**EEE 505: Time-Frequency Signal Processing**

**Prerequisites:** EEE 407 (Digital Signal Processing) or equivalent.

**Course Description:** This course is on time-frequency signal processing methods. Classical signal theory treats signals separately, either in the time domain or in the frequency domain. However, time-varying signals (such as speech, music, or biological sounds) and time-varying systems (such as the impulse response of a time-frequency selective wireless communication channel) have frequency content that changes with time or multiple frequencies that occur at the same time. The adequate processing tools to completely characterize these signals and systems are time-frequency representations (TFRs). These are two-dimensional transforms that provide information in the joint time-frequency (TF) plane. Many TFRs and their usefulness in many applications will be covered in this course.

**Course Topics:**

• Signals and signal properties; Uncertainty principle.

• Review of 1-D transforms: Fourier transform (FT), group delay, instantaneous frequency.

• Classical TFRs

• Desirable properties; linear vs quadratic TFRs.

• Linear TFRs: Short-time Fourier transform (STFT); Wavelet transform; filter banks.

• Spectrogram: relation to STFT; tradeoff between TF resolution and cross-term attenuation; application examples.

• Wigner distribution (WD): definition; properties; signal examples; relation to narrowband ambiguity

function; cross-term geometry; applications; Smoothed WDs.

• Choi-Williams distribution; Cohen’s class; covariance properties; kernel formulations; applications.

• Scalogram: relation to wavelet transform; properties; TF resolution; applications.

• Affine class; covariance properties; kernel formulation; applications.

• Altes Q-distribution; warping transformations; matching TFRs with signal characteristics.

• New time-frequency concepts: Potential projects

• Adaptive TFRs: adaptive spectrogram; radially-Gaussian optimal distribution; positive TFRs; short-time techniques; time-frequency distribution series.

• Reassignment method; Matching pursuit algorithms.

• TFRs in real-world applications: wireless communications, biomedicine, genomics, radar, sonar, detection, estimation, classification, geophysics, speech processing, image processing, machine monitoring, structural health monitoring, and many more.