A 300GHz Wireless Transceiver in 65nm CMOS for IEEE802.15.3d Using Push-Push Subharmonic Mixer

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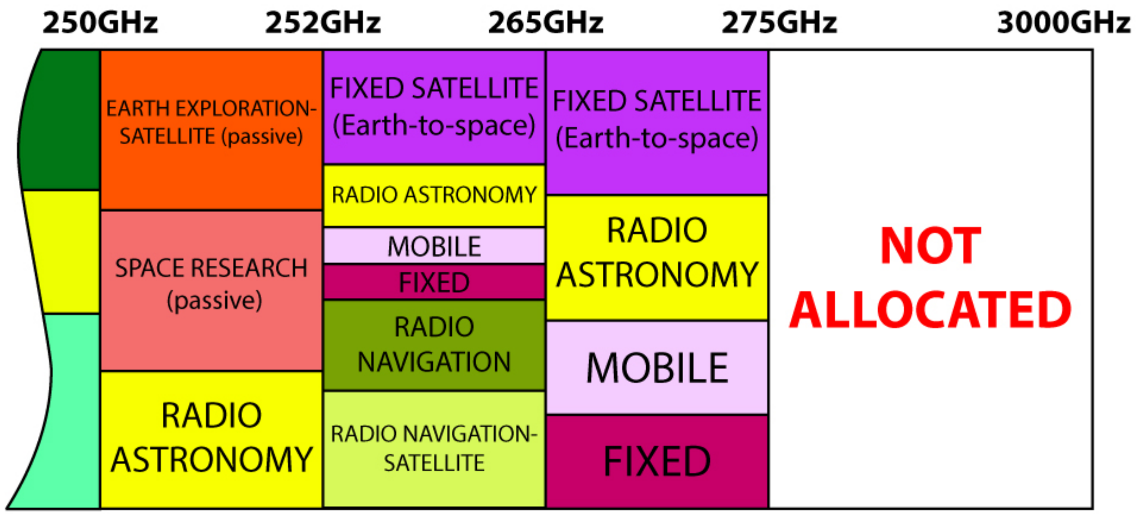
Outline

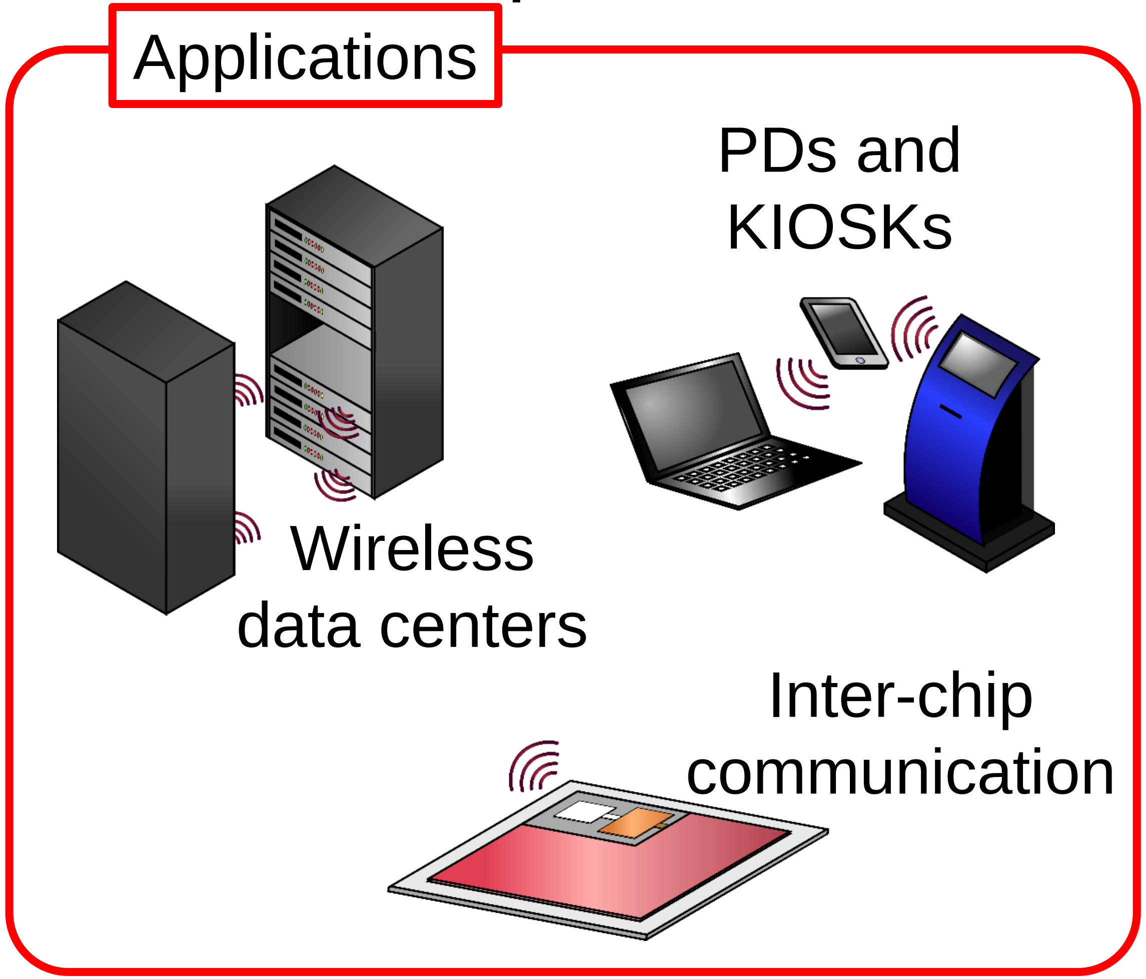
- Introduction
- Proposed 300GHz CMOS TRX
- Push-Push Subharmonic Mixer
- Fundamental Blocking Tripler
- Measurement Results
- Performance Comparison
- Conclusion

Motivation for 300GHz Communication

- Wide available bandwidth at an unallocated spectrum

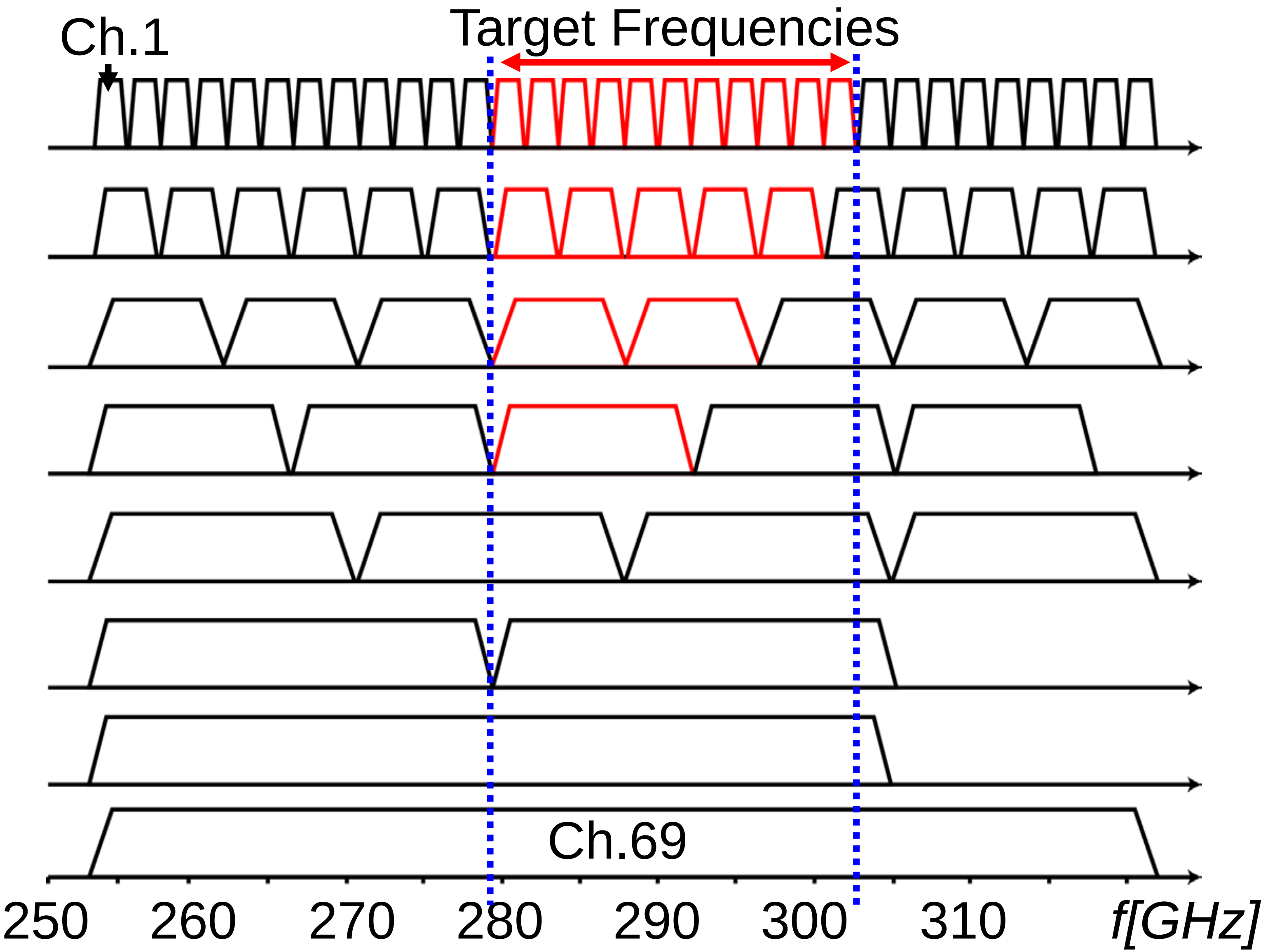


FCC Online Table of Frequency Allocations, Mar. 2020



IEEE 802.15.3d

- 69 channels
- Target channels:
  - –Ch.13-23 (2.16GHz)
  - –Ch.39-43 (4.32GHz)
  - –Ch.52-53 (8.64GHz)
  - –Ch.59 (12.96GHz)



The Main Challenge

- f_{max} of CMOS processes < 300GHz
  - –PA and LNA are not feasible
  - –Lower achievable SNR

Solutions

Mixer-last-mixer-first with power combining:

☺ High output power

☹ Large area and P_{DC}

Mixer-last-mixer-first single-stream:

☺ Large area and P_{DC}

☹ Low output power

III-V semiconductors:

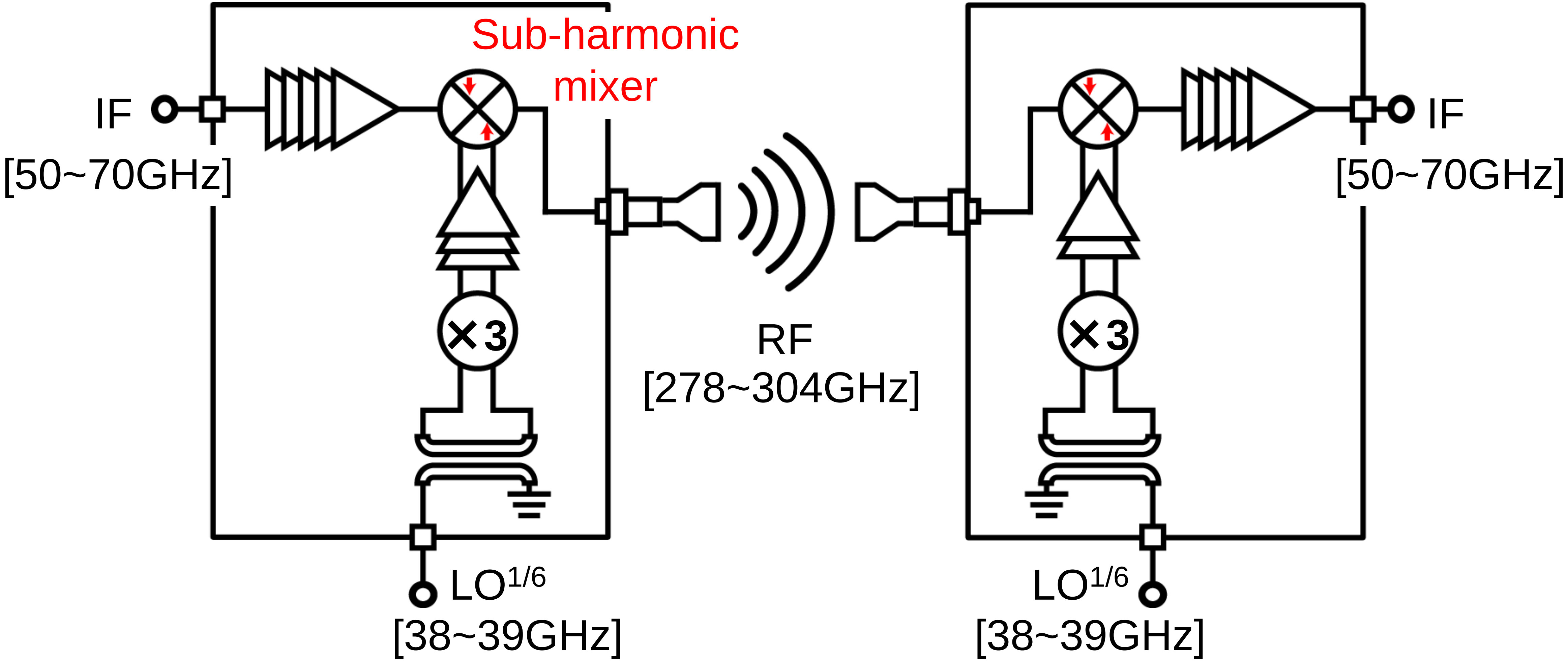
☺ High output power

☺ Good SNR

☹ Large area and P_{DC}

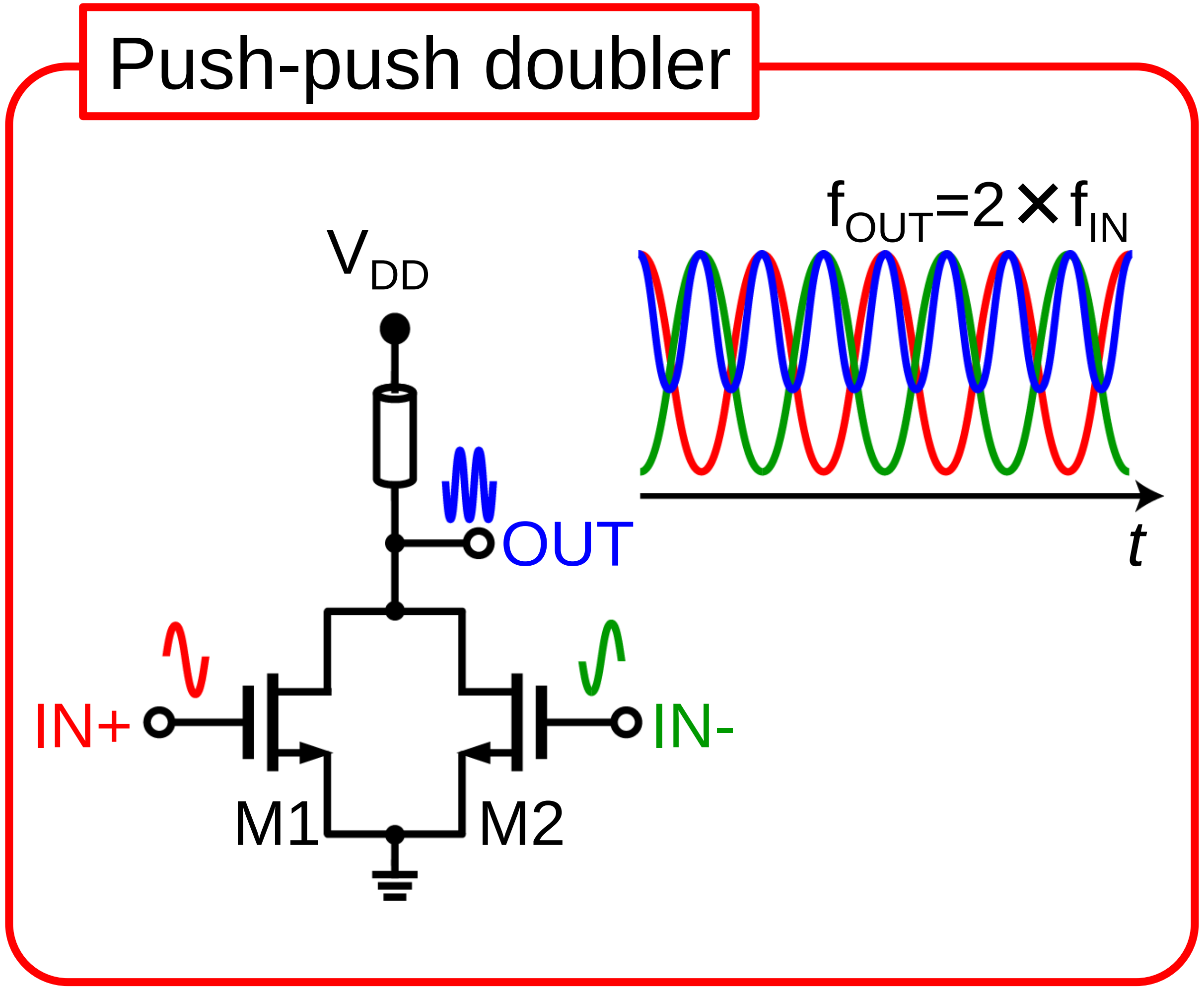
☹ Higher cost

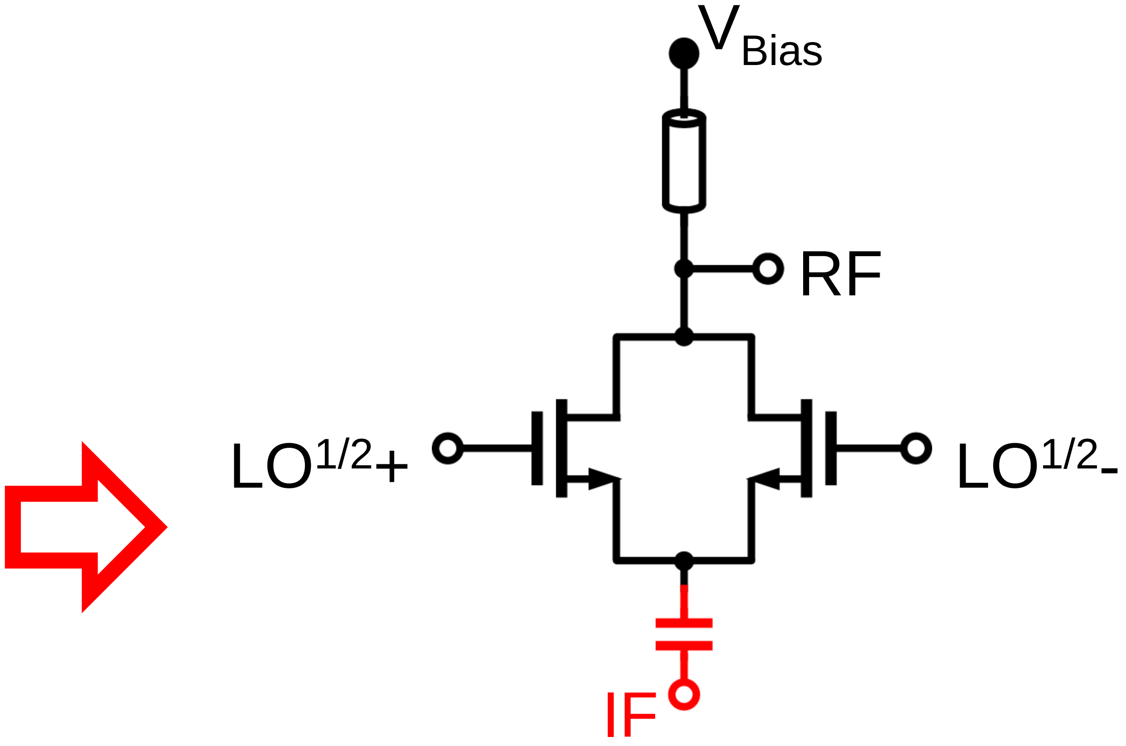
Proposed 300GHz CMOS TRX



High mixer conversion gain is required to overcome the absence of amps

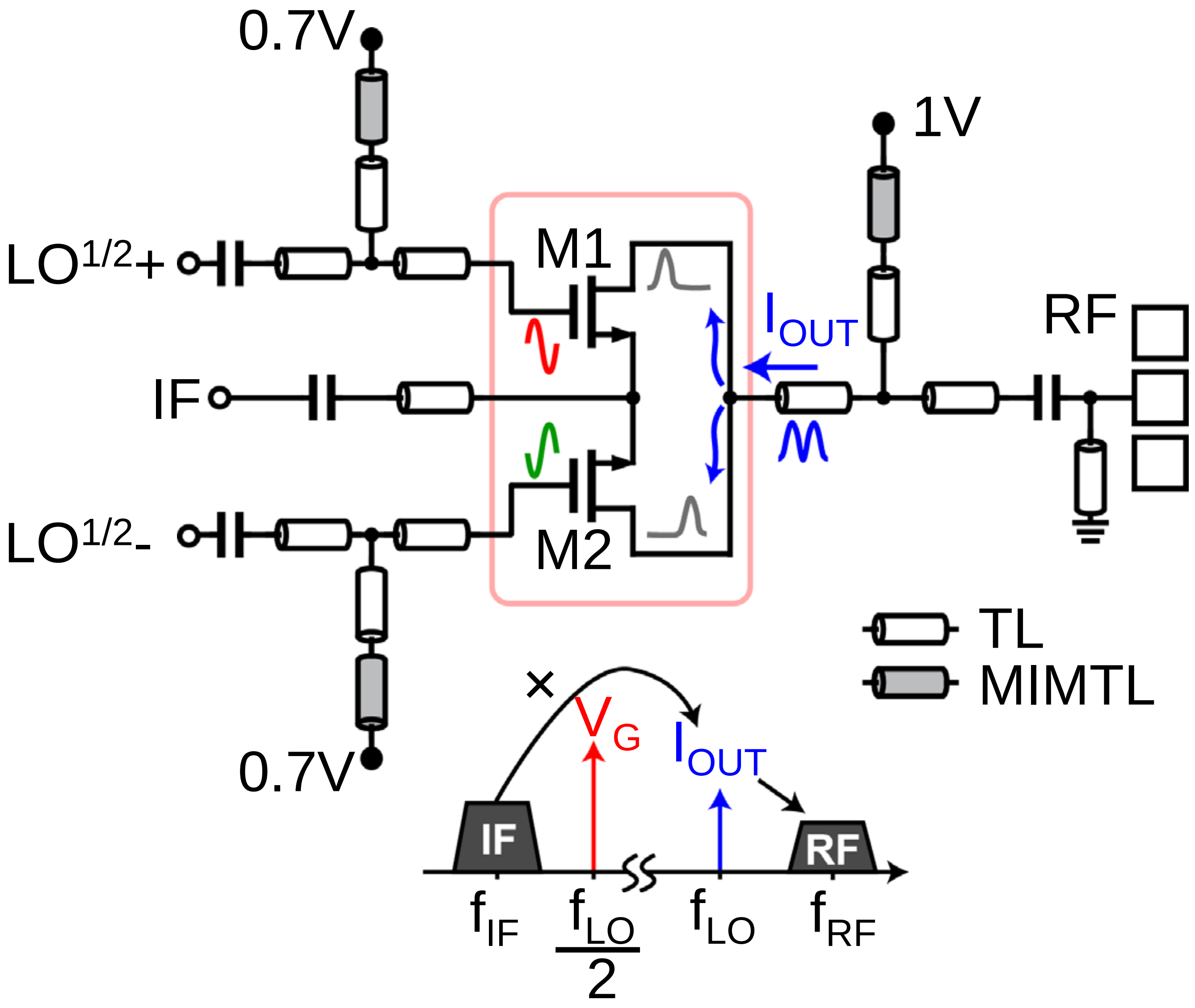
Push-Push Subharmonic Mixer

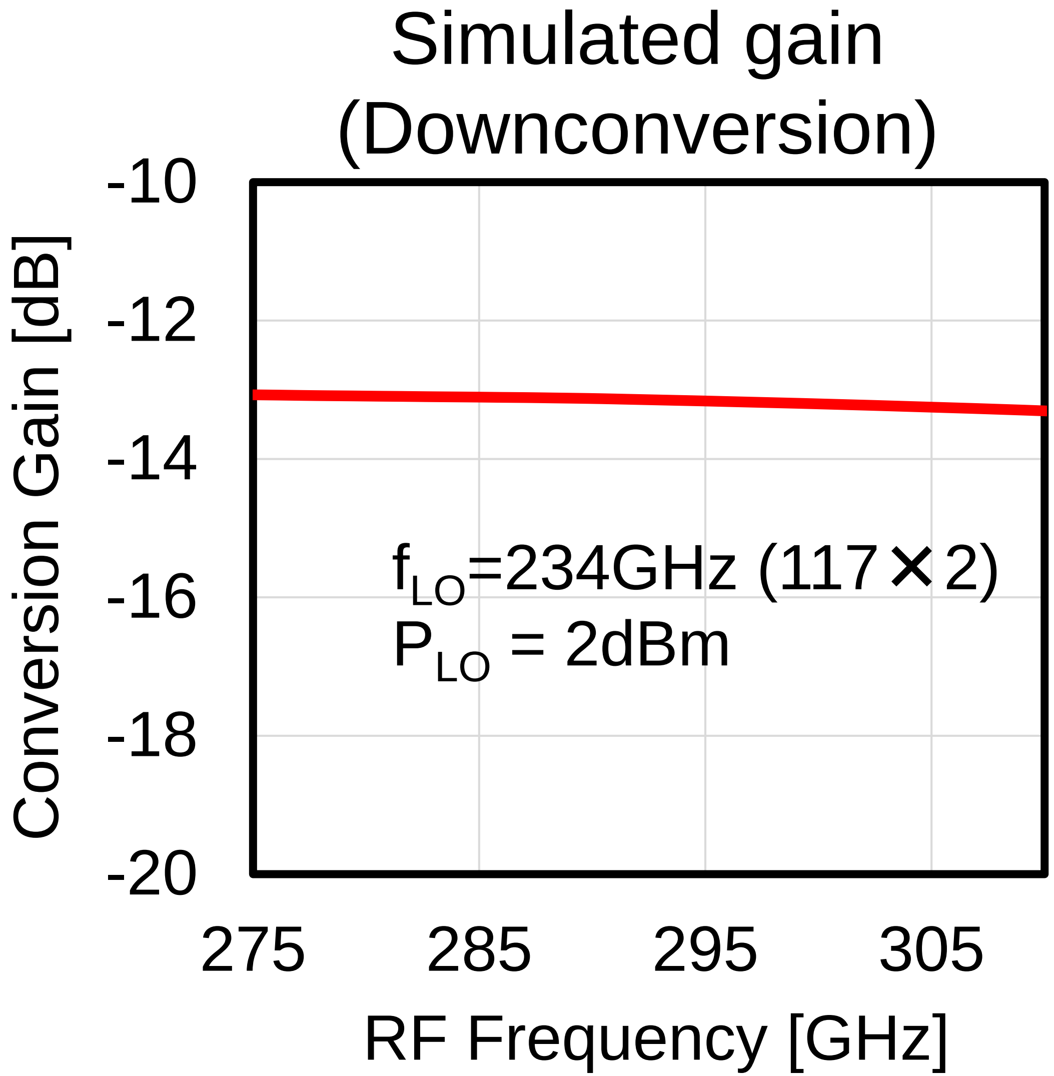




- ☺ Fundamental-like mixing
- ☺ Passive and single-ended
- ☹ High LO feedthrough

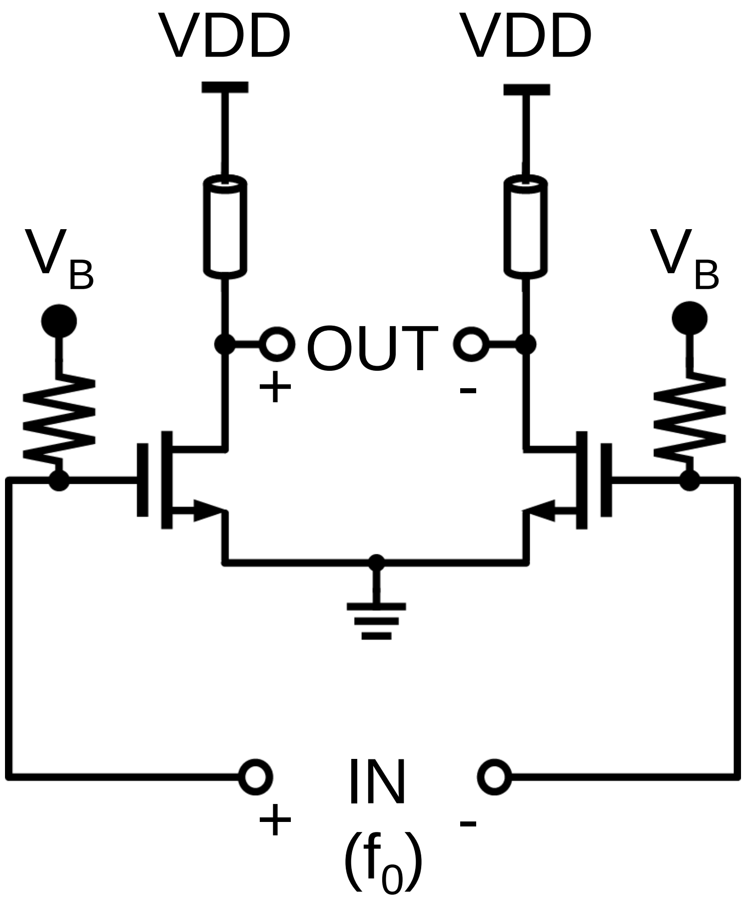
Push-Push Subharmonic Mixer

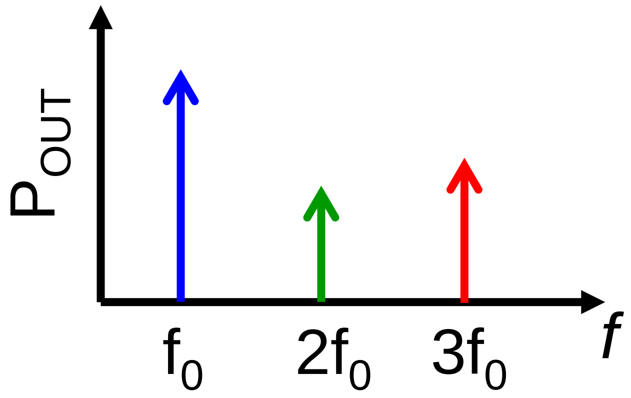




Fundamental Blocking Tripler

- Conventional design issues

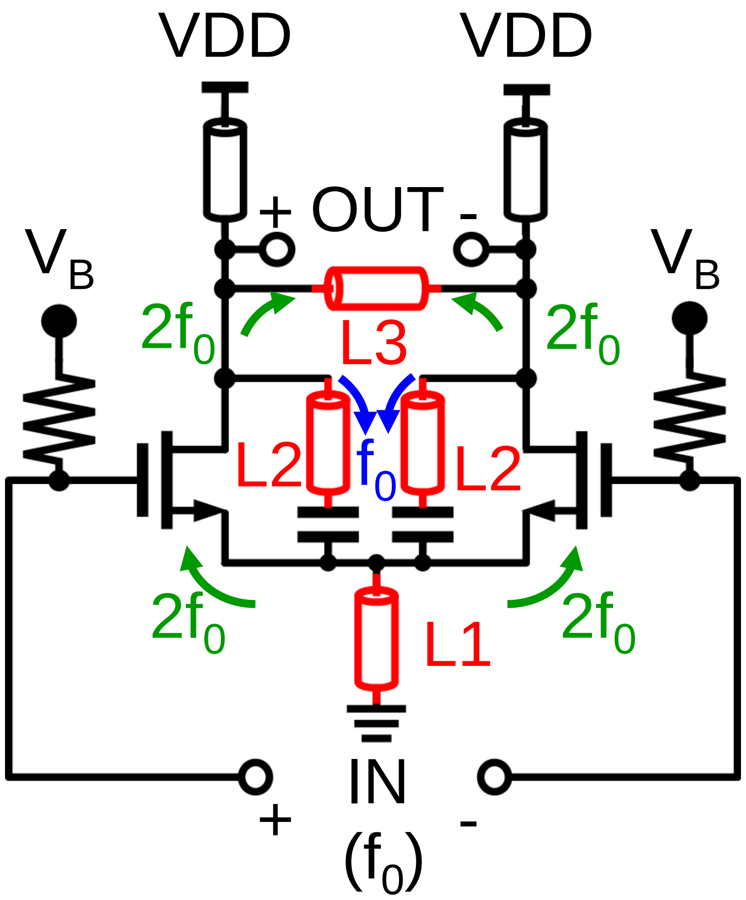




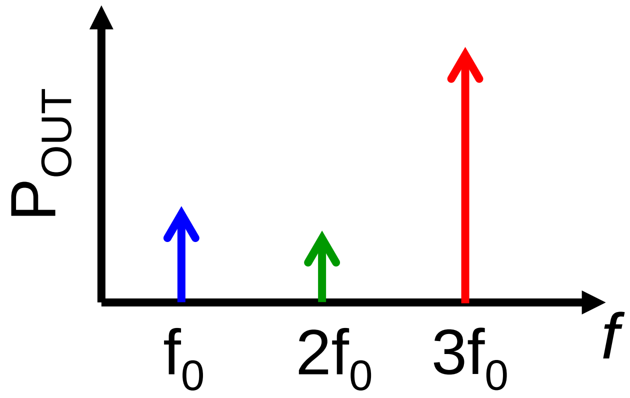
☹ f_0 dominates the output.
☹ $2f_0$ appears due to balun mismatch

Fundamental Blocking Tripler

- Proposed tripler



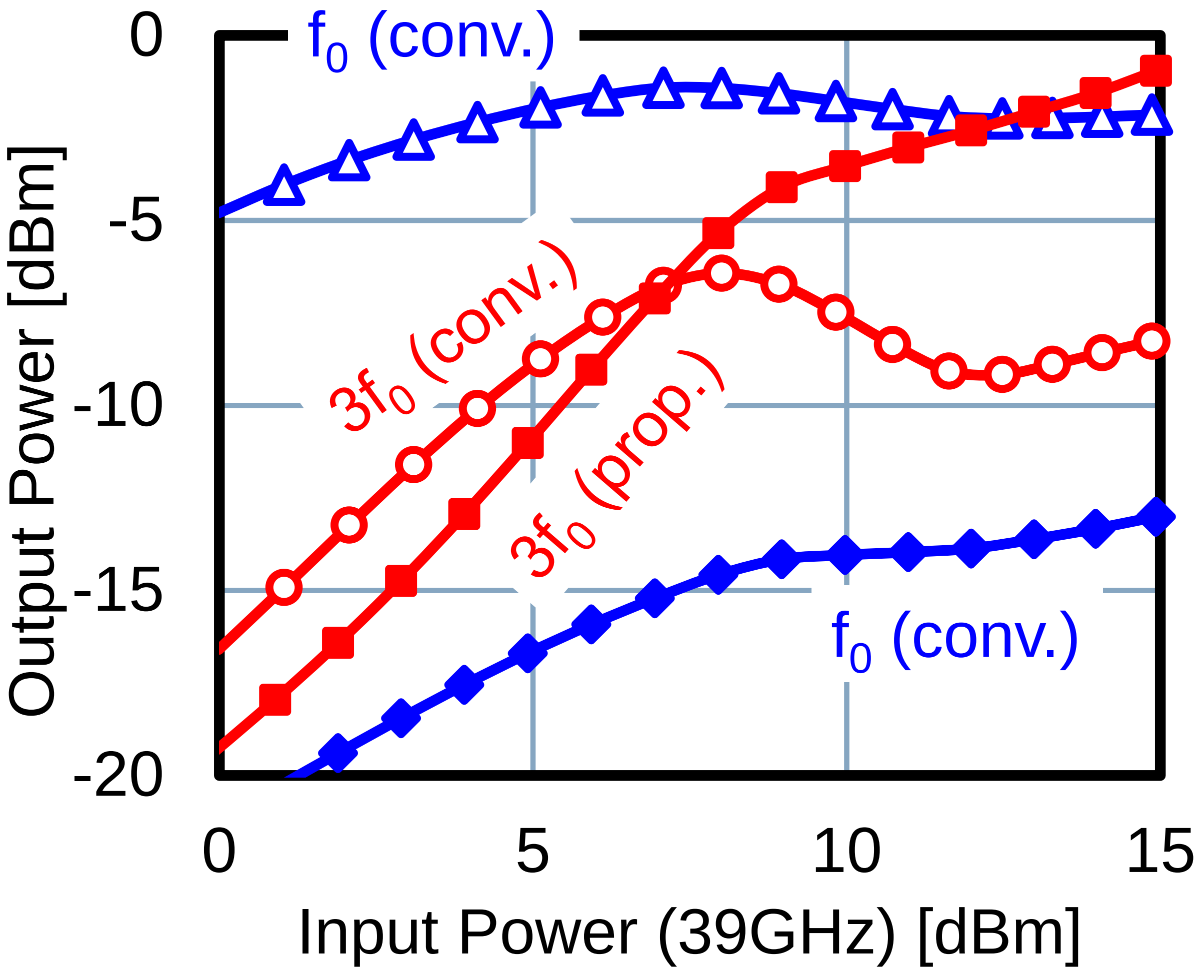
Line	Electrical length		
	@f_0	@$2f_0$	@$3f_0$
L1	λ/12	λ/6	λ/4
L2	λ/12	λ/6	λ/4
L3	λ/4	λ/2	3λ/4

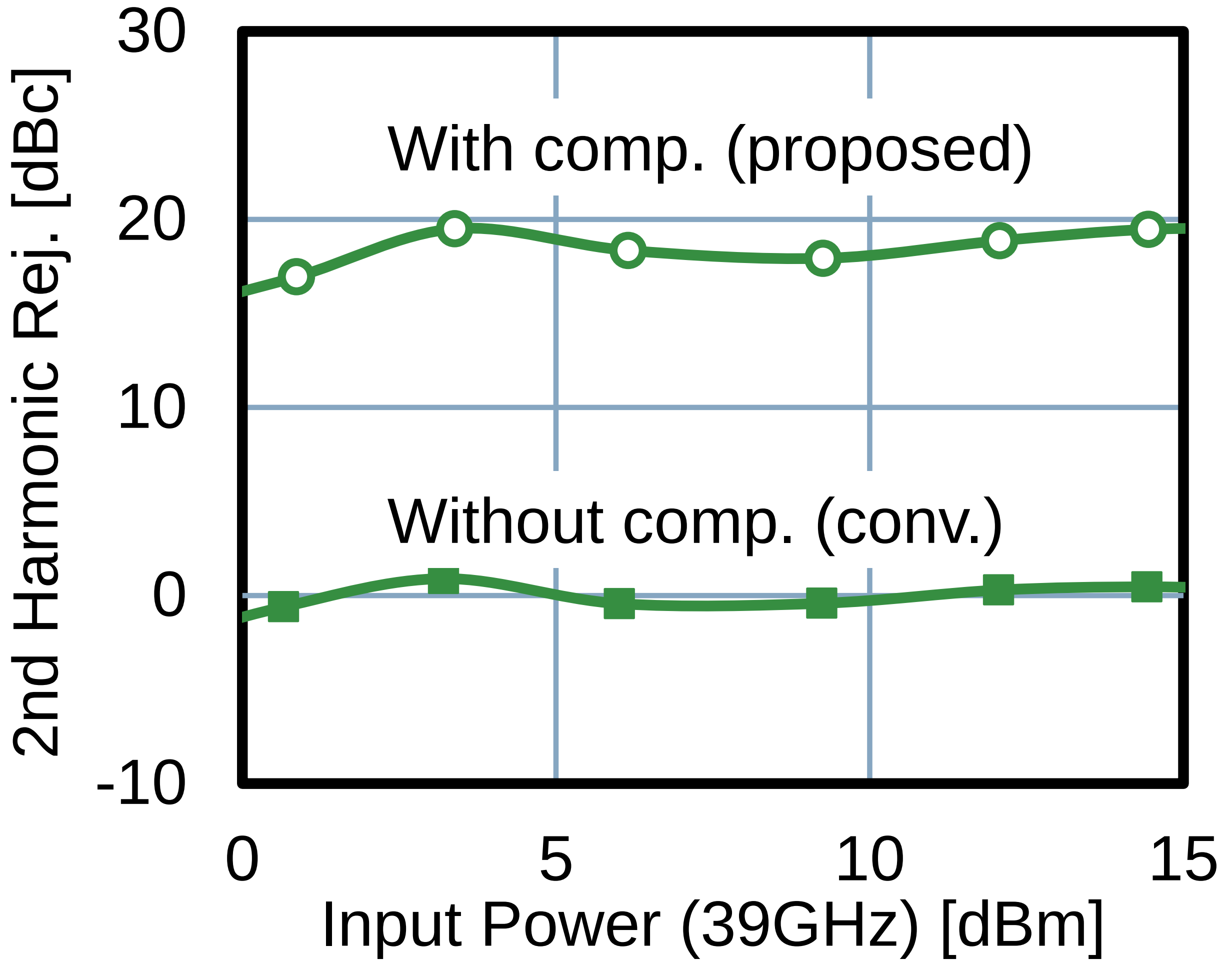


☺ f_0 cancelled or grounded.
☺ $2f_0$ reduced by mismatch cancellation.
☺ $2f_0$ reused at tail node by mixing with f_0.
☺ Improved linearity.

Fundamental Blocking Tripler

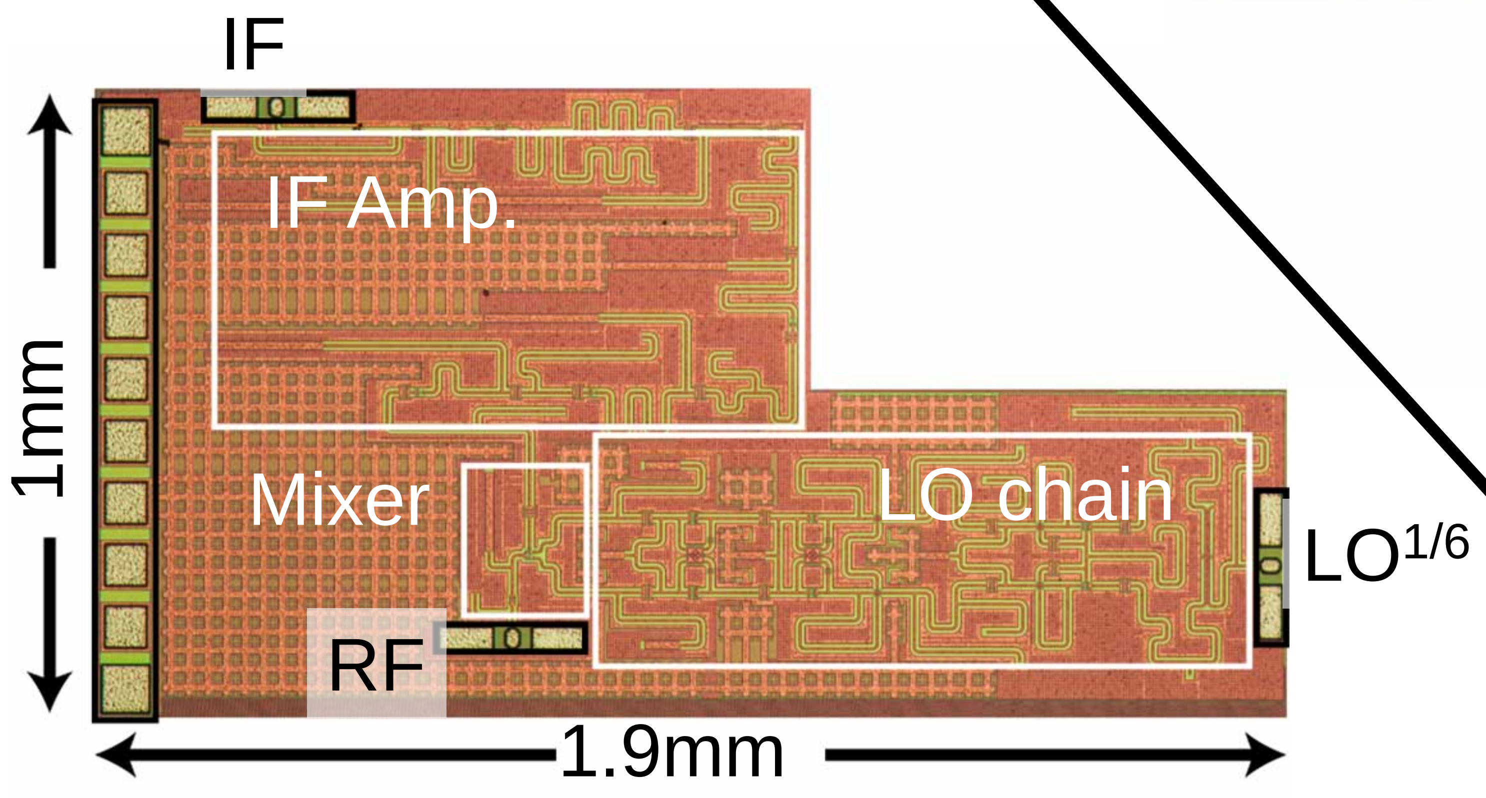
- Simulation Results

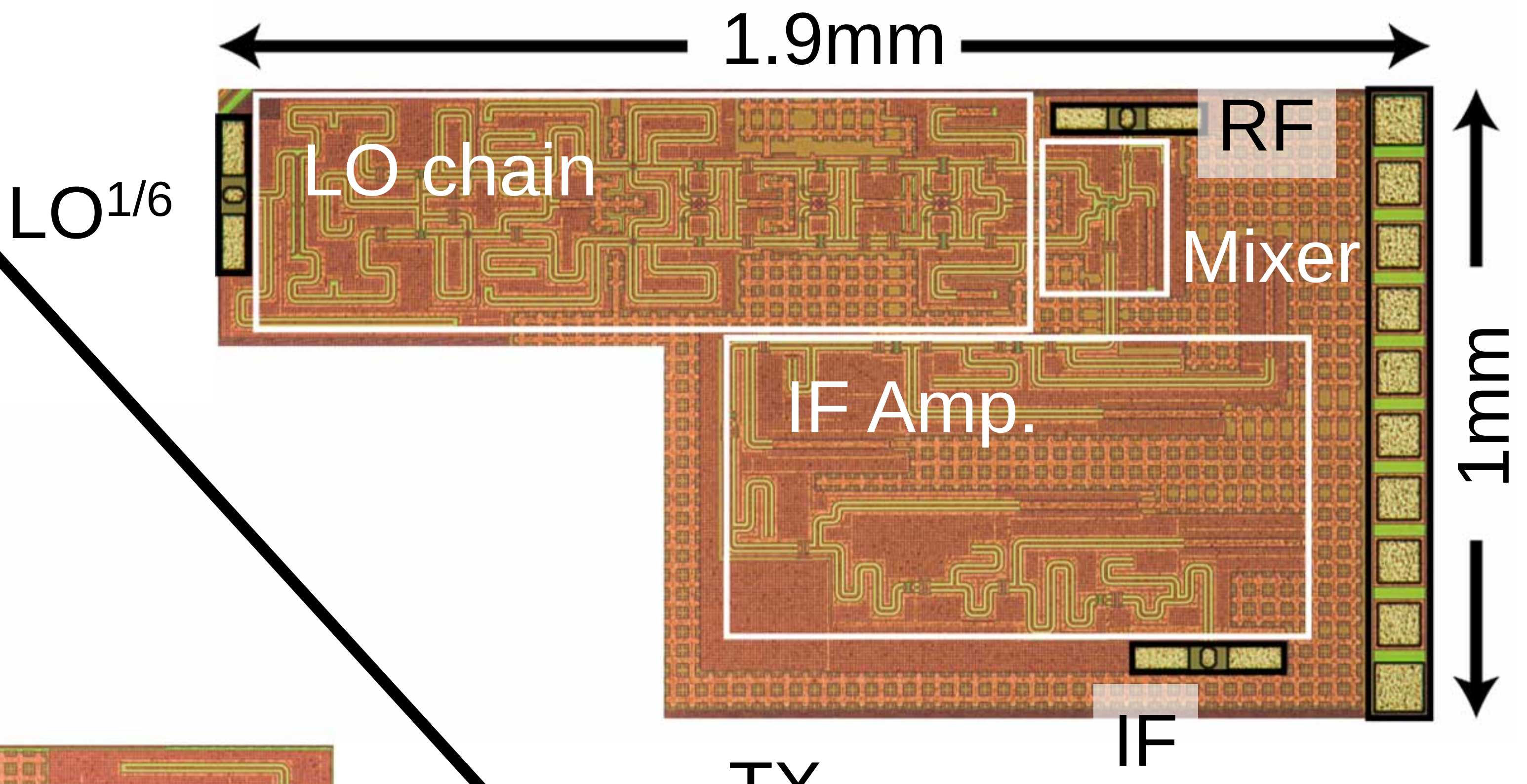




Chip Dimensions

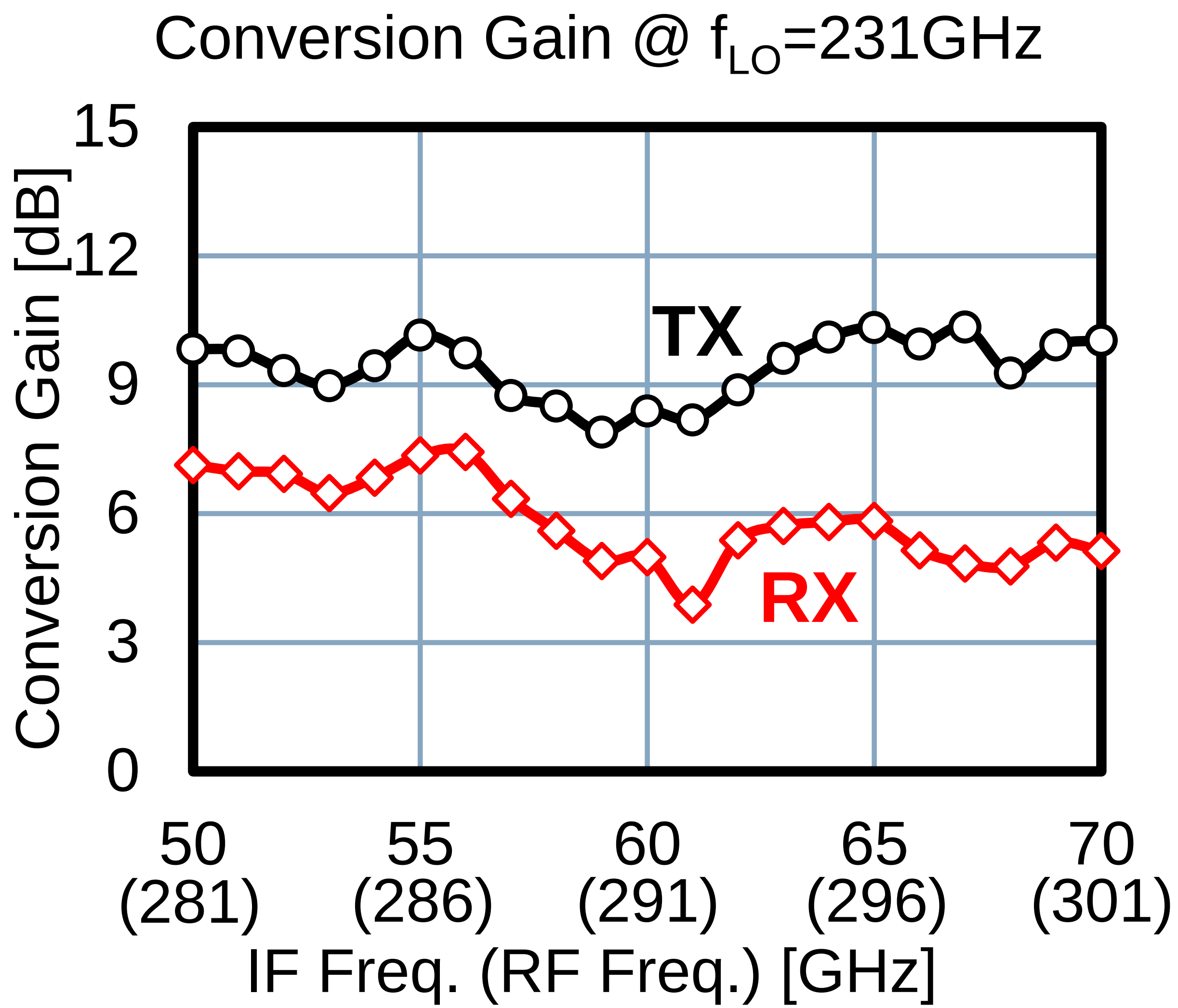
RX
Die area = 1.9mm^2
Circuit area = 1.52 mm^2

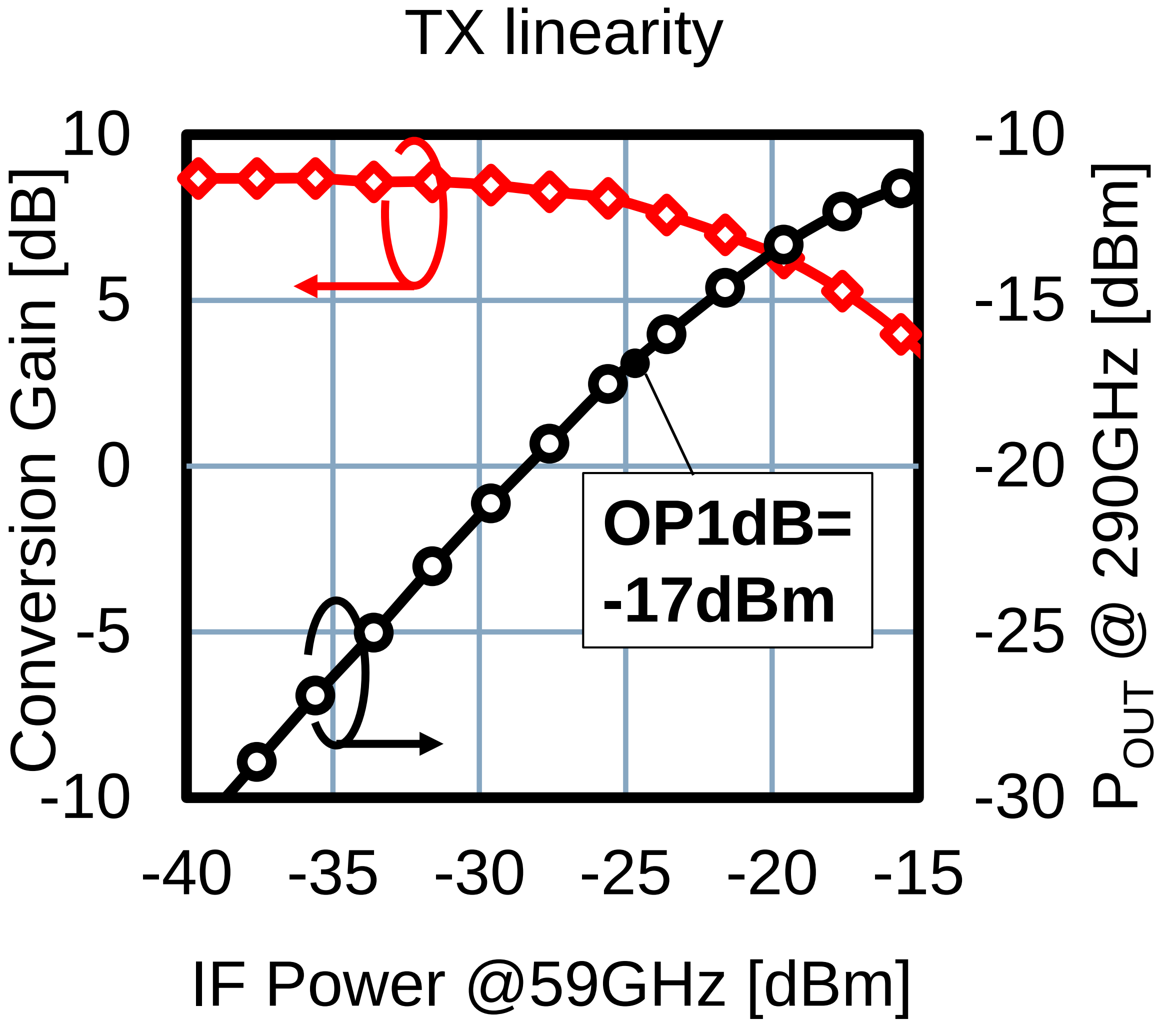




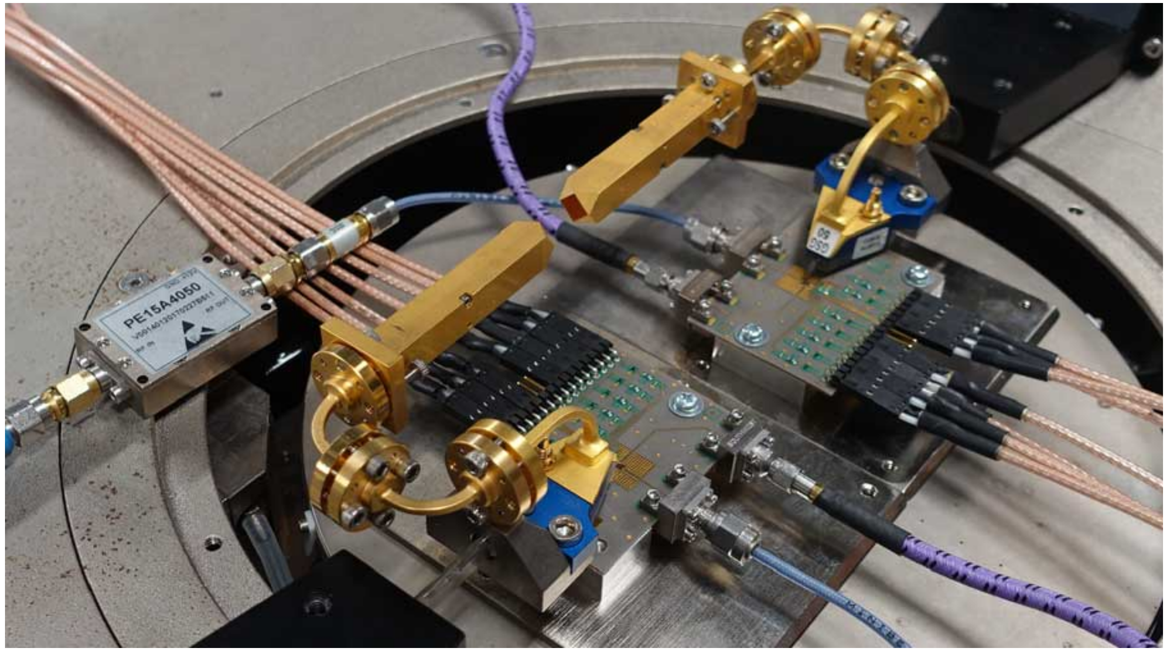
TX
Die area = 1.9mm^2
Circuit area = 1.49 mm^2

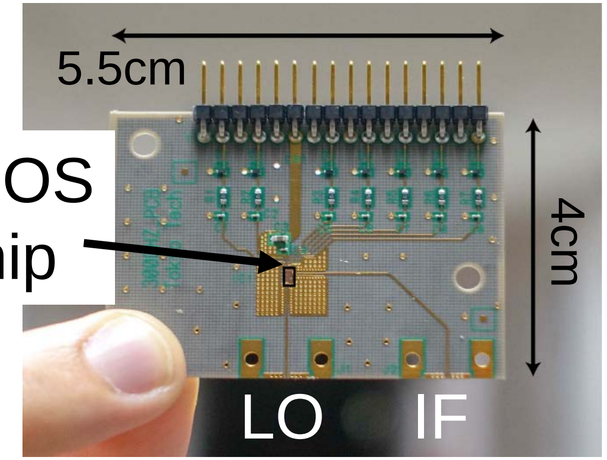
Measurement Results (Characterization)



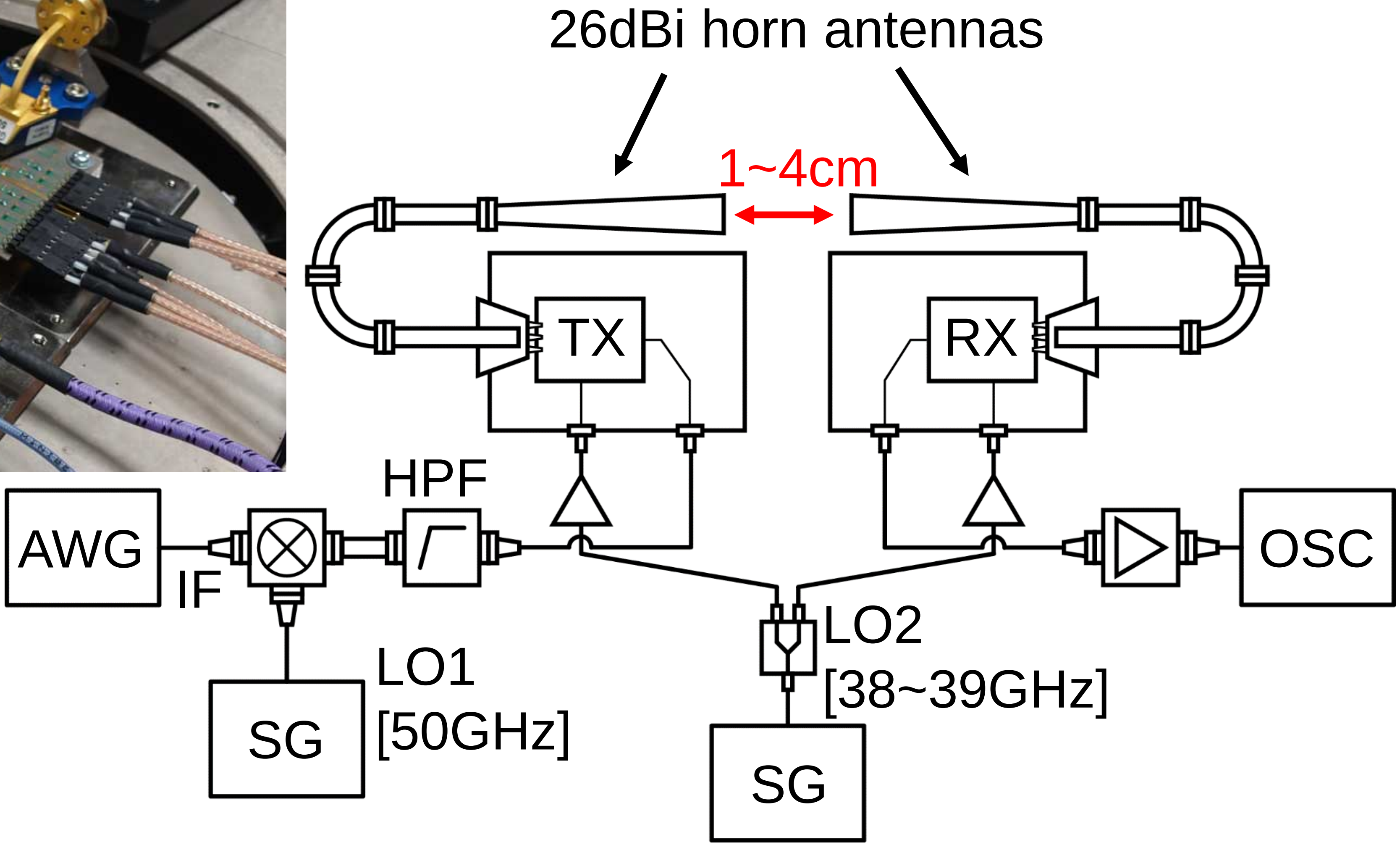


TRX Wireless Measurement Setup



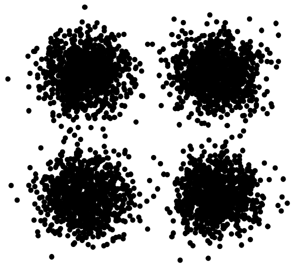
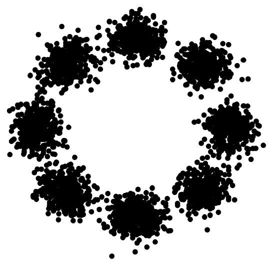
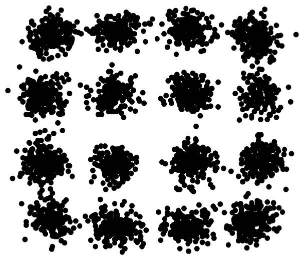


CMOS chip



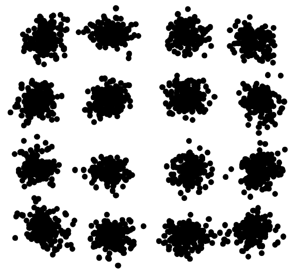
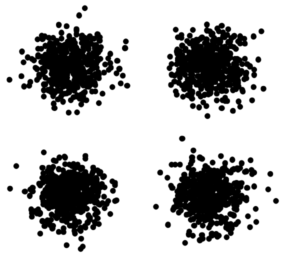
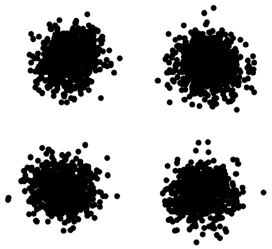
TRX Measurement Results

- Maximum data rate conditions

Distance [cm]	1		
f_{center} [GHz]	288		
f_{LO} [GHz]	228		
Bandwidth [GHz]	20.86	12.27	7.36
Symbol rate [Gbaud]	17	10	6
Modulation	QPSK	8PSK	16QAM
TX-to-RX Constellation			
TX-to-RX EVM [dB]	-10.12	-14.83	-16.72
Data rate [Gb/s]	34	30	24

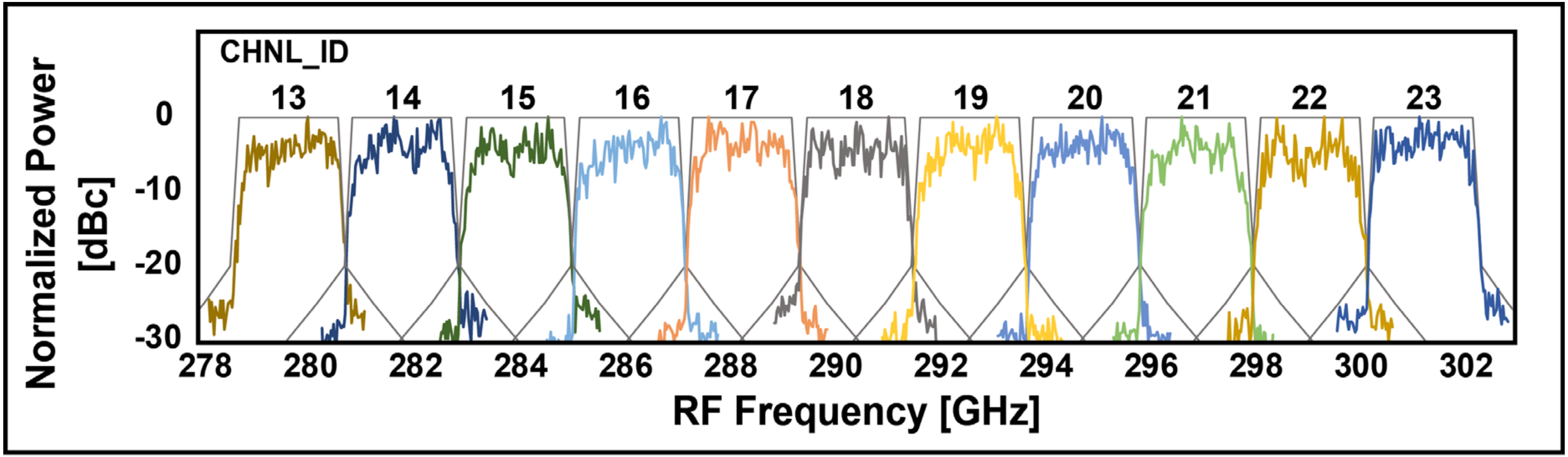
TRX Measurement Results

- IEEE802.15.3d channels:

CHNL_ID	41	43	59
f_{center} [GHz]	289.44	298.08	285.12
f_{LO} [GHz]	228	234	228
Bandwidth [GHz]	4.32	4.32	12.96
Symbol rate [Gbaud]	3.52	3.52	10.56
Modulation	16QAM	QPSK	QPSK
TX-to-RX Constellation			
TX-to-RX EVM [dB]	-17.81	-11.98	-13.04
Data rate [Gb/s]	14.08	7.04	21.12

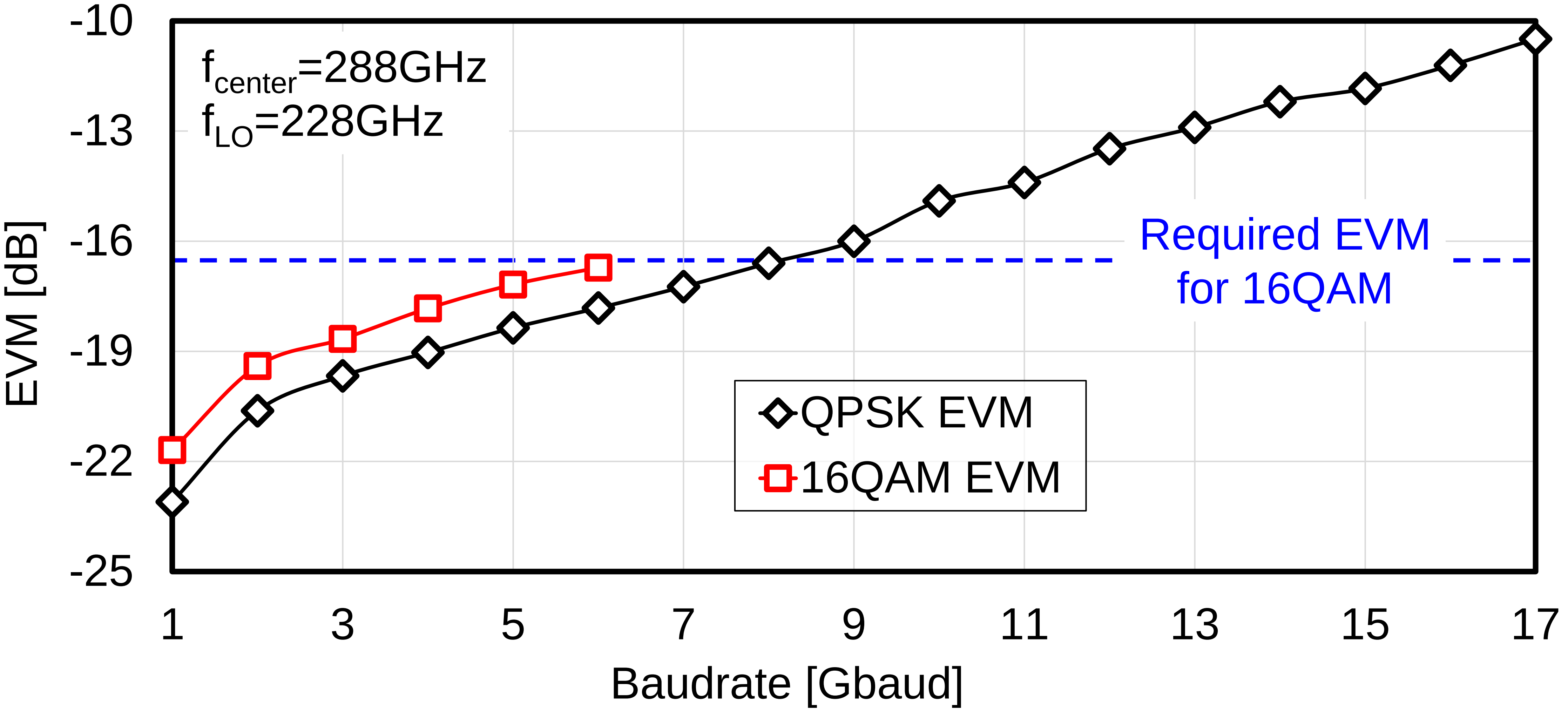
TX Spectrum

- IEEE802.15.3d Standard compatibility



*CHNL_ID is the channel ID as defined by IEEE802.15.3d standard [1] (e.g. for ch.20, CHNL_ID=20).
**Roll-off factor of all the measurements is 0.25 as specified by the standard.

EVM vs Baud Rate (1cm distance)



Performance Comparison

	[4] IHCT	[5] NTT	[6] NTT	[7],[9] UCB	[8],[10] Hiroshima	[11], [12] Hiroshima	This work
Technology [nm]	130 SiGe	80 InP-HEMT	80 InP-HEMT	65 CMOS	40 CMOS	40 CMOS	65 CMOS
RF freq. [GHz]	220-255	272-302	290*	240*	290*	252-279	278-304
Max. baud rate [Gbaud]	23.75	25	30	8	14	20	17
Max. data rate [Gb/s]	95	100	120	16	32	80	34

*Center frequency.

Performance Comparison

	[4] IHCT	[5] NTT	[6] NTT	[7],[9] UCB	[8],[10] Hiroshima	[11], [12] Hiroshima	This work
RX mixer CG [dB]	8$	-15	-	-	-19	-	-16.5
TX P_{sat} [dBm]	5.5	9.5	12	1	-5.5	-1.6	-11.6
Standard-based	No	No	No	No	No	IEEE 802.15.3d	IEEE 802.15.3d
P_{DC} [W]	TX: 0.96 RX: 0.45	TX: N/A RX: N/A	TX: N/A RX: N/A	TX: 0.22 RX: 0.26	TX: 1.4 RX: 0.65	TX: 0.89 RX: 0.9	TX: 0.27 RX: 0.14
Area [mm^2]	TX: N/A RX: N/A	TX: N/A RX: N/A	TX: N/A RX: N/A	TX: 2 RX: 2	TX: 5.19 RX: 3.15	TRX: 11	TX: 1.9 RX: 1.9

$Including baseband amplifier gain.

Conclusion

- A 300GHz CMOS-only TRX that achieves a maximum data rate of 34Gb/s was presented.
- A push-push sub-harmonic mixer with a conversion gain of around -16.5dB is proposed to enable single-stream operation.
- Accordingly, Power consumption and total area are reduced to less than 500mW and $4mm^2$, respectively.
- QPSK communication is achievable for baud rates as large as 17Gbaud.

Acknowledgement

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