Al-Mustaqbal University College
Biomedical Engineering Department

Subject: Biomedical Instrumentation Design.

Class (code): 5th (BME515)

Lecture: *6*

MRI Design: Fast or turbo spin echo FSE or TSE

- Fast or turbo spin echo (FSE or TSE): much faster version of CSE.
- Also called a rapid acquisition with relaxation enhancement ***(RARE)*** sequence.
- In spin echo sequences, one phase encoding only is performed during each TR.
- The ***scan time*** is a function of ***TR***, ***NSA*** (***number of excitations (NEX)*** or ***number of signals averaged (NSA)***, which is a determinant of SNR) and ***phase matrix***.
- To speed up a conventional sequence, TSE performs the same number of phase encodings, thereby maintaining the phase matrix and resolution, but more than one phase encoding is performed per TR, reducing the scan time.

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- TSE employs a train of 180° rephasing pulses, each one producing a spin echo. This train of spin echoes is called an **echo train**. The number of 180° RF pulses and resultant echoes is called the **echo train length (ETL)** or **turbo factor**. The spacing between each echo is called the **echo spacing**.
- After each rephasing, a phase-encoding step is performed and data from the resultant echo is stored in a different line of K space (k-space is an array of numbers representing spatial frequencies in the MR image).

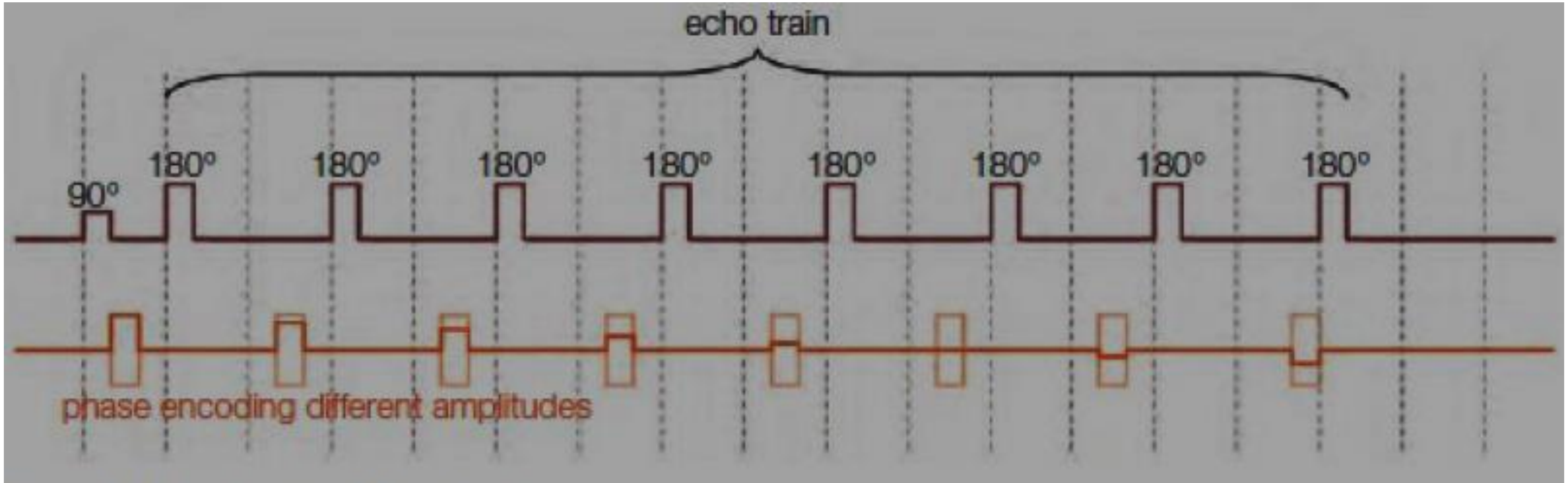

Figure 14.1 The echo train in TSE.

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- Typically, 2 to 30 180° RF pulses are applied during every TR. Since several phase encodings are also performed during each TR, several lines of K-space are filled each TR and the scan time is reduced.
- The *higher* the turbo factor the *shorter* the scan time.
- Each echo has a different TE and data from each echo is used to produce one image.
- This is different from CSE, where several echoes may be generated with a different TE, but each echo is used to produce a different image.
- In TSE multiple echoes with a different TE are used to produce the same image. This would normally result in a mixture of weighting. In TSE this problem is overcome by using **phase reordering**.
- In any sequence, each phase-encoding step applies a different slope of phase gradient to phase shift each slice by a different amount. This ensures that data is placed in a different line of K space.

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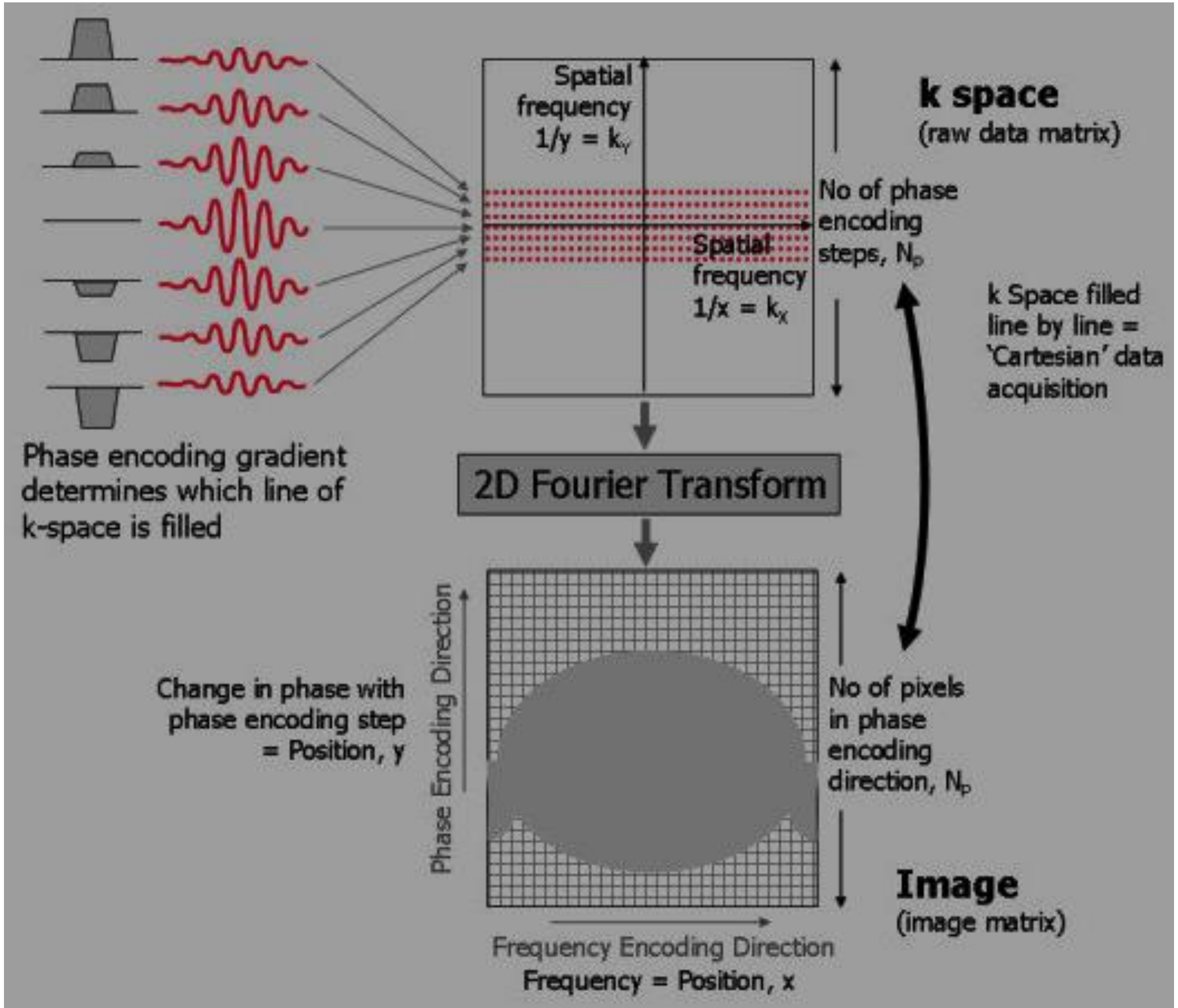

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- The very *steep* gradient slopes significantly *reduce the amplitude* of the resultant echo/signal, because they reduce the rephasing effect of the 180° rephasing pulse.
- *Shallow* gradients, on the other hand, do not have this effect and the *amplitude of the resultant echo/signal is maximized*.

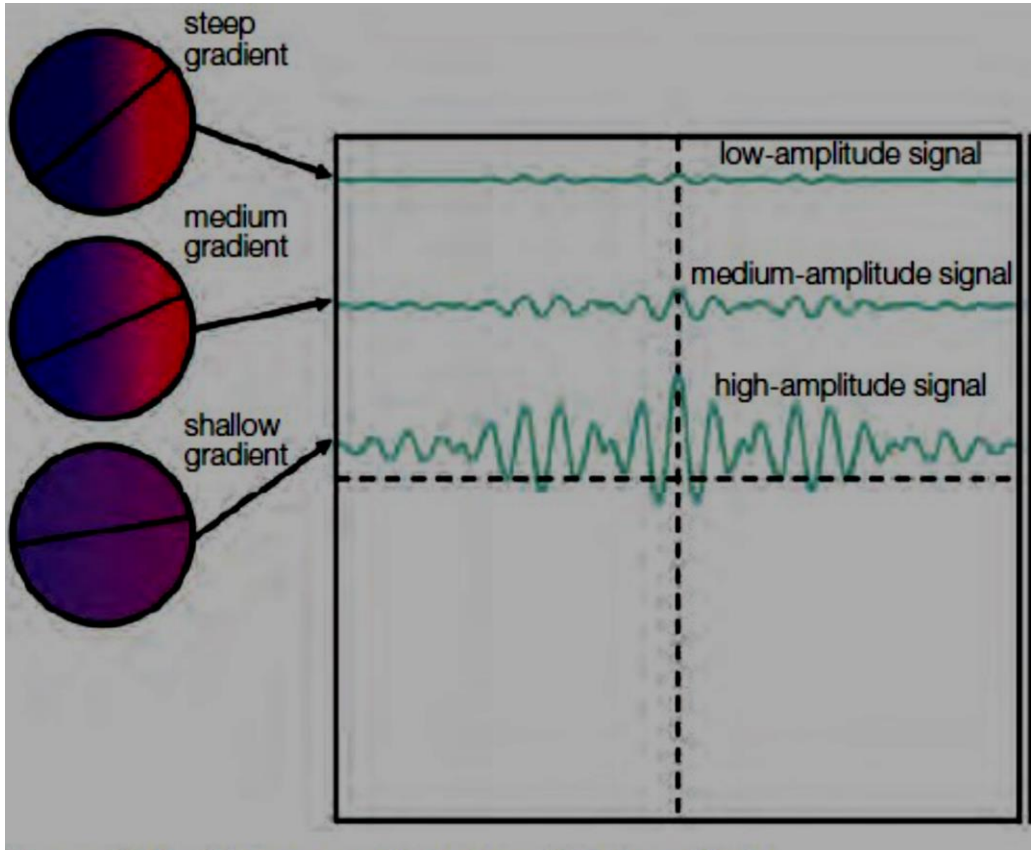

Figure 14.2 Phase encoding versus signal amplitude.

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- When **effective TE** is selected, the resultant image must have a weighting corresponding to that TE; that is, if the TE is set at 102 ms a T2 weighted image is obtained (assuming the TR is long).
- The system orders the phase encodings so that:
  - the most signal (the shallowest ones) are used on echoes produced from 180° pulses nearest to the effective TE selected.
  - The steepest gradients (which reduce the signal) are reserved for those echoes that are produced by 180° pulses furthest away from the effective TE.
  - Therefore, the resultant image is mostly made from data acquired at approximately the correct TE, although some other data is present.

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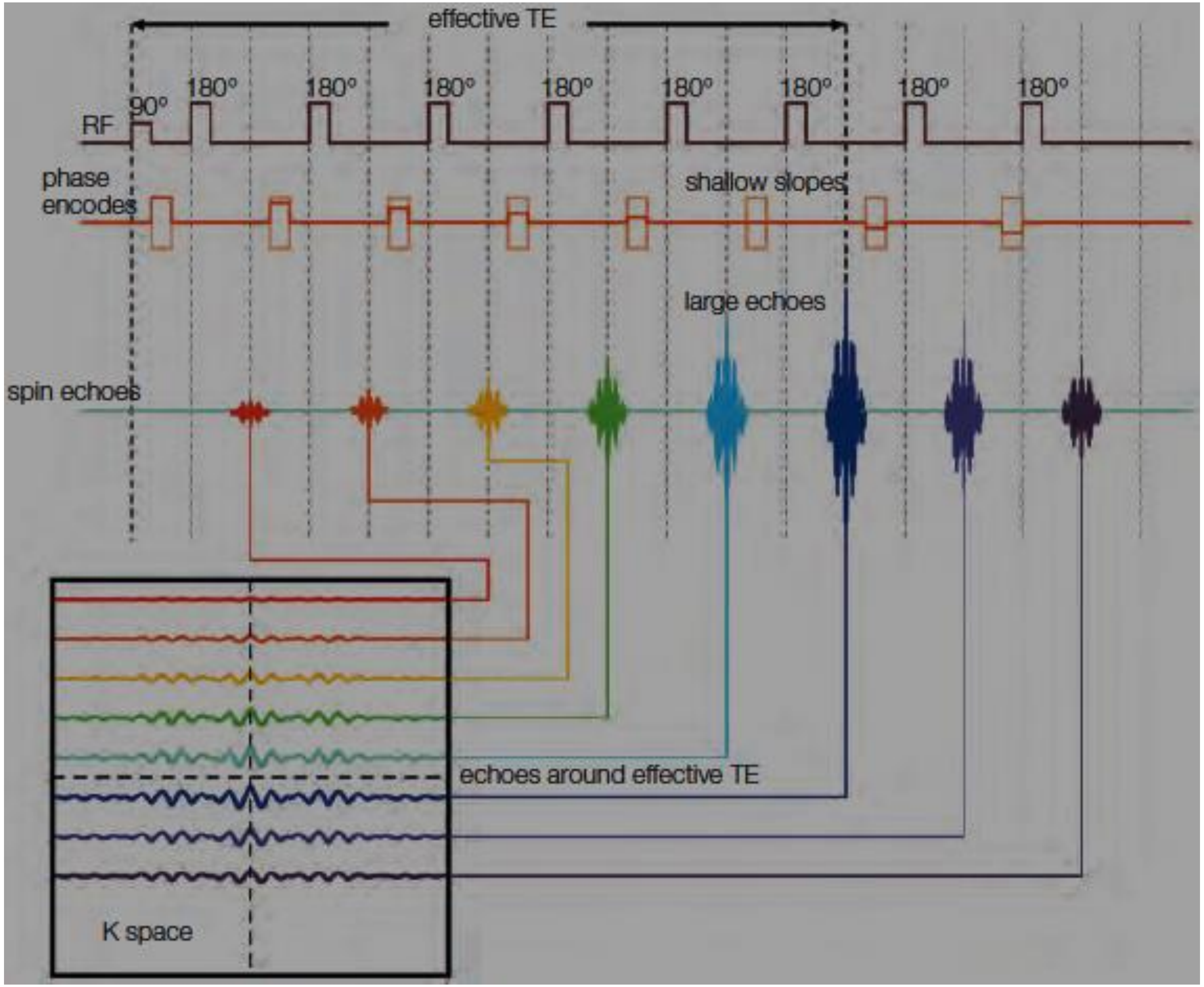

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- The contrast of TSE is unique!!!
  - In T2 weighted scans, water and fat are hyperintense (bright). Why?
  - Muscle is often darker than in conventional spin echo T2 weighted images. Why?
- When used with a very long echo train and long TE, TSE can sometimes result in blurred images. Why?
- Extending the TR lengthens the scan time, but this is more than compensated for by using long echo trains. Discuss!

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- The TSE produces T1, T2 or proton density scans in a fraction of the time of CSE.
- Since the scan times are reduced, phase matrix size can be increased to improve spatial resolution.
- TSE is normally used in the brain, spine, joints, extremities and pelvis.
- As TSE is incompatible with phase-reordered respiratory compensation techniques, it can only be used in the chest and abdomen with respiratory triggering, breath-hold or multiple NSA.

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- Using very long TEs and TRs permits very heavy T2 weighting (**watergrams**) that is used in, e.g., gallbladder imaging, where only signal from bile in the biliary system is seen.
- Systems that have sufficiently powerful gradients can use TSE in a single-shot mode **(SS_TSE)** or half Fourier single-shot TSE **(HASTE)** to permit image acquisition in a single breath-hold. In addition, using very long TEs and TRs permits very heavy T2 weighting (**watergrams**). An example of this technique is in gallbladder imaging, where only signal from bile in the biliary system is seen. Table 15.2 lists some advantages and disadvantages of TSE.