



IBM Research

Broadband Communications  
at mmWave Frequencies:

***An MSK system for Multi-Gb/s Wireless  
Communications at 60GHz***

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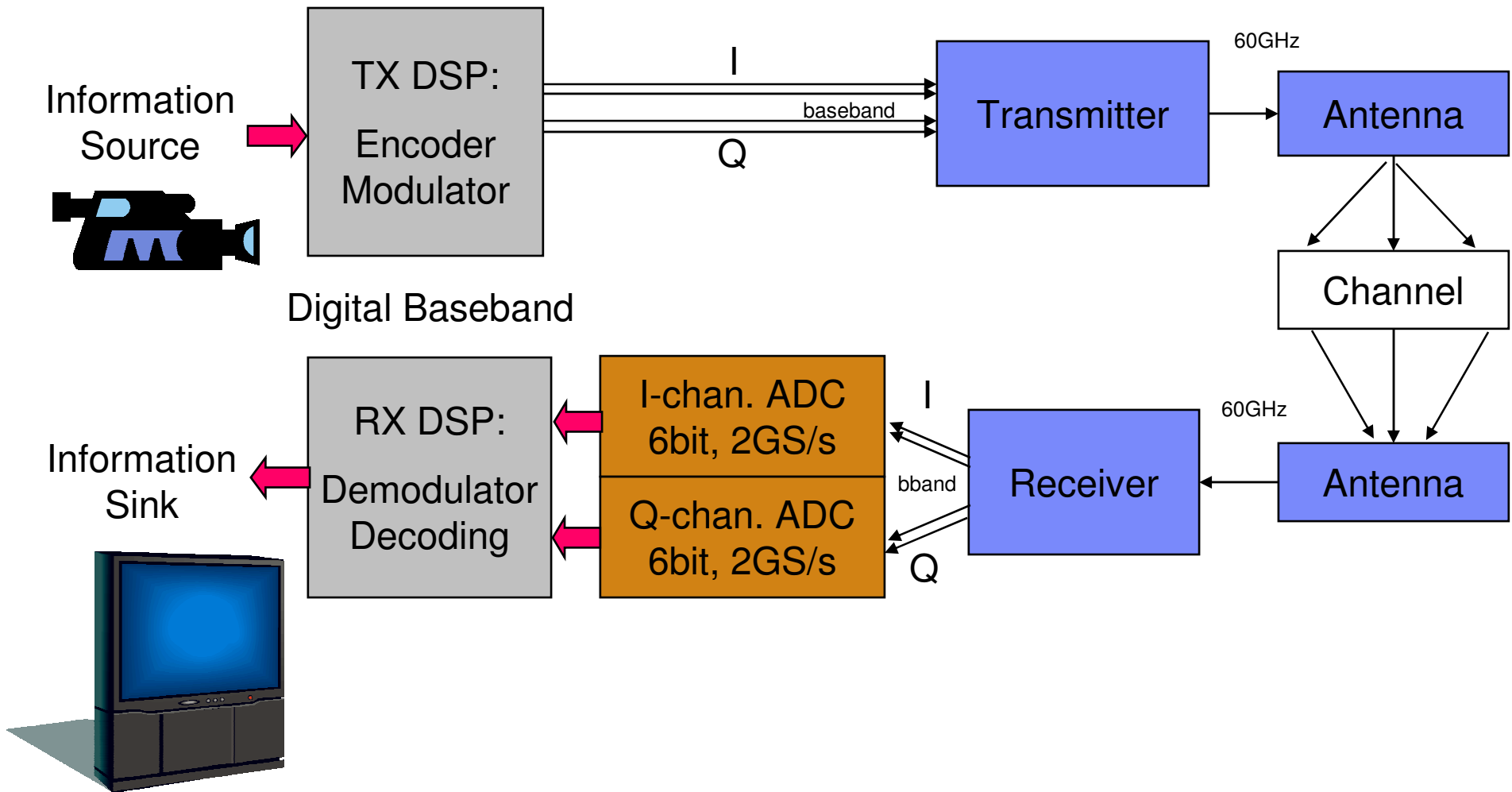
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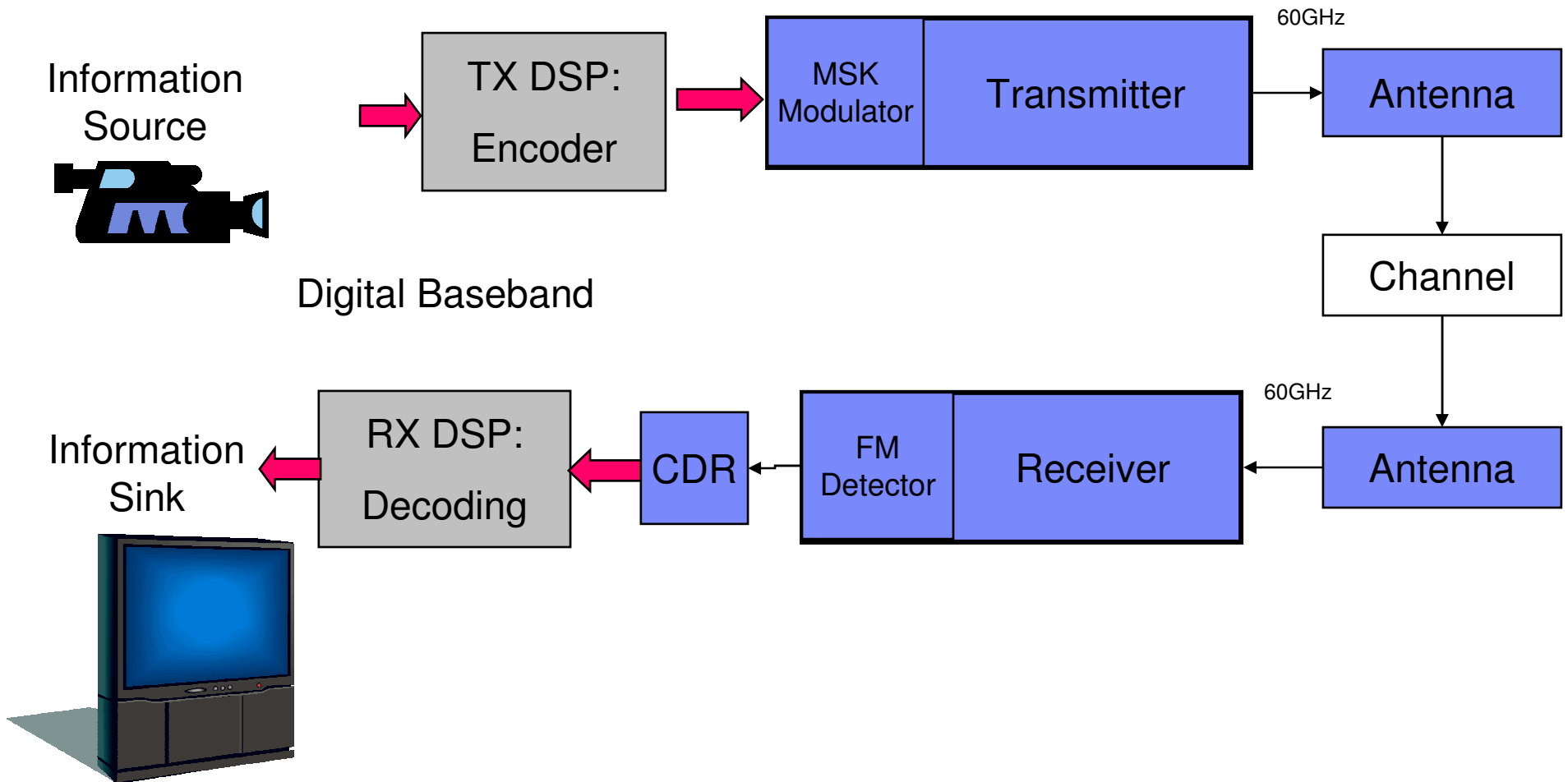
## Outline

- **Complex modulation system for multi-path channel Vs. MSK system for directional channel.**
- **Trade-offs for MSK multi-GB/s mmWave system.**
- **60GHz TX architecture with MSK modulator.**
- **60GHz RX architecture with FM detector.**
- **MSK Modulator/Demodulator transistor-level simulations.**
- **Efficient 60GHz switching-mode PA for constant envelope modulation.**
- **Summary.**

# Application Block Diagram 1: Complex Modulation, Multi-Path Channel



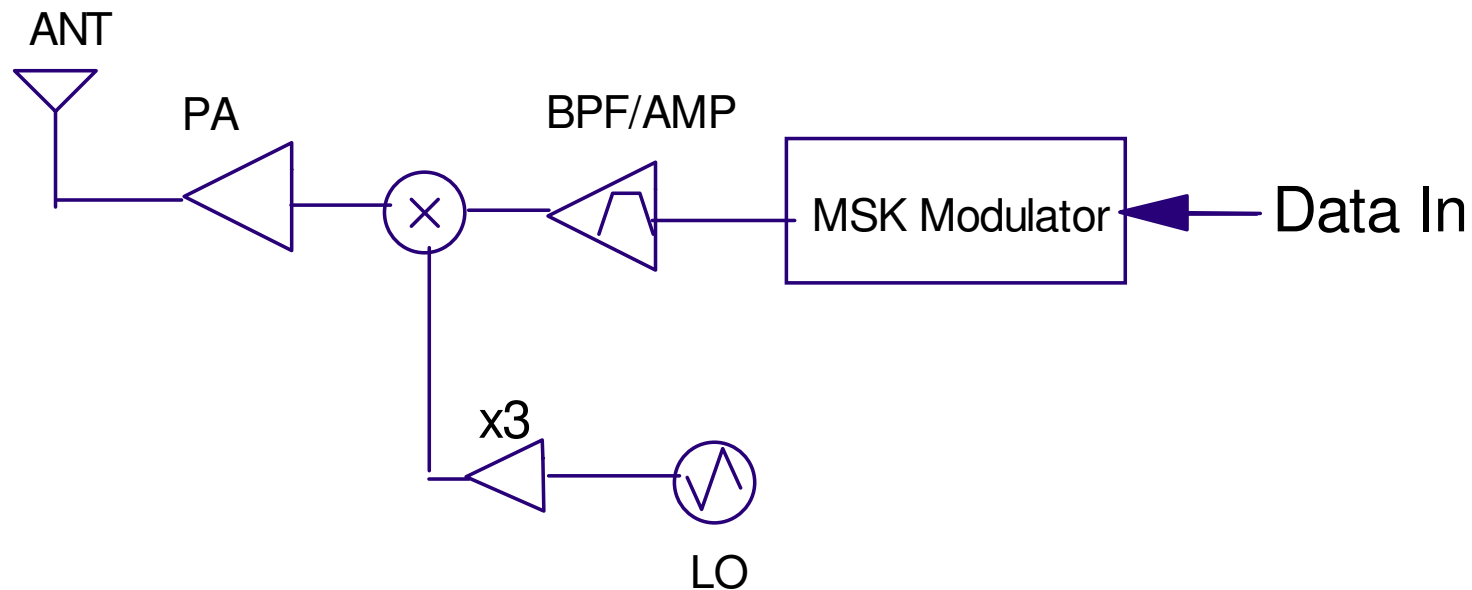
# Application Block Diagram 2: MSK Modulation, Directional Channel



## MSK System for Directional Channels: Trade-offs

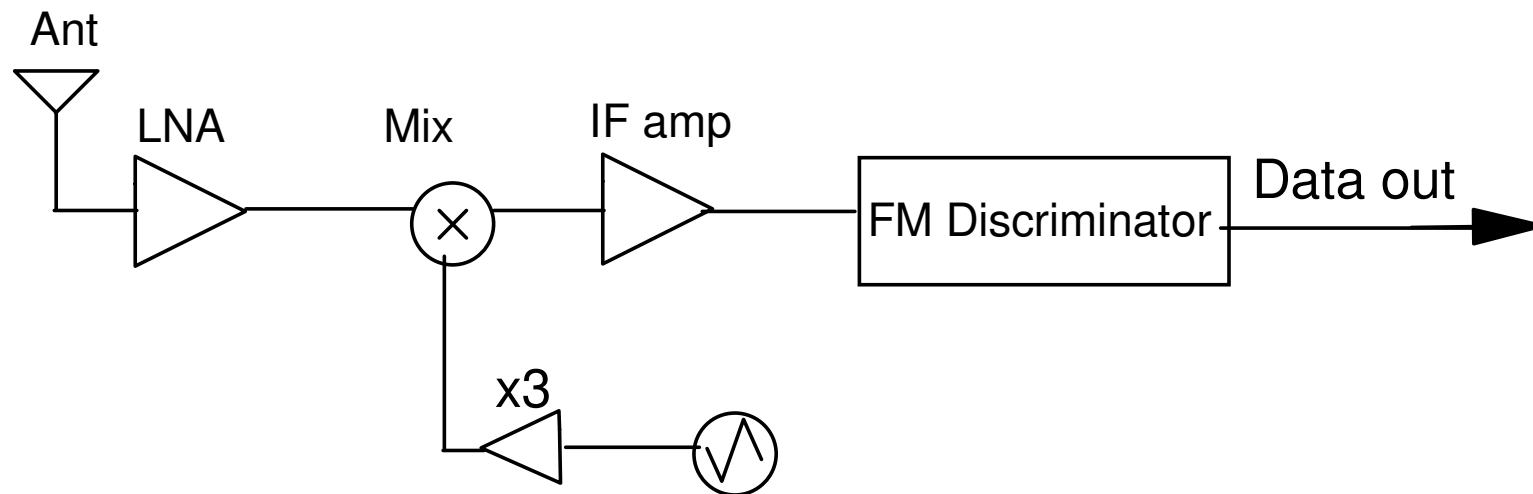
- **Better spectral efficiency than OOK and BPSK**
- **High RX efficiency in terms of mW/bit:**
  - Power of FM discriminator + CDR: tens of mWatts
  - Power of Multi-GS/s ADC (I&Q) + DSP: 0.2-1Watt or higher
- **Obviates the need for receiver AGC and ADC.**
- **Lower TX complexity and possibility of using more efficient non-linear PA.**
- **Overall, excellent for “point-and-shoot” applications using portable devices: lower size, cost and power.**
- **Robustness in a short-range multi-path channel requires further investigation.**

## Latest 60GHz Transmitter with Modulator for MSK



- MSK baseband signal can be generated without complex baseband processing.
- Simple hardware implementation without area or power consumption overhead.
- HW design has been completed, measurements will follow.

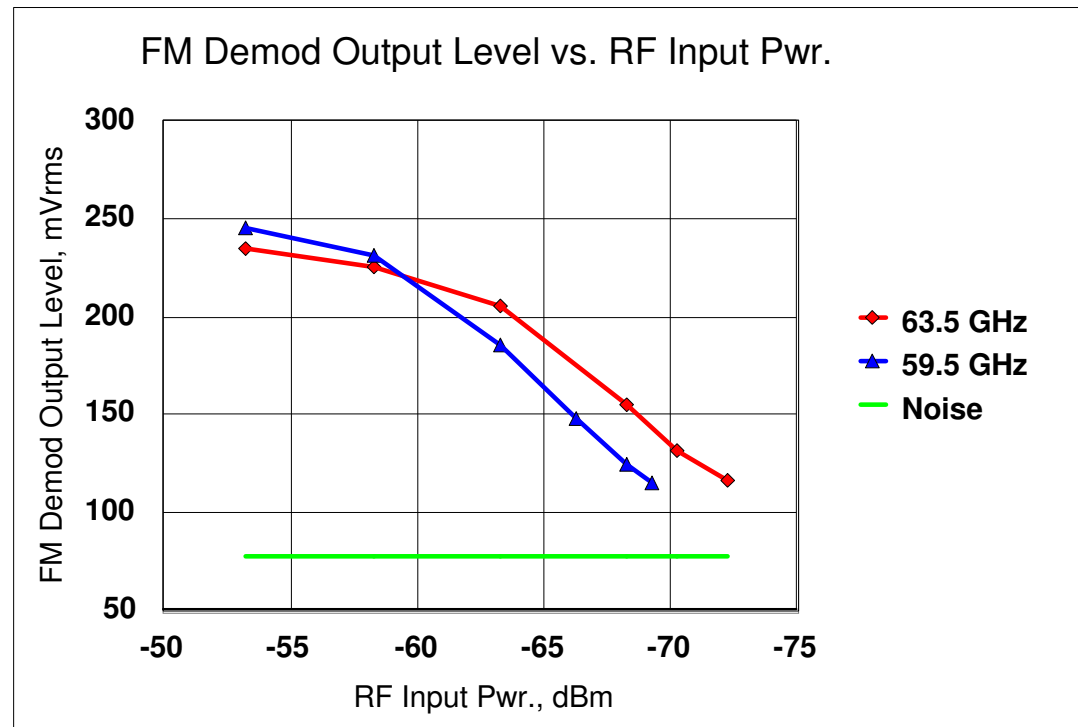
## Latest 60GHz Receiver with On-Chip AM/FM Demodulators



- FM/FSK limiter-discriminator output muxed into baseband output.
- Increases versatility of chipset by eliminating the need for an ADC and digital baseband for non-coherent modulations (FSK/PSK, MSK, etc.).
- Preliminary measurement results available.

## Receiver FM Demodulator Measurements

- For initial testing, a tone with 1-GHz frequency deviation was produced by beating together RF tones at 59 and 60 GHz, with one tone  $\approx 10$ -dB lower in amplitude than the other.
- Limiter rejects AM portion of signal.
- The combined input signal was attenuated until the demodulated 1 GHz sine wave disappeared into the noise floor at  $\approx -68$  dBm.
- Testing with real modulated signals pending.





# Mod/Demod Transistor-level Simulation Results

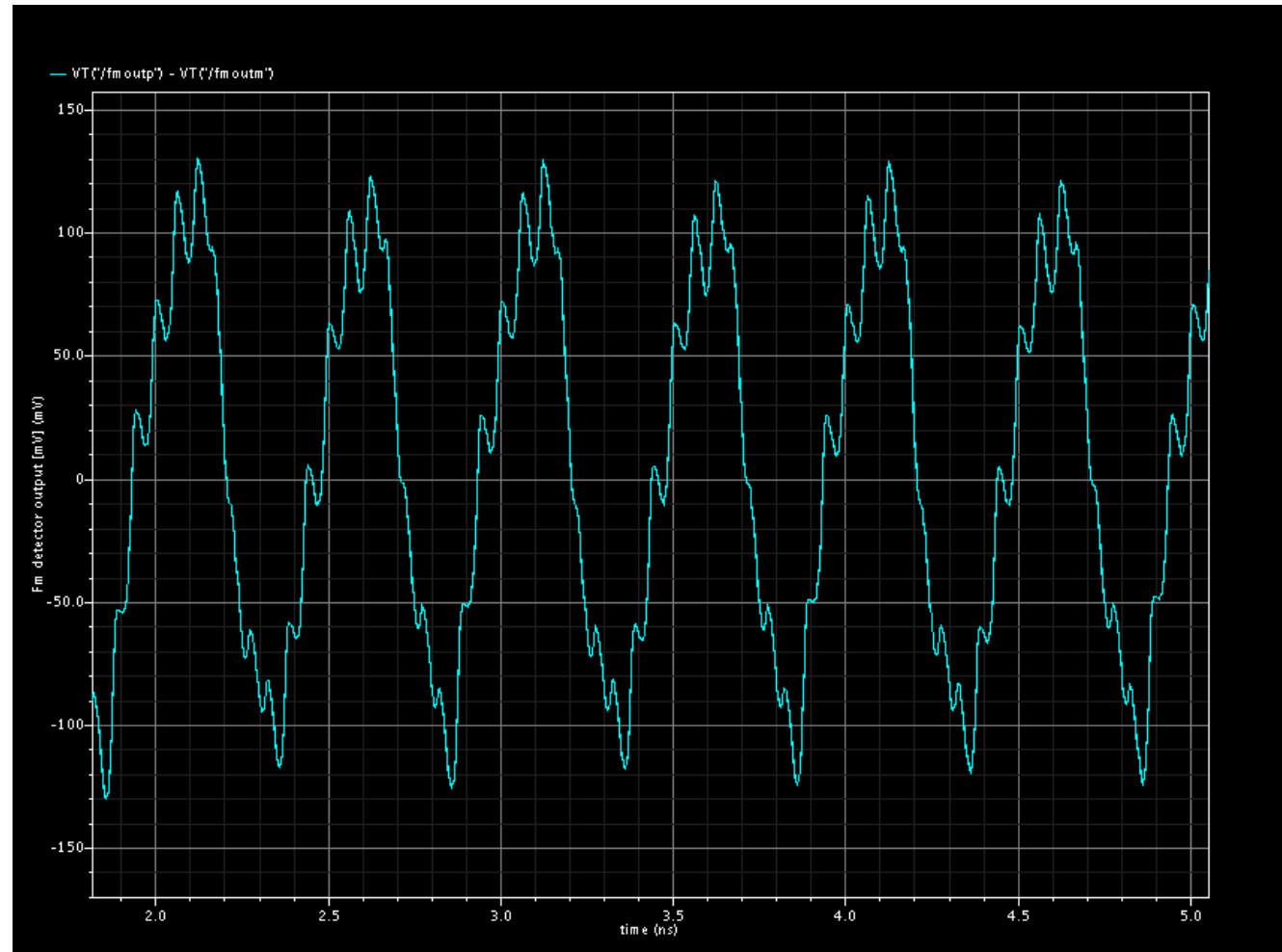
9GHz, constant-  
envelope modulated  
signal

I@Q Switching  
Signals (4Gb/s)



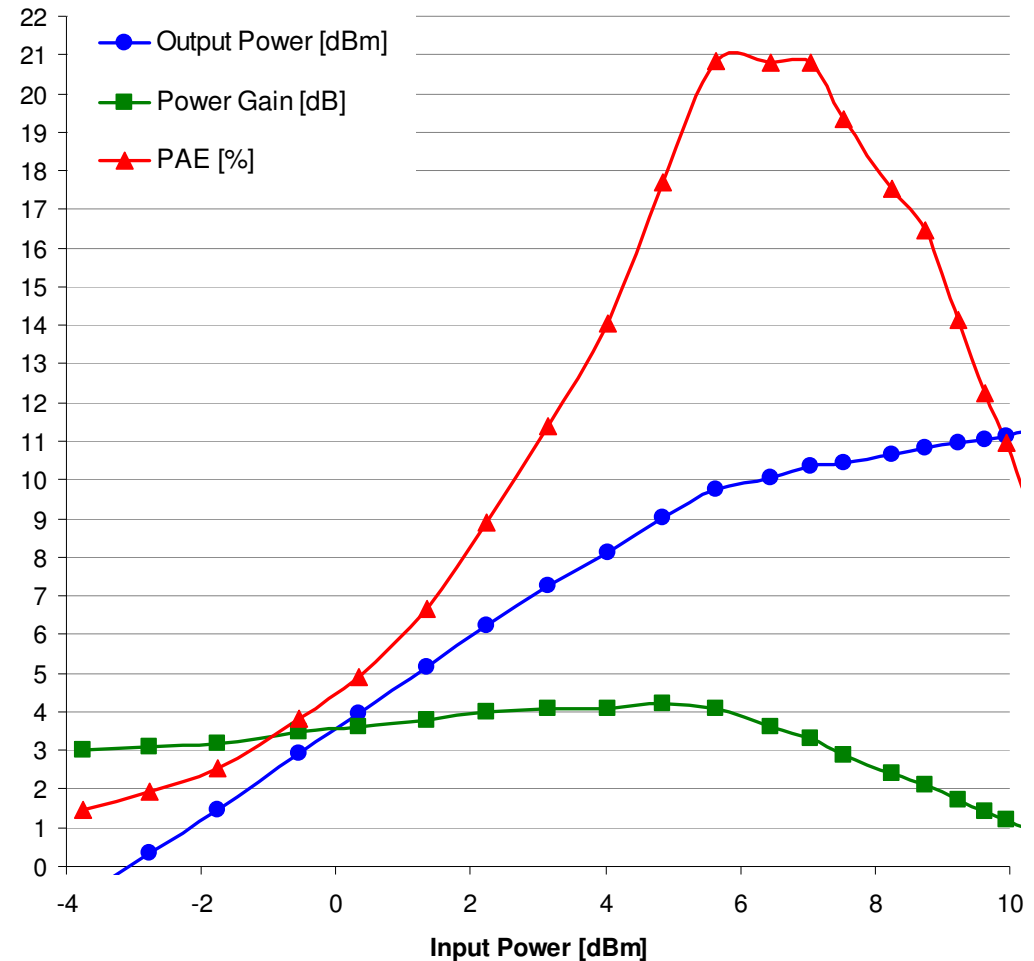
# Mod/Demod Transistor-level Simulation Results

Receiver FM  
detector output  
4Gb/s



# Efficient Switching-Mode MMW PA

- Constant-envelope modulation system may use switching-mode PAs for power reduction.
- An experimental mmWave class-E PA has been demonstrated in SiGe 8HP technology.
- Peak PAE > 15% has been measured from 55 to 62GHz
- Record efficiency at mmWave frequencies in Silicon has been achieved.



Measured performance @ 58GHz

## Summary

- **An MSK-based system for multi-GB/s comm. at 60GHz presents significant advantages (i.e. lower complexity and power consumption) in a directional channel.**
- **Simulation results support the feasibility of such system and indicate that up to 4GB/s may be possible in SiGe 8HP technology.**
- **FSK detector has been characterized in 60GHz RX.**
- **MSK modulator has been characterized in simulations.**
- **A MMW switching-mode PA for constant envelope modulation has proven to be feasible.**
- **Full TX and RX with MSK mod/demod have been fabricated, characterization is in progress.**