# Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

**Submission Title:** [An MSK system for Mobile Multi-Gb/s at 60GHz, concept, application and implementation]

**Date Submitted:** [17 September, 2006]

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**Re:** [Request of contributions for the 802.15.3c subgroup

**Abstract:** [Design considerations and preliminary results of an MSK-based system for Multi-GB/s communications at 60GHz over a band limited directional channel, suitable for 'MAC-less' systems, MP3 player/HD synchronization applications…]

**Purpose:** [For discussion only]

# Outline

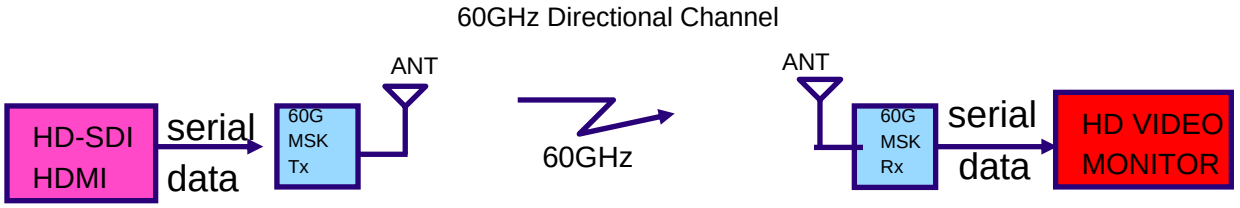
- Applications for a 60GHz directional channel.
- Principles of MSK modulation.
- Performance and effects of band limitation.
- Integrated MSK modulator and measurement results.
- Summary.

# Tiered standard needed:

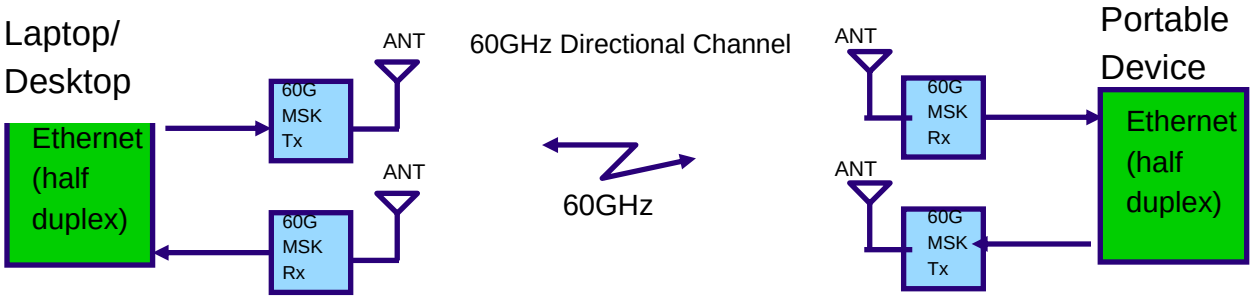
- **'Simple' multi-Gbps portable applications require low complexity, low power, low cost solutions: e.g. Directional, single carrier link**
  - Kiosk applications
  - Synchronization (MP3 Players, HDs, iPODs…)
  - Point-point links (Campus, HDMI…)
- **'More complex' multi-Gbps less portable applications can afford higher complexity, power and cost solutions: e.g. Omni-directional, multi-carrier network**
  - WPAN
  - High definition video system network

# Ex. Applications for 60GHz Systems

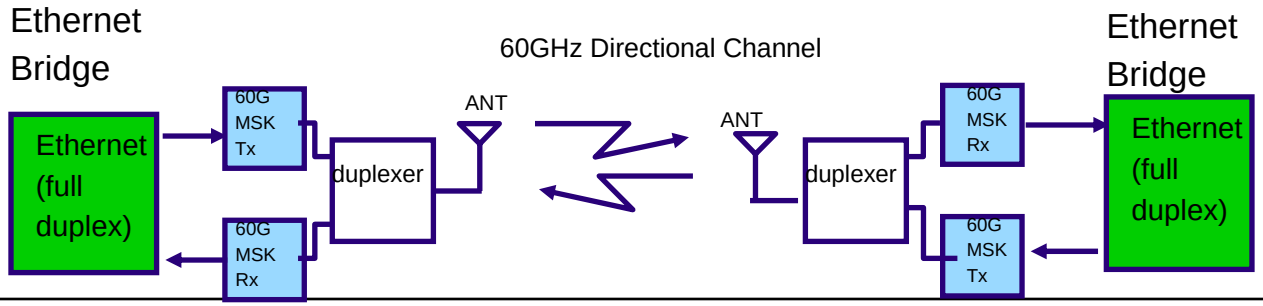
**No-MAC Wireless Point-to-Point Cable : e.g. One-way uncompressed video, Kiosk, MP3 Player or HD sync…**




**e.g. Half-Duplex Ethernet Mac for Wireless Point-to-Point 2Gb/s "Point and Shoot" Ethernet**




**e.g. Full-Duplex Ethernet Mac for 1Gb/s Wireless Point-to-Point Ethernet Bridges**



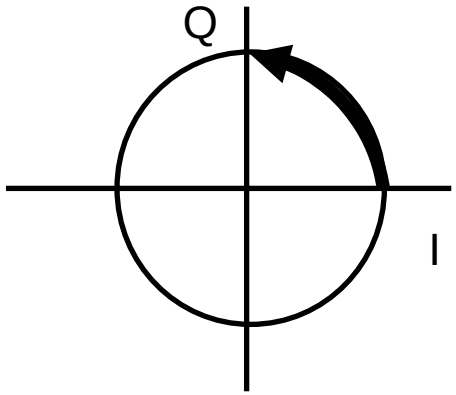
# MSK Modulation Overview

MSK can be described as phase-continuous 2-level FM with deviation = R/4 where R = data rate.

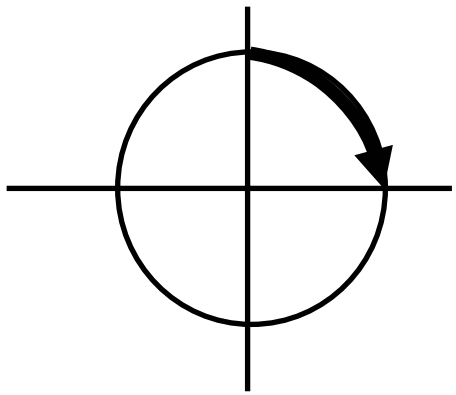
The frequency is allowed to change polarity on quadrant boundaries only.

MSK data encoding :

1 bit : freq = +R/4




0 bit : freq = -R/4



Frequency changes at phase= 0, pi/2, pi, and 3pi/2 radians only

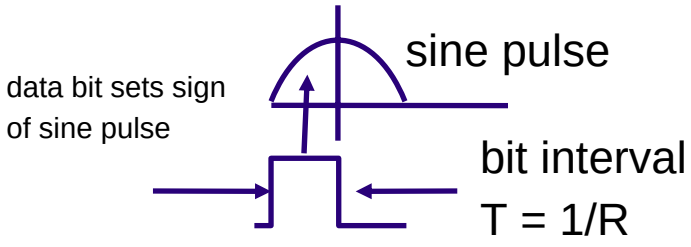
# Example MSK Generation

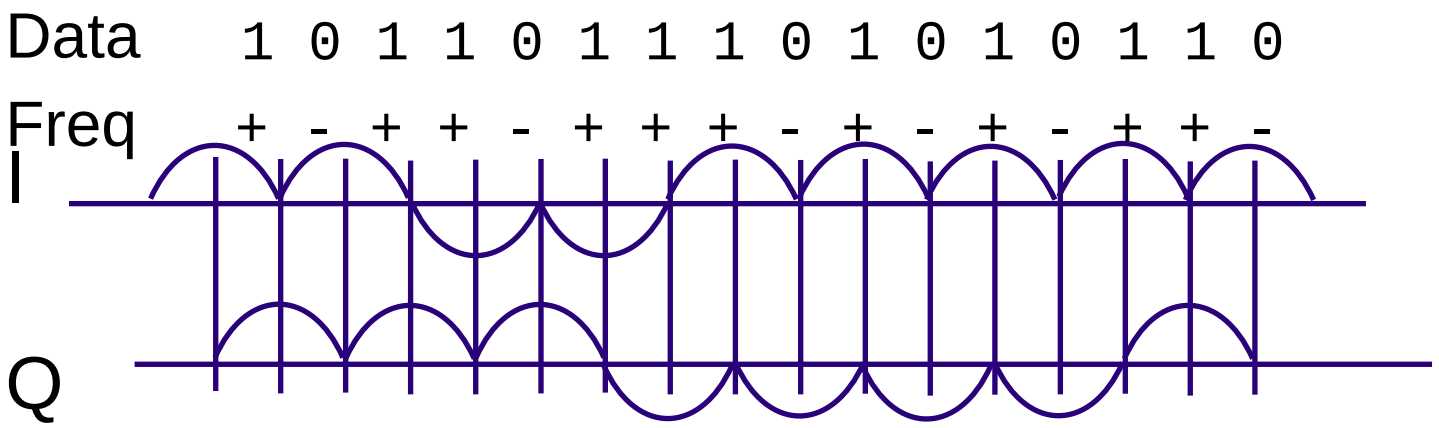
MSK can be generated by modulating the signs of half-sine pulses separated by 90 degrees on I and Q axes.

A sine pulse sign is encoded with a data bit corresponding to the first half of the pulse in time duration.

To encode + Frequency (1) data bit value :
- on Q pulse : Q pulse sign = I pulse sign over bit interval
- on I pulse : I pulse sign = opposite of Q pulse sign over bit interval

To encode - Frequency (0) data bit value :
- on Q pulse : Q pulse sign = opposite of I pulse sign
- on I pulse : I pulse sign = Q pulse sign

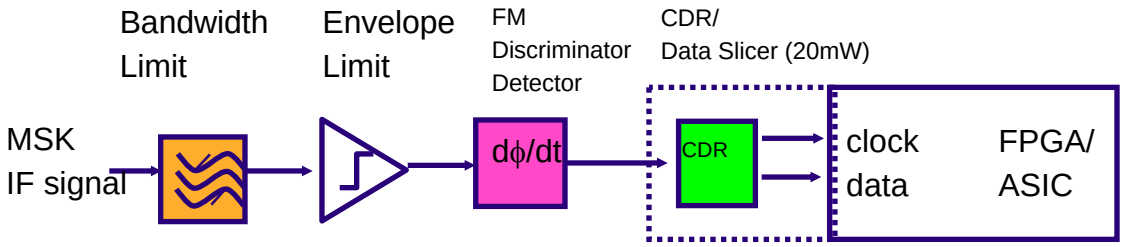


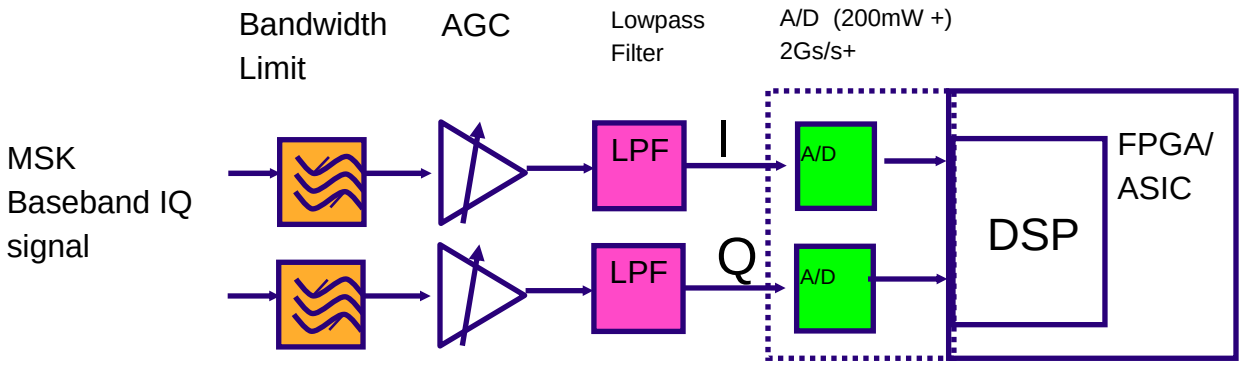
# MSK Demodulation

MSK can be demodulated using a FM limiter/discriminator + CDR for low power/low complexity, or with conventional A/D + DSP for higher power/higher complexity and better sensitivity.

FM Discriminator/CDR approach :

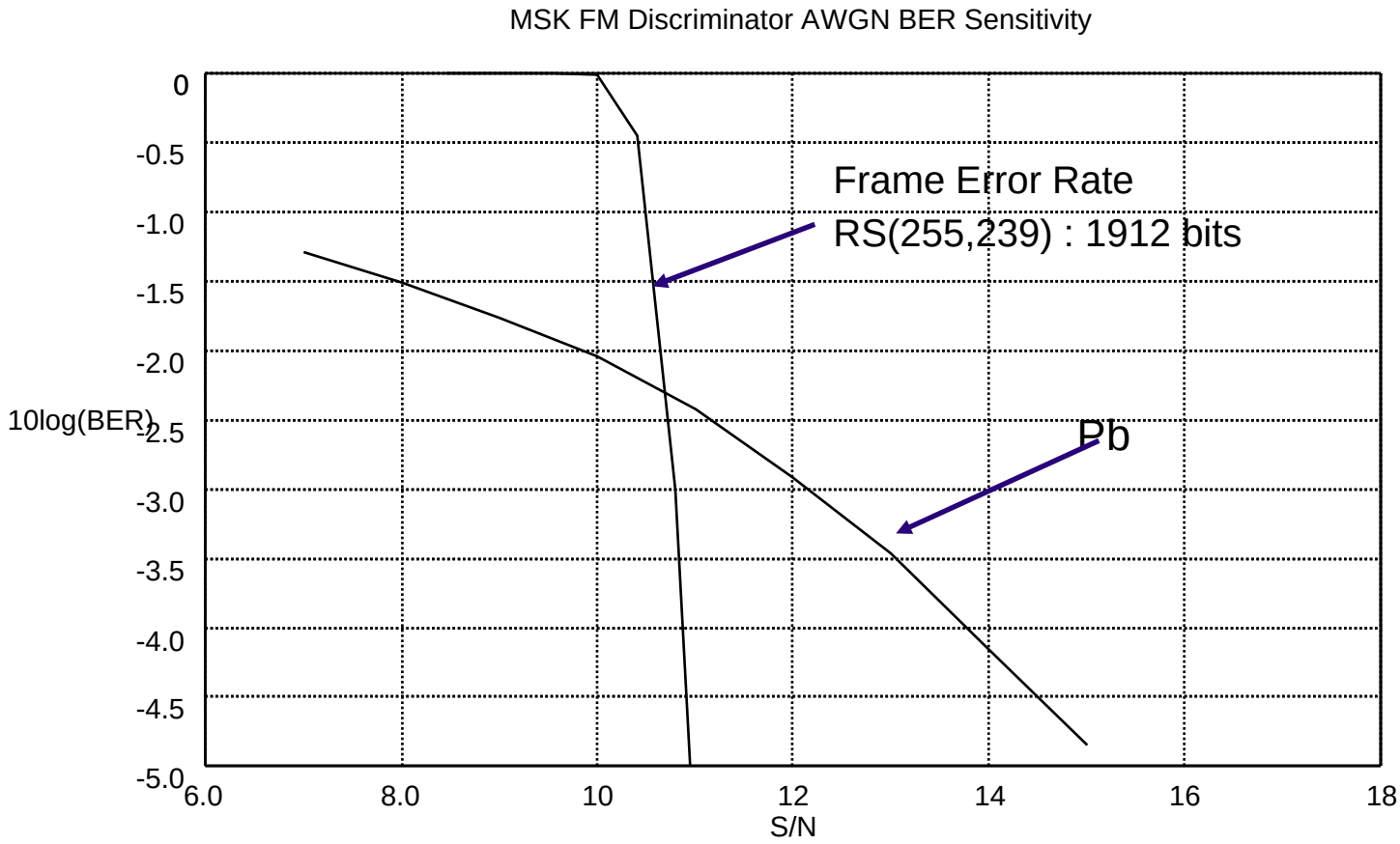



A/D + DSP approach (~3dB better sensitivity; can also add channel equalization)

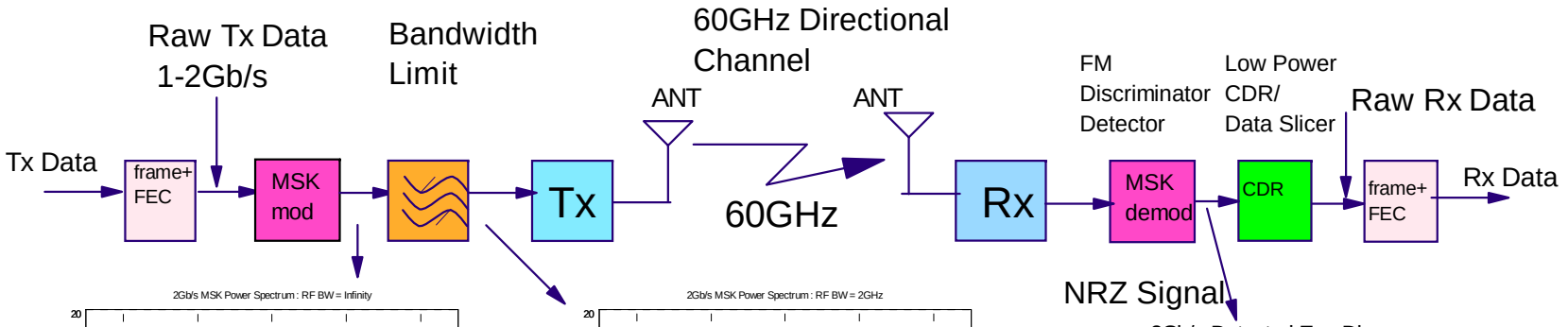


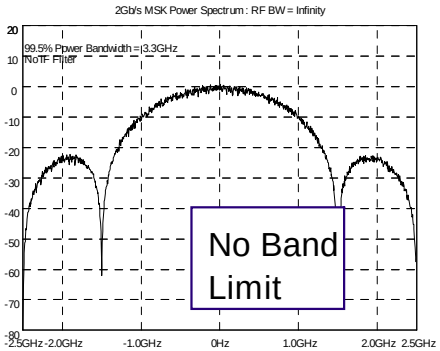
# MSK AWGN Sensitivity

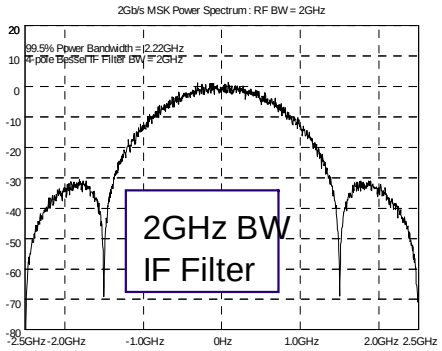
FM limiter/Discriminator Pb is shown below: 15dB SNR is needed for low error rate (1e-5) operation. The addition of a RS(255,239) code improves sensitivity to ~11dB SNR for length 1912 bit payload.

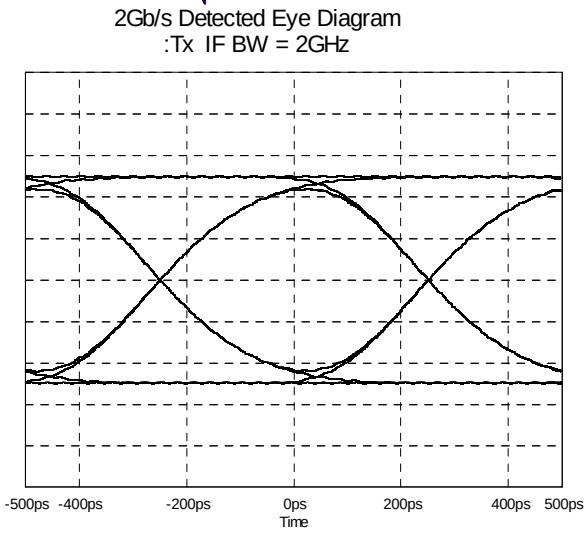


# 60GHz Bandwidth Limited MSK Modulation System (Simulation)



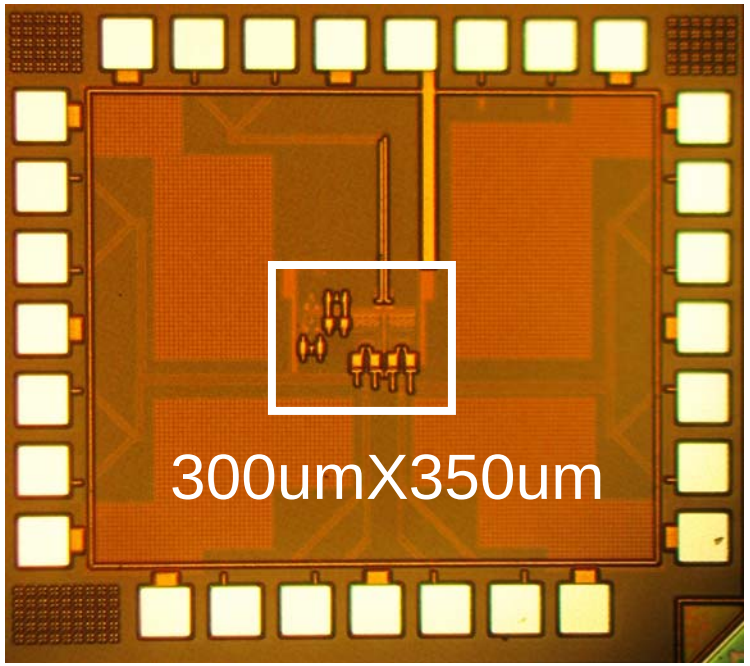




| Data Rate | 3dB IF BW[1] | 1st Sidelobe | 99.5% BW |
|---|---|---|---|
| 1Gb/s | infinity | -23dB | 1.6 GHz |
| 1Gb/s | 1GHz[2] | -30dB | 1.1 GHz |
| 2Gb/s | infinity | -23dB | 3.3 GHz |
| 2Gb/s | 2GHz | -30dB | 2.2 GHz |

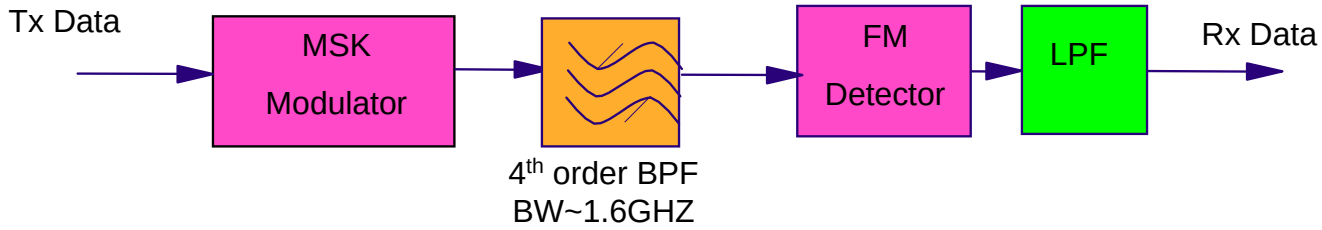
# Integrated MSK Modulator

- **The prototype IC incorporates:**
  - MSK modulator
  - IF up-conversion mixer
  - Active IF filter.
- **Designed to support multi-Gbps data rates**
- **Compact implementation for 60GHz transmitter**

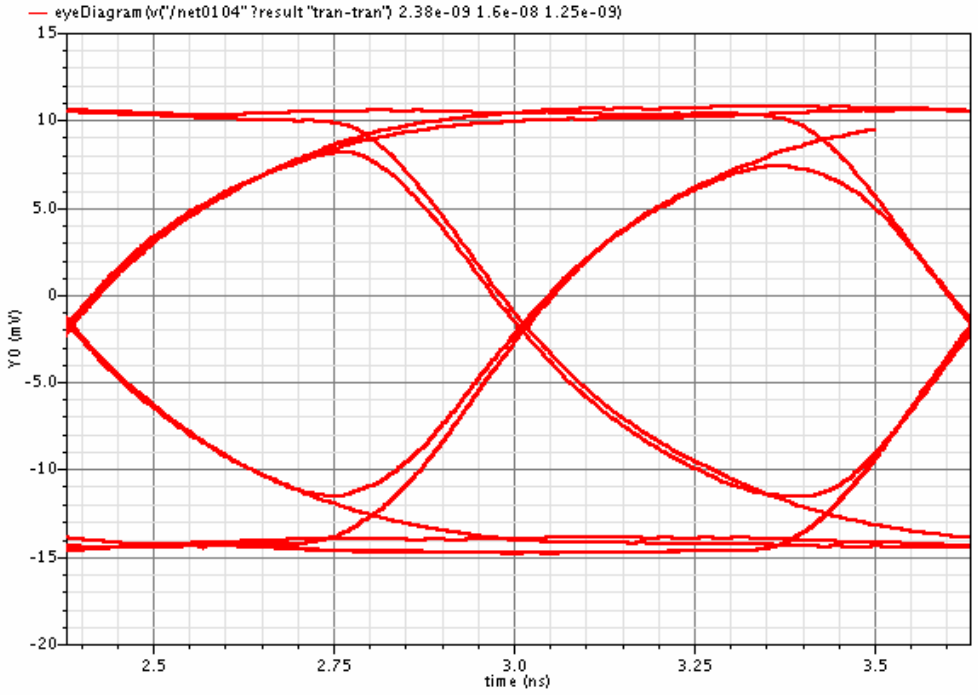


# MSK system transistor-level simulation

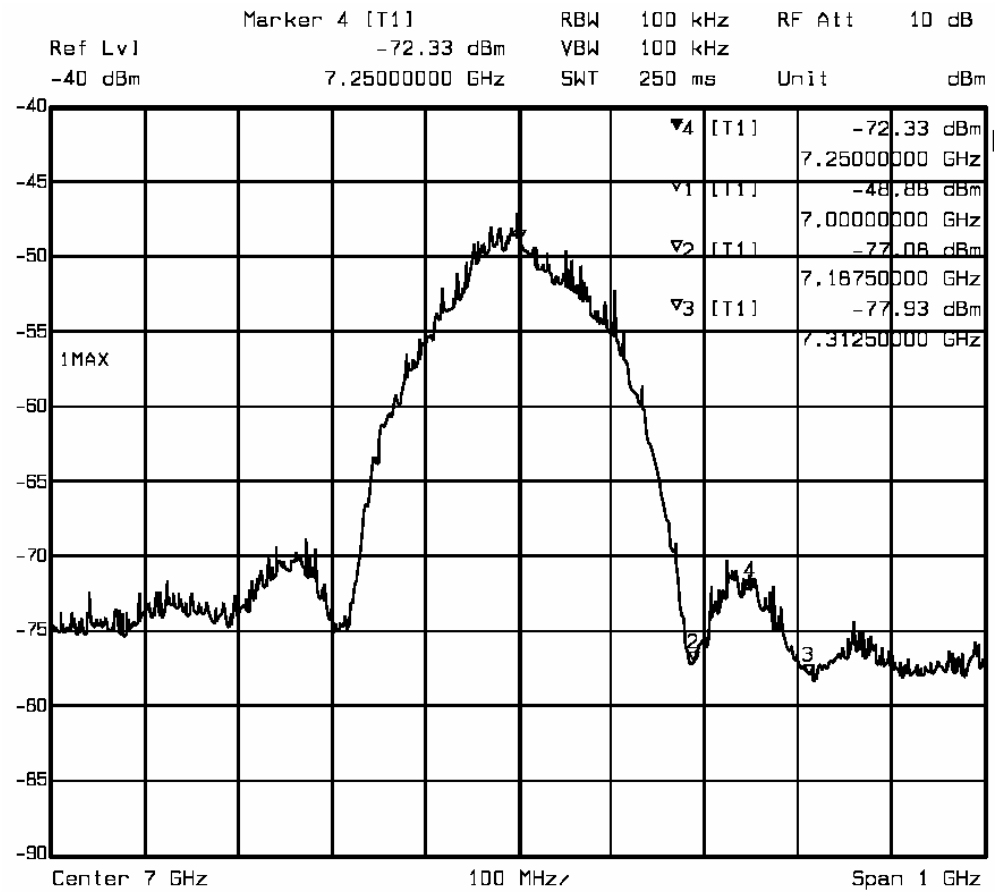
- **Setup includes cascaded TX/RX transistor-level IF bandpass filters**




- **1.6Gb/s eye diagram**
- **Data rate suitable for HDMI**



# MSK modulator measurement results




- First test results at moderate speeds confirm proof of concept.
- 250MB/s IF (7GHz) MSK spectrum in good agreement with theory.
- IF filter BW ~2GHz, side-lobe suppression is due to modulation only.

# 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.**
- **An FSK detector has been characterized in 60GHz RX.**
- **An integrated MSK modulator has been demonstrated.**
- **A full TX and RX with MSK mod/demod have been fabricated, characterization for a high data rate link will follow.**
- **This work supports the lower power, lower complexity, lower cost directional link systems.**

Appreciation to DARPA for partial funding N66001-05-C-8013