

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]

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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]

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Outline

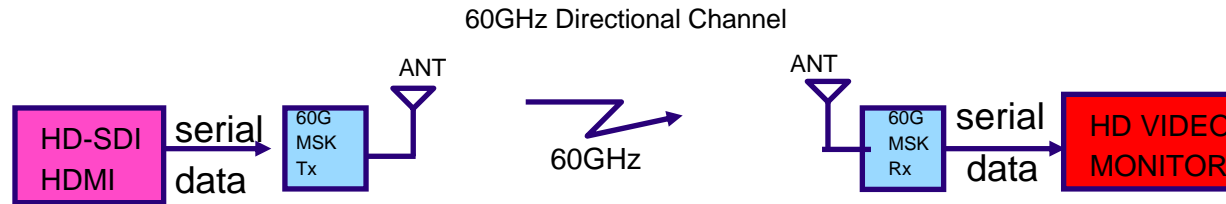
- **Applications for a 60GHz directional channel.**
- **Principles of MSK modulation.**
- **Performance and effects of band limitation.**
- **Integrated MSK modulator and measurement results.**
- **Summary.**

Tiered standard needed:

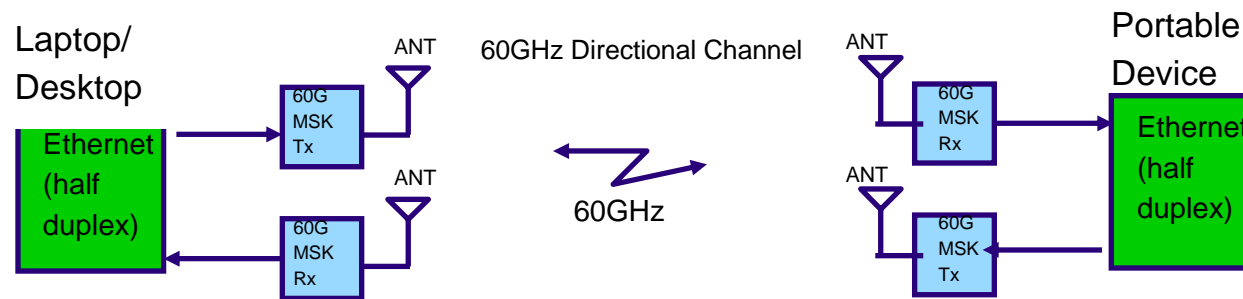
- **‘Simple’ multi-Gbps portable applications require low complexity, low power, low cost solutions: e.g. Directional, single carrier link**
 - Kiosk applications
 - Synchronization (MP3 Players, HDs, iPODs...)
 - Point-point links (Campus, HDMI...)
- **‘More complex’ multi-Gbps less portable applications 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

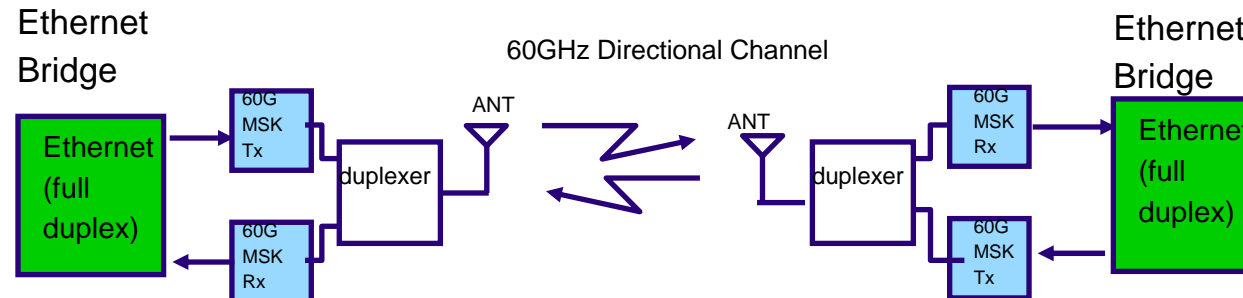
No-MAC Wireless Point-to-Point Cable : e.g. One-way uncompressed video, Kiosk, MP3 Player or HD sync...



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



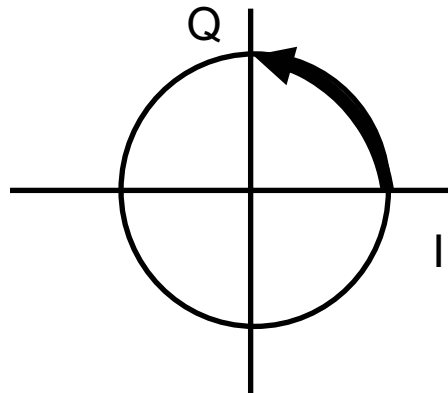
MSK Modulation Overview

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

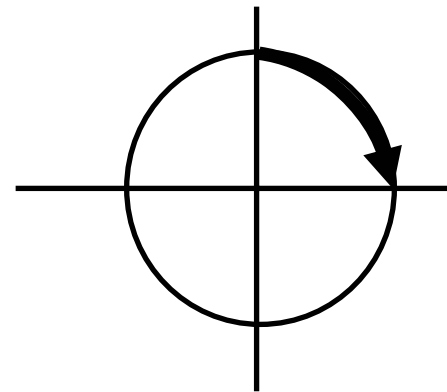
The frequency is allowed to change polarity on quadrant boundaries only.

MSK data encoding :

1 bit : freq = $+R/4$



0 bit : freq = $-R/4$



Frequency changes at phase= 0, $\pi/2$, π , and $3\pi/2$ 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.

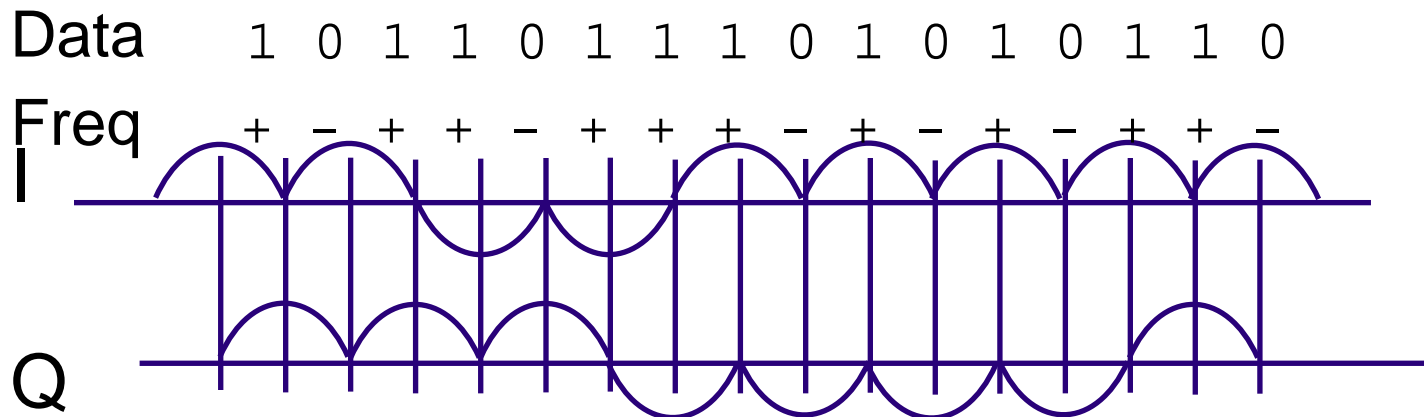
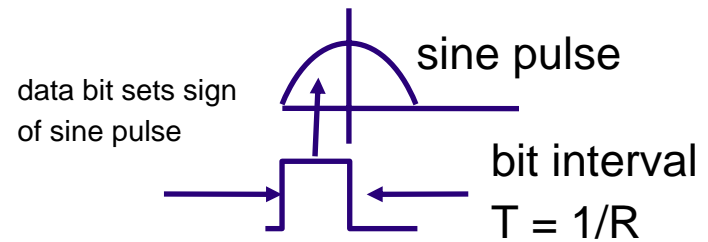
A sine pulse sign is encoded with a data bit corresponding to the first half of the pulse in time duration.

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 :

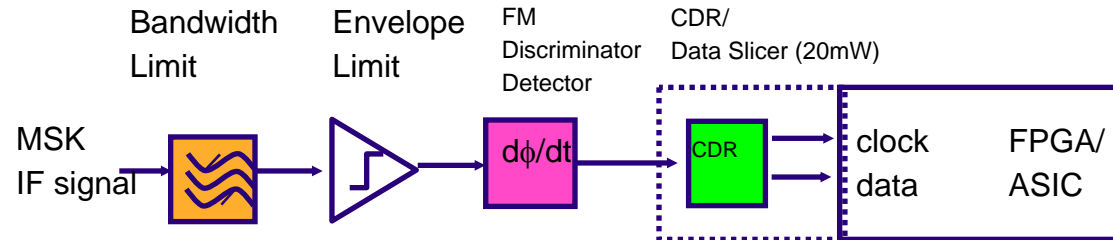
- on Q pulse : Q pulse sign = opposite of I pulse sign
- on I pulse : I pulse sign = Q pulse sign



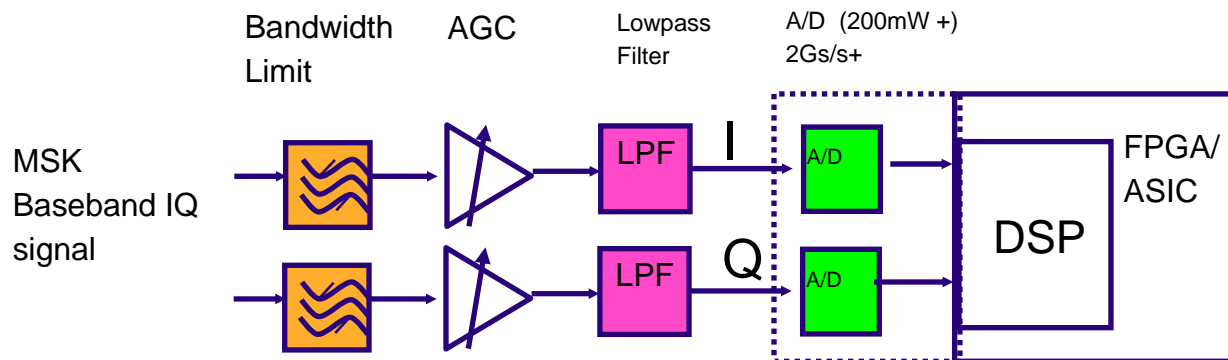
MSK Demodulation

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 :



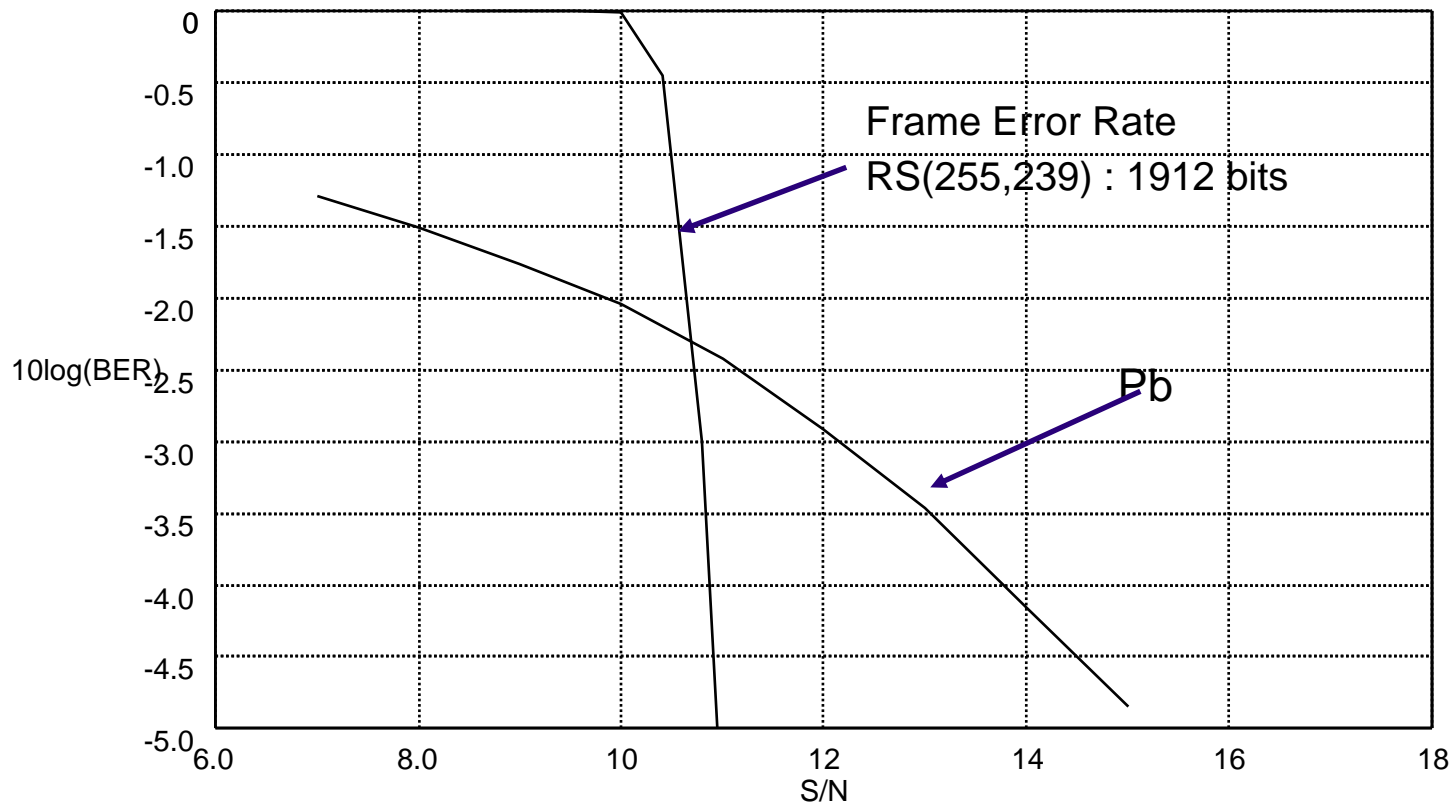
A/D + DSP approach (~3dB better sensitivity; can also add channel equalization)



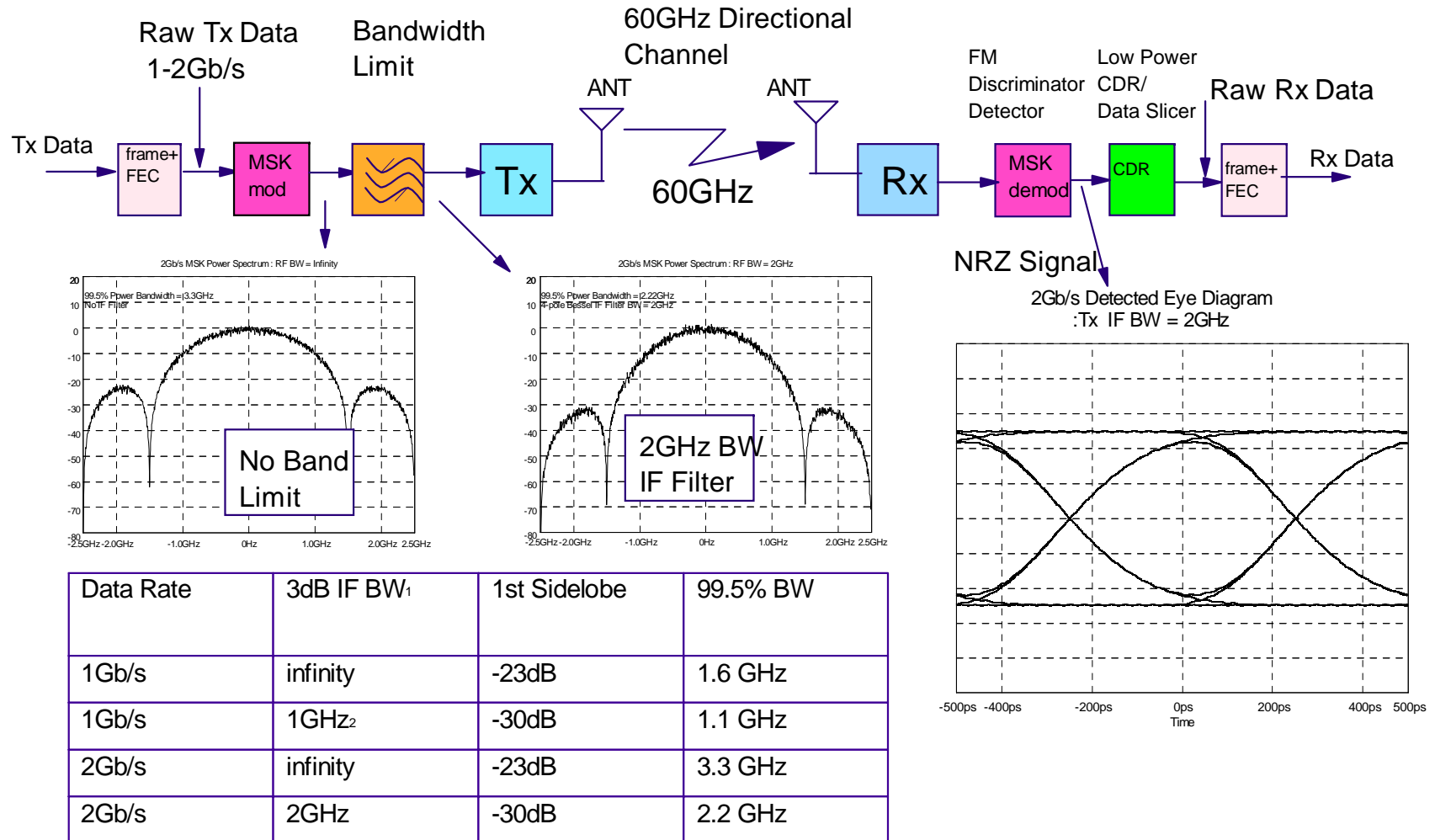
MSK AWGN Sensitivity

FM limiter/Discriminator P_b 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.

MSK FM Discriminator AWGN BER Sensitivity

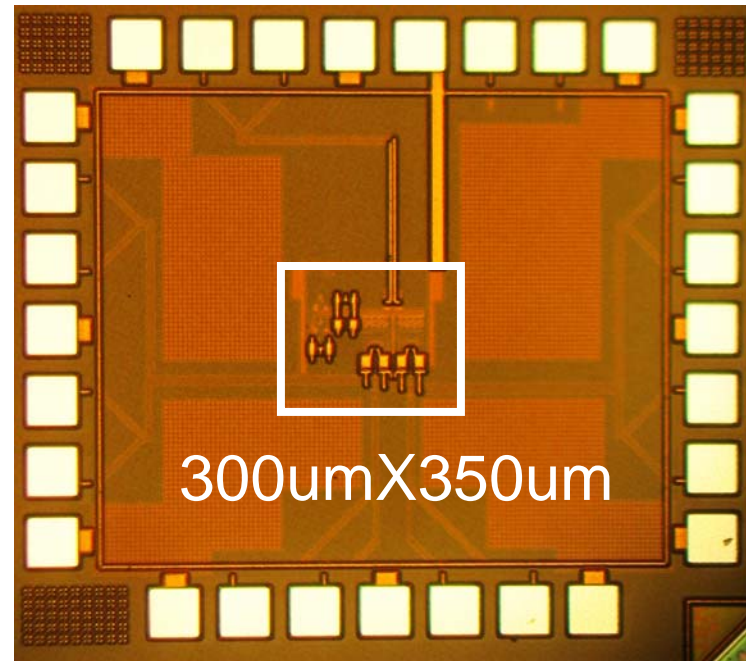


60GHz Bandwidth Limited MSK Modulation System (Simulation)

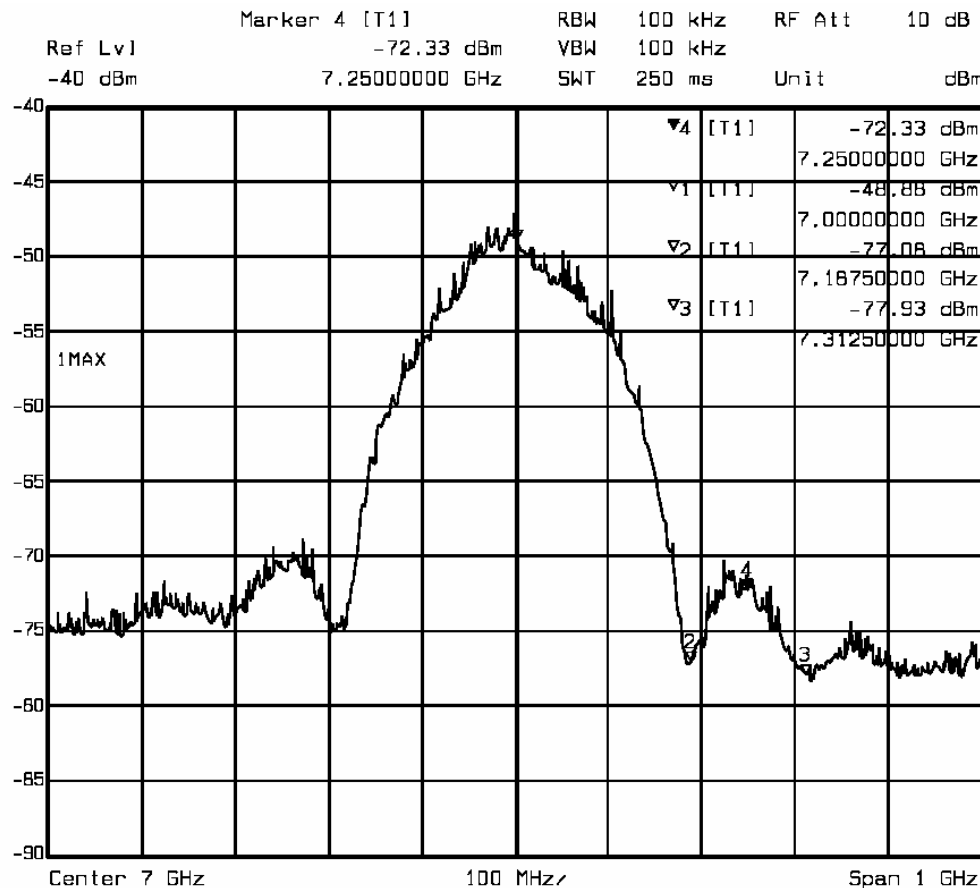


Integrated MSK Modulator

- **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 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.**