

CODED & CHIRP EXCITATION

STUDENT LEARNING GUIDE | Understanding the basic idea

WHY USE A CODED PULSE?

Ultrasound systems need echoes that are strong enough to distinguish from background electronic noise. Echoes from deeper tissues are often weak because sound loses energy as it travels through the body.

A short pulse helps separate closely spaced reflectors along the beam, but carries limited energy. Simply making an ordinary pulse longer adds energy while making those reflectors harder to distinguish. Coded excitation combines a longer, patterned transmission with processing that recovers a short effective echo.

CODED EXCITATION: SEND A PATTERN, THEN RECOGNIZE IT

The system transmits a longer pulse or pulse sequence with a known pattern, called a code. The pattern may involve changes in frequency or in the timing of the wave cycles (phase). Students do not need to memorize individual code types to understand the principle.

1. Transmit. The longer coded signal delivers more total energy without necessarily increasing the peak acoustic intensity.
2. Receive. Returning echoes contain a version of the transmitted pattern, mixed with noise and altered by tissue.
3. Decode and compress. A digital filter looks for the known pattern and concentrates its response into a short peak. This is called pulse compression.
4. Form the image. The processed echoes can stand out more clearly from noise while retaining useful detail along the beam.

WHAT DOES PULSE COMPRESSION ACTUALLY COMPRESS?

It compresses the received signal in time through digital processing. It does not physically shorten the sound pulse already traveling through the patient. The transmitted pulse is long; the effective echo used to build the image is short.

Axial resolution is the ability to distinguish two reflectors positioned one behind the other along the beam. With effective compression and suitable bandwidth, a coded pulse can preserve axial resolution comparable to a short pulse.

CODED & CHIRP EXCITATION

STUDENT LEARNING GUIDE | Chirps, benefits, and practical limits

CHIRP EXCITATION: A FREQUENCY SWEEP

A chirp is one form of coded excitation. Its frequency changes during the transmitted pulse. An up-chirp sweeps from lower to higher frequency; a down-chirp sweeps from higher to lower frequency. Unlike a conventional short pulse, it deliberately spreads a recognizable frequency pattern over a longer time.

Think of a siren rising in pitch. If a listener already knows the sweep, that pattern is easier to recognize within background noise. The ultrasound system similarly recognizes the chirp in the returning echo and processes it into a short response. The analogy explains recognition; the actual compression is electronic.

WHAT CAN STUDENTS EXPECT IT TO IMPROVE?

Signal-to-noise ratio (SNR). Useful echoes become easier to distinguish from background electronic noise. SNR describes the strength of the useful signal relative to the noise.

Penetration. Weak echoes from deeper tissues may remain usable, helping the system display structures that would otherwise be obscured by noise.

Axial detail. Effective pulse compression can retain the ability to separate nearby reflectors along the beam despite the longer transmission.

IMPORTANT LIMITATIONS

Compression must work well. Imperfect decoding can leave small extra responses before or after the main echo. These range sidelobes may obscure weak echoes near a strong reflector and reduce contrast.

Performance varies. Motion, tissue attenuation, the transducer, and the coding method can affect the result. Additional processing is required; some methods also need multiple transmissions.

More energy still needs control. Keeping peak intensity unchanged does not mean total exposure is unchanged. Pulse duration and repetition rate also matter, so the system must operate within acoustic-output limits.

Coded excitation is used in selected ultrasound systems and imaging methods; it may work in the background rather than appear as a separate operator control. It does not automatically remove speckle or improve every type of resolution.

REMEMBER THE RELATIONSHIP

Coded excitation = the broader family of patterned transmissions.

Chirp excitation = a code based on a frequency sweep.

Pulse compression = processing that turns the long coded echo into a short effective response.

Further reading: Park et al. (2017), A New Dynamic Complex Baseband Pulse Compression Method for Chirp-Coded Excitation in Medical Ultrasound Imaging. PubMed: 28880168. <https://pubmed.ncbi.nlm.nih.gov/28880168/>