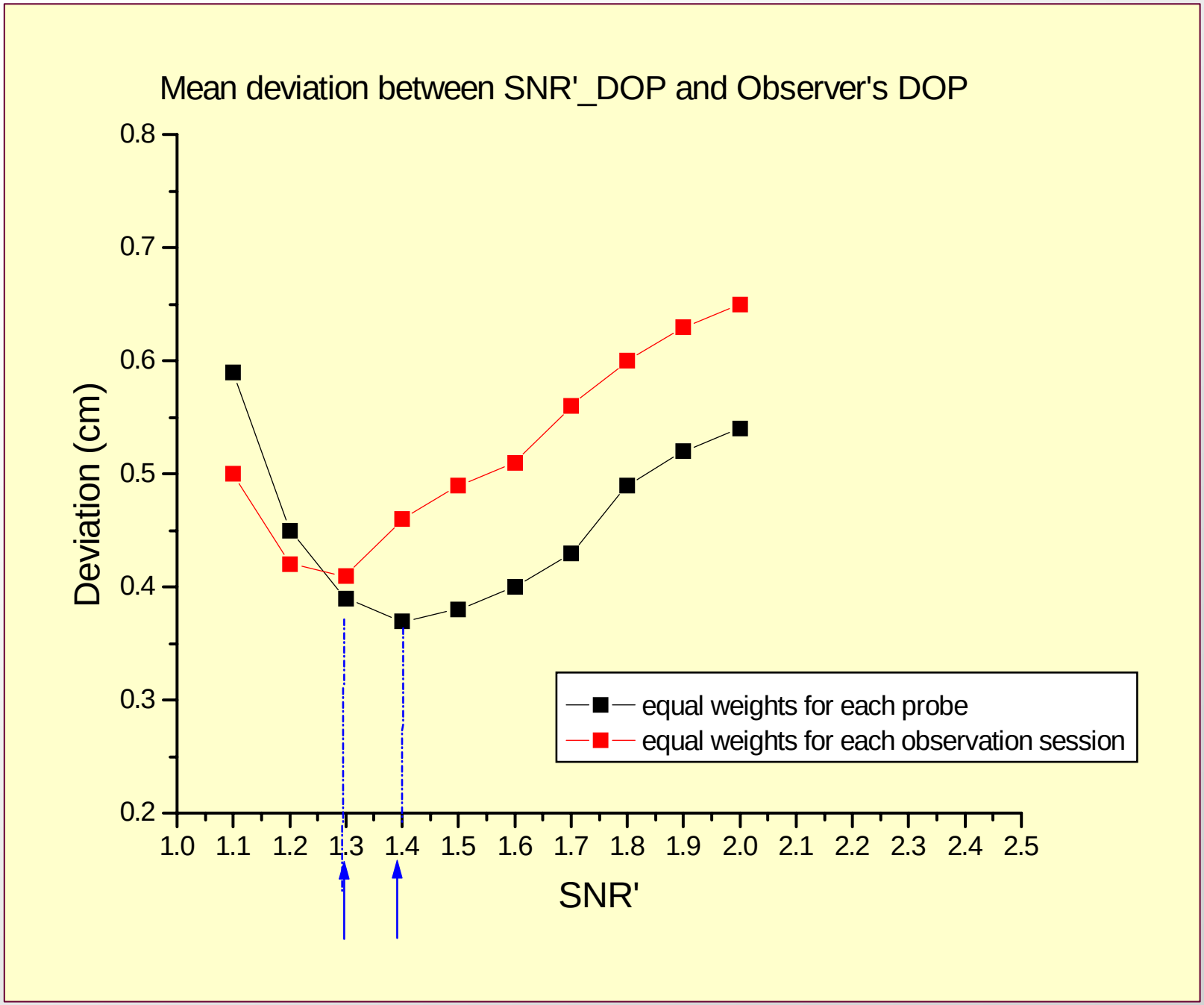
- Answer:
  - We need ***Quantative measure of agreement***
  - it is the ***mean deviation*** between users DOP and Depths at which SNR’ cutoff occurs

How much SNR'-DOP deviate from Observers-DOP for three levels of Frame averaging or persistence

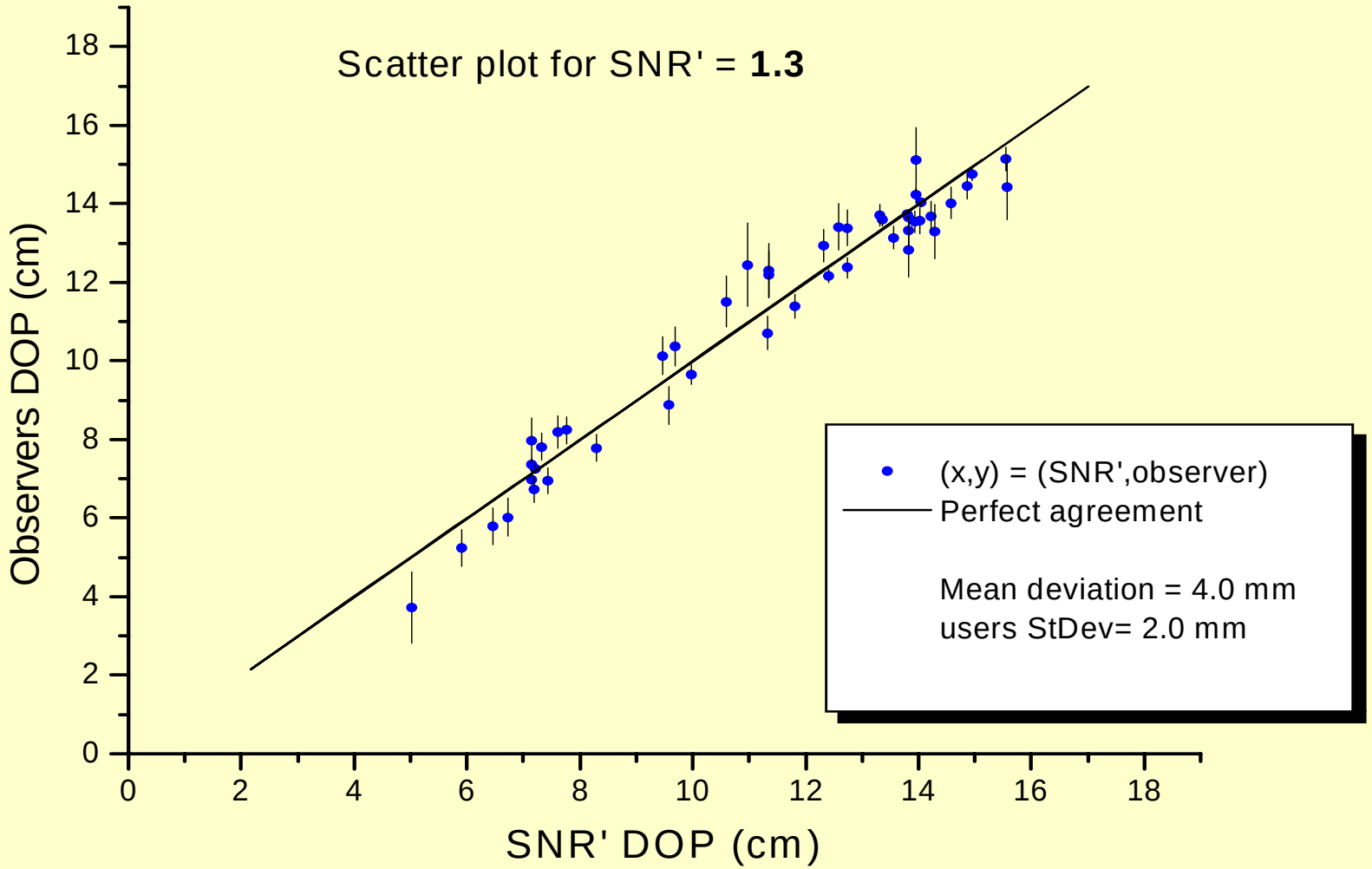


Experiments done

Probe	**runs**	**Parameters**
Siemens C52	14	Frequency, processing map
ATL L7-4	5	Transmit level
ATL C52	14	Transmit level
GE 10L	4	Transmit level
GE M7C	3	Frequency
GE M12	2	Frequency
GE 10L	1	
Siemens C52	3	Persistence
Siemens VFX	2	Persistence
8	**48**	← total


Mean deviation between SNR'_DOP and Observer's DOP
Deviation (cm)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0 2.1 2.2 2.3 2.4 2.5
SNR'
equal weights for each probe
equal weights for each observation session

Scatter plot → mean deviation



Conclusions

- SNR’ tracks/predicts well observers-DOP
- Observers DOP goes to depths of SNR’ as low as 1
- SNR’ corresponding to user defined DOP varies somewhat with persistence, maps, and likely other parameters

- A global SNR’ lies between 1 and 2
- **1.3 – 1.5** is a good selection
- deviation of 4.0 mm (users StDev= 2.0mm)