EMI In Wireless Communications: Full-scale Behavioural-level Simulation

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Wireless Reality Today

- World is digital

- Exponential growth

- Limited spectrum and space available

- New systems and services

Wireless Problems on Horizon

- Smart antennas for 3G and beyond
- Broadband wireless (W-CDMA etc.)
- MIMO/BLAST[1]

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[1]MIMO - Multiple-Input Multiple-Output, BLAST - Bell Labs Layered Space-Time

EMI in Analog and Digital Wireless Systems

Present-day approach:

- EMI analysis during frequency planning
- No accurate Tx & Rx models
- No accurate and efficient techniques
- Huge gap between system and circuit levels
- System design: comply with regulations

Interference effects:

- **Linear:** well understood and developed area

- **Nonlinear:** much more difficult to handle, no unified approach, computationally-intensive, much room for future work

Nonlinear interference effects in wireless systems:

- Tx spurious radiation (harmonics, IMPs, noise)

- Rx spurious responses (adjacent, image and IF channels)

- Rx nonlinear behaviour (desensitization, IMPs, LO noise and harmonics conversion)
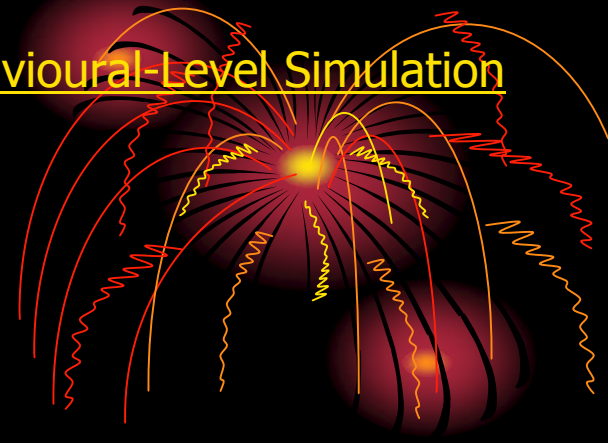
Analysis methods:

- Empirical or semi-empirical

- Simple analytical models

- Complex numerical models: circuit level (i.e., SPICE) and system-level (behavioural or black-box)

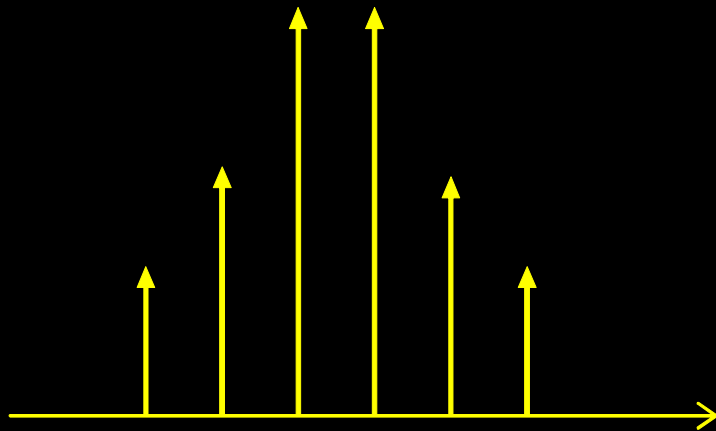# Difference between analog and digital systems:

- Different signals (analog and digital modulation)

- Different circuits (design criteria)

- Different performance parameters: ACPR, EVM, spectral regrowth versus two-tone IMPs

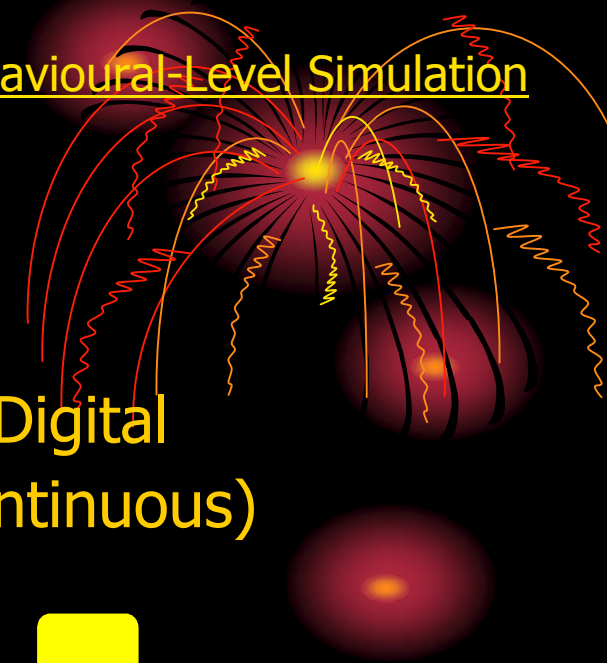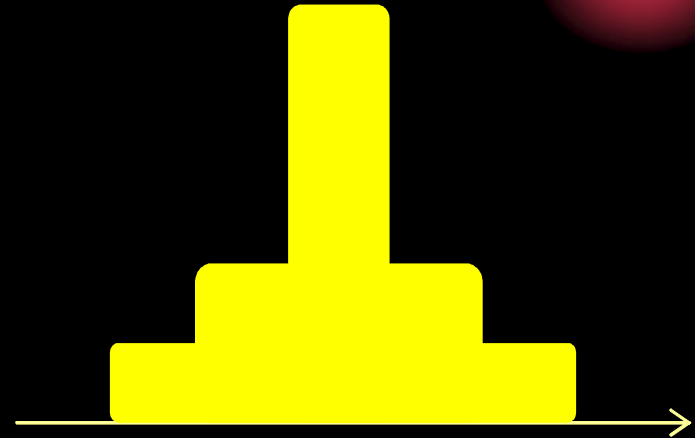- Consequence: different analysis techniques

Spectra

## Analog
(discrete)

Digital
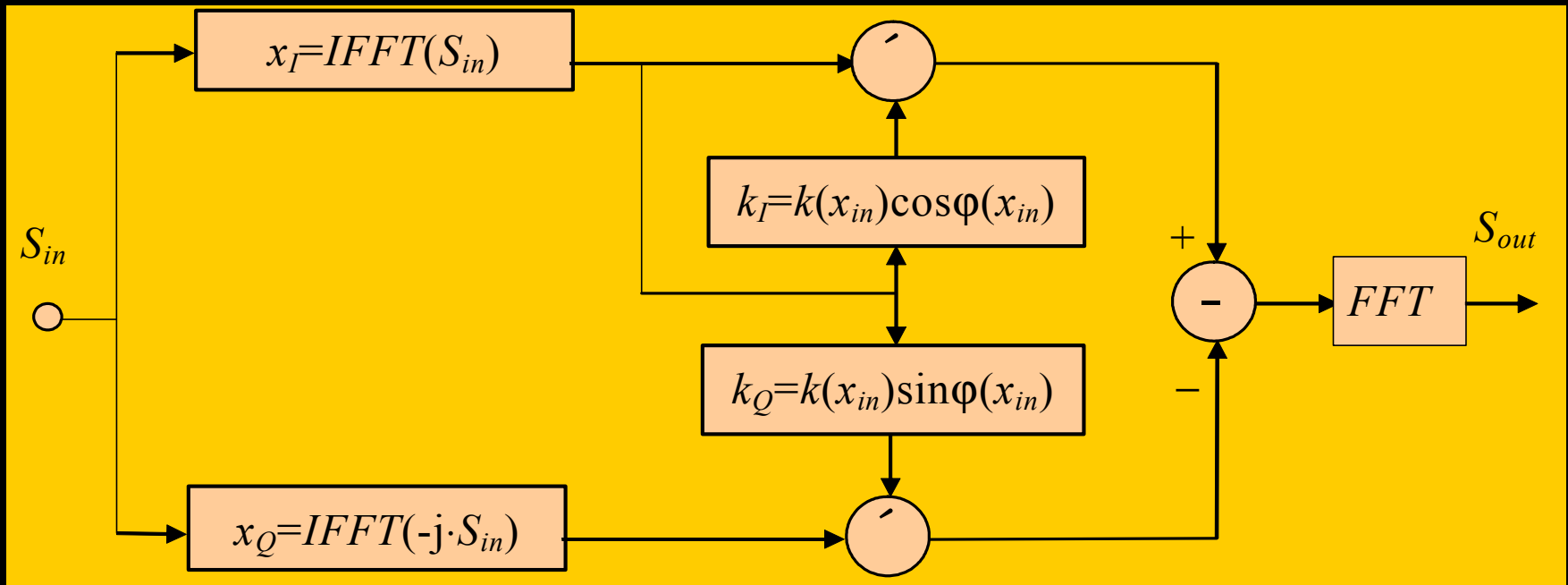## (continuous)
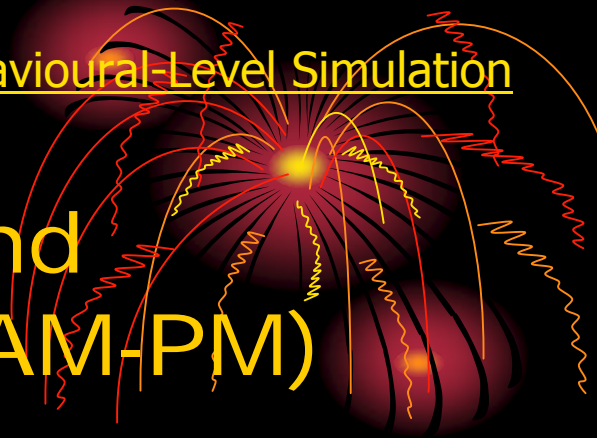
Simulation Techniques

- Quadrature modeling technique (early 1970s, PA in satellites)

- Discrete technique (early 1980s, EMI in a group of RF systems)

- Instantaneous quadrature technique (late 1990s, unified approach for RF/IF/baseband)
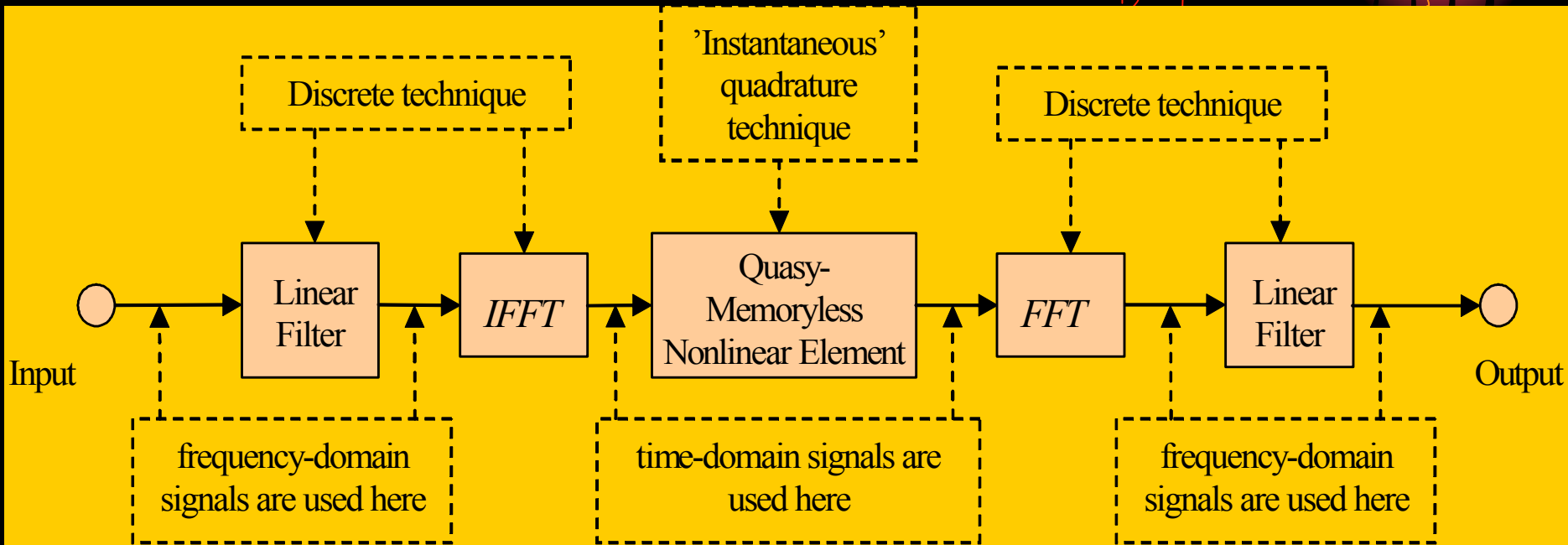
Instantaneous Quadrature Technique

1. Linear stages ➡ frequency domain

2. Nonlinear stages ➡ time domain

3. The transform ➡ FFT/IFFT
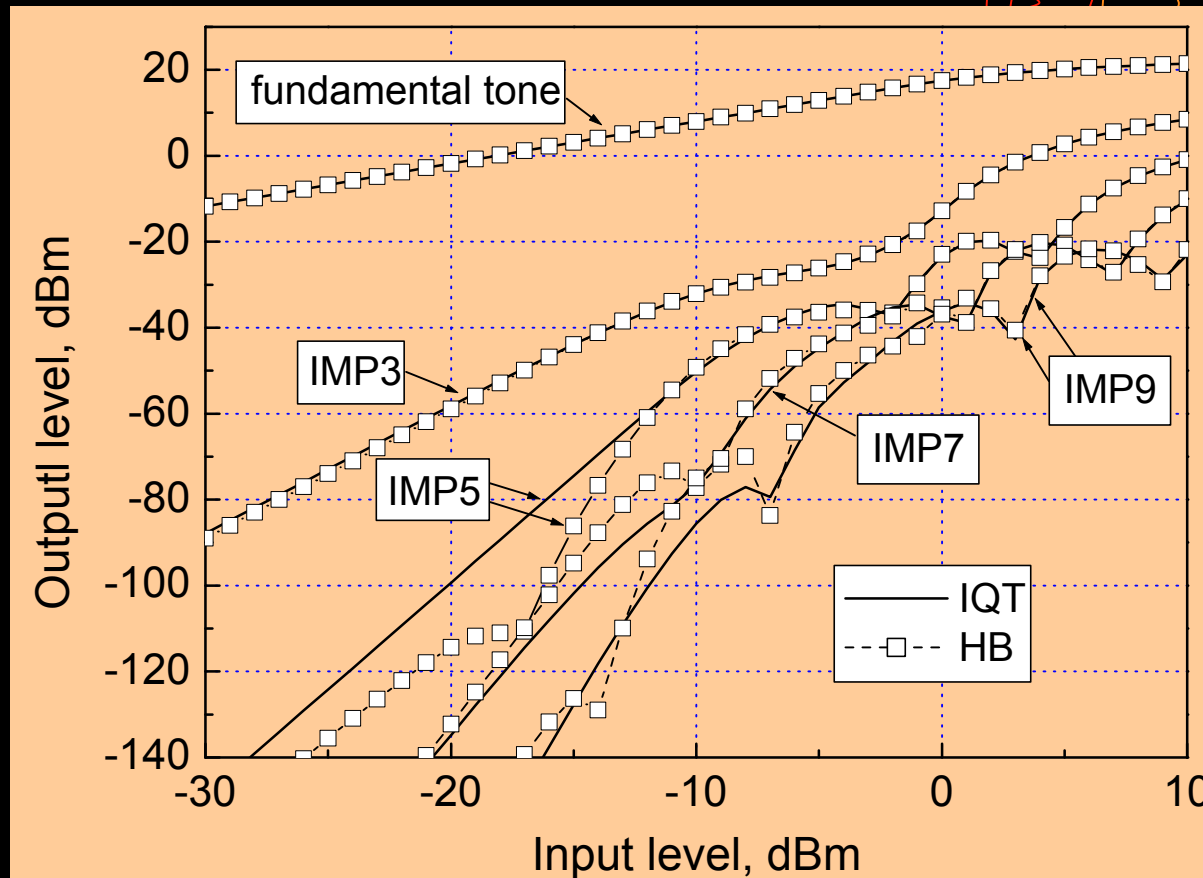
4. IQ components ➡ Hilbert transform
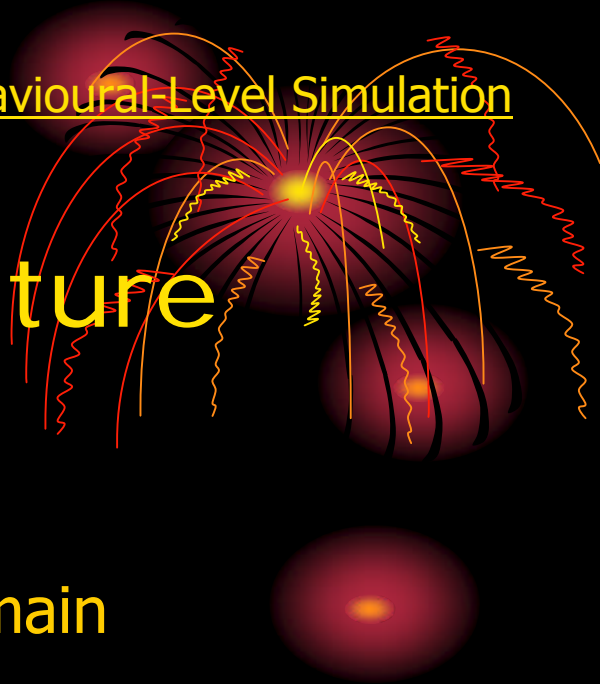
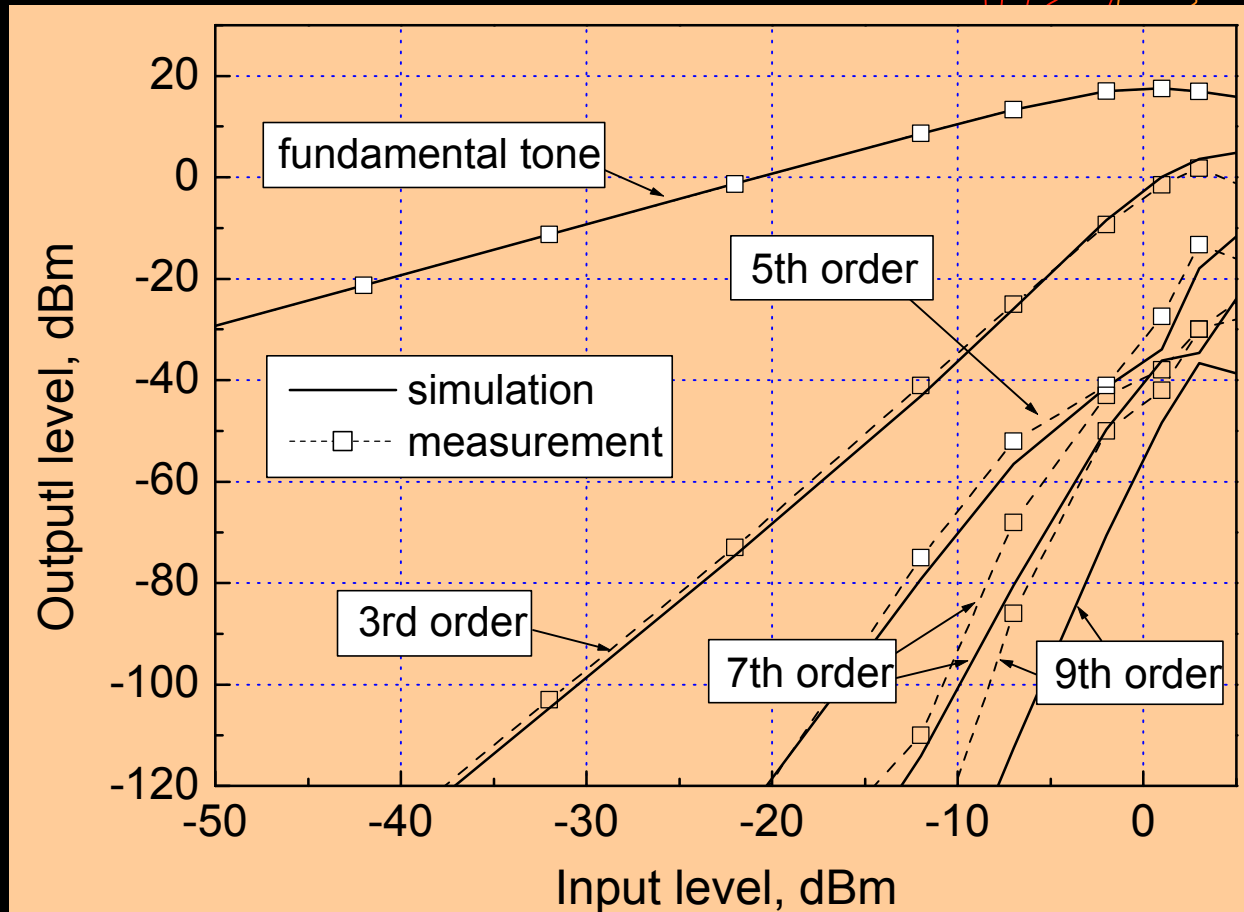# modeling broadband nonlinearity (AM-AM & AM-PM)

Example: single-stage RF amplifier

Input

Discrete technique

'Instantaneous' quadrature technique

Discrete technique

Linear Filter → *IFFT* → Quasy-Memoryless Nonlinear Element → *FFT* → Linear Filter

Output

frequency-domain signals are used here

time-domain signals are used here
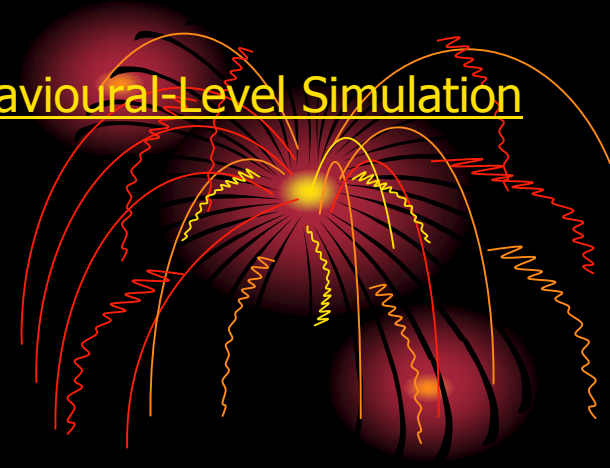
frequency-domain signals are used here

IMPs in microwave amplifier

Harmonics in MMIC amplifier

Conclusion

- many challenges in EMC/EMI analysis of present and future wireless networks

- big difference between digital and analog systems

- Behavioural-level simulation by instantaneous quadrature technique