# ALL-STANDARD-ALL-BAND POLAR MODULATOR FOR DIGITAL TELEVISION BROADCASTING

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**Tokyo Institute of Technology**

2015/12/12

# Outline



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- **Motivation**
- **TxMER degradation**
- **Direct Polar Modulator Design**
- **Conclusion**

# Worldwide Frequency Allocation



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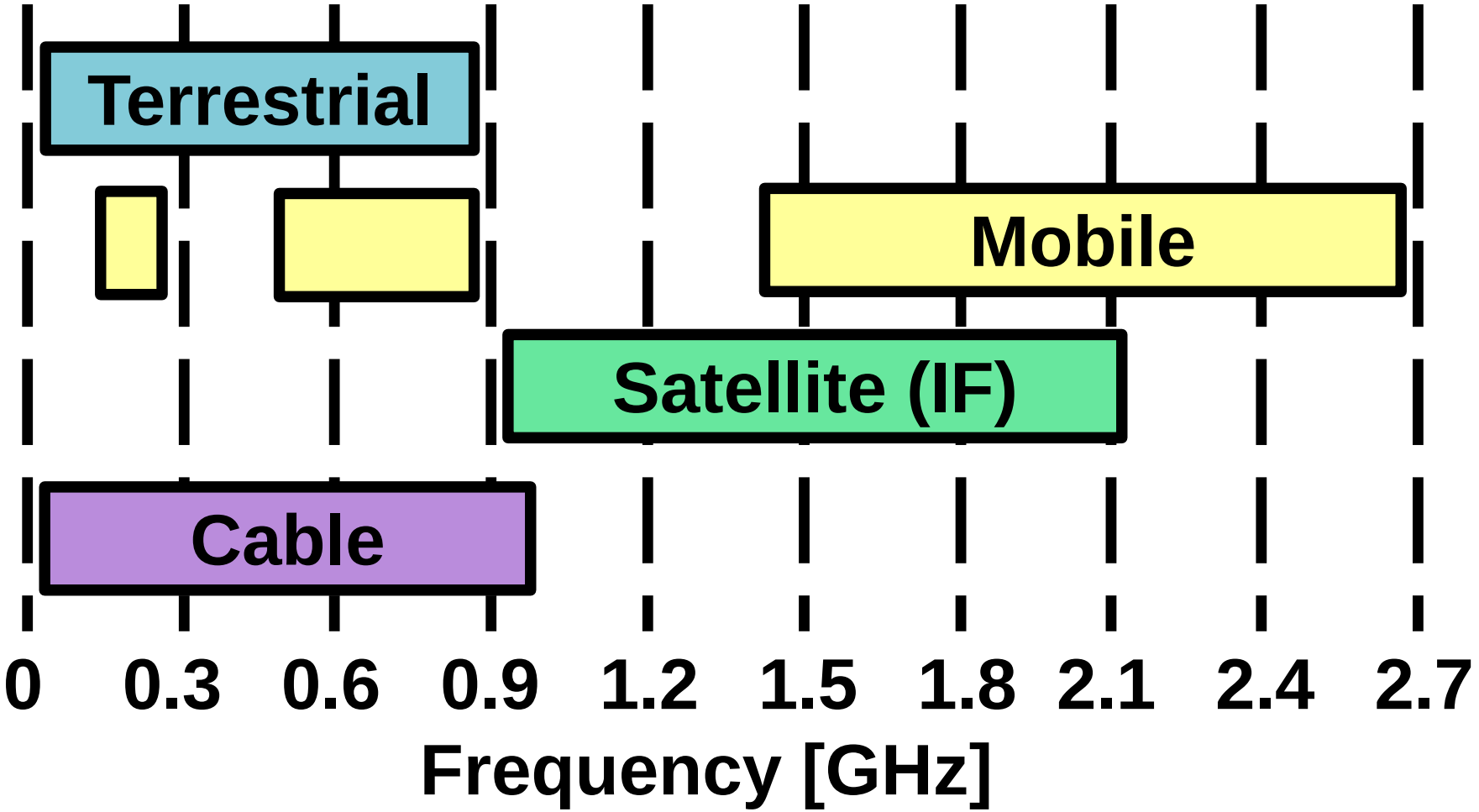
## VHF/UHF/L/S Bands




**Integrated All-standard Modulator hasn't been reported yet.**

# UHDTV Broadcasting Roadmap



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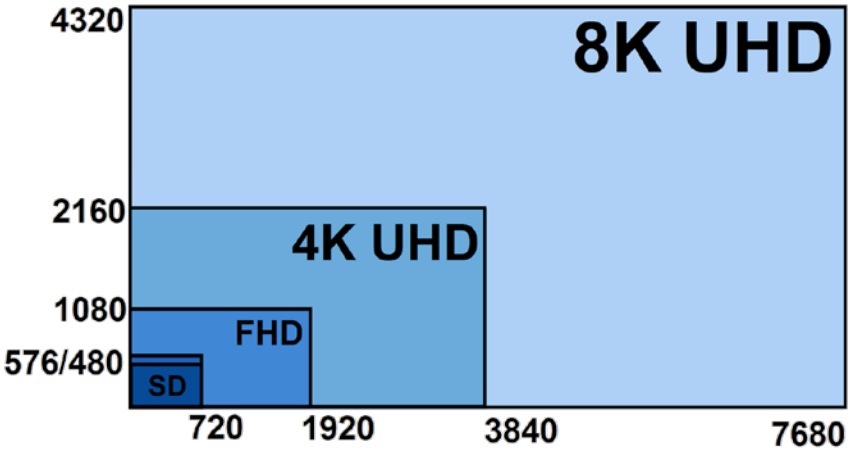


**8K = 16 x FHD !**

**2014**

**4K Test Broadcast**
**Bit Rate = 35 Mb/s**

**2016**

**8K Test Broadcast**
**Bit Rate = 91.8 Mb/s**

**2020**

**4K/8K Full Scale Broadcasting (Tokyo Olympics)**

**From "Promoting the Advancement of Broadcasting Services: the Road Map to 4K and 8K". MIC. 2014.*

**Increasing data rates ➡ Higher order modulation schemes**

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# BER over AWGN



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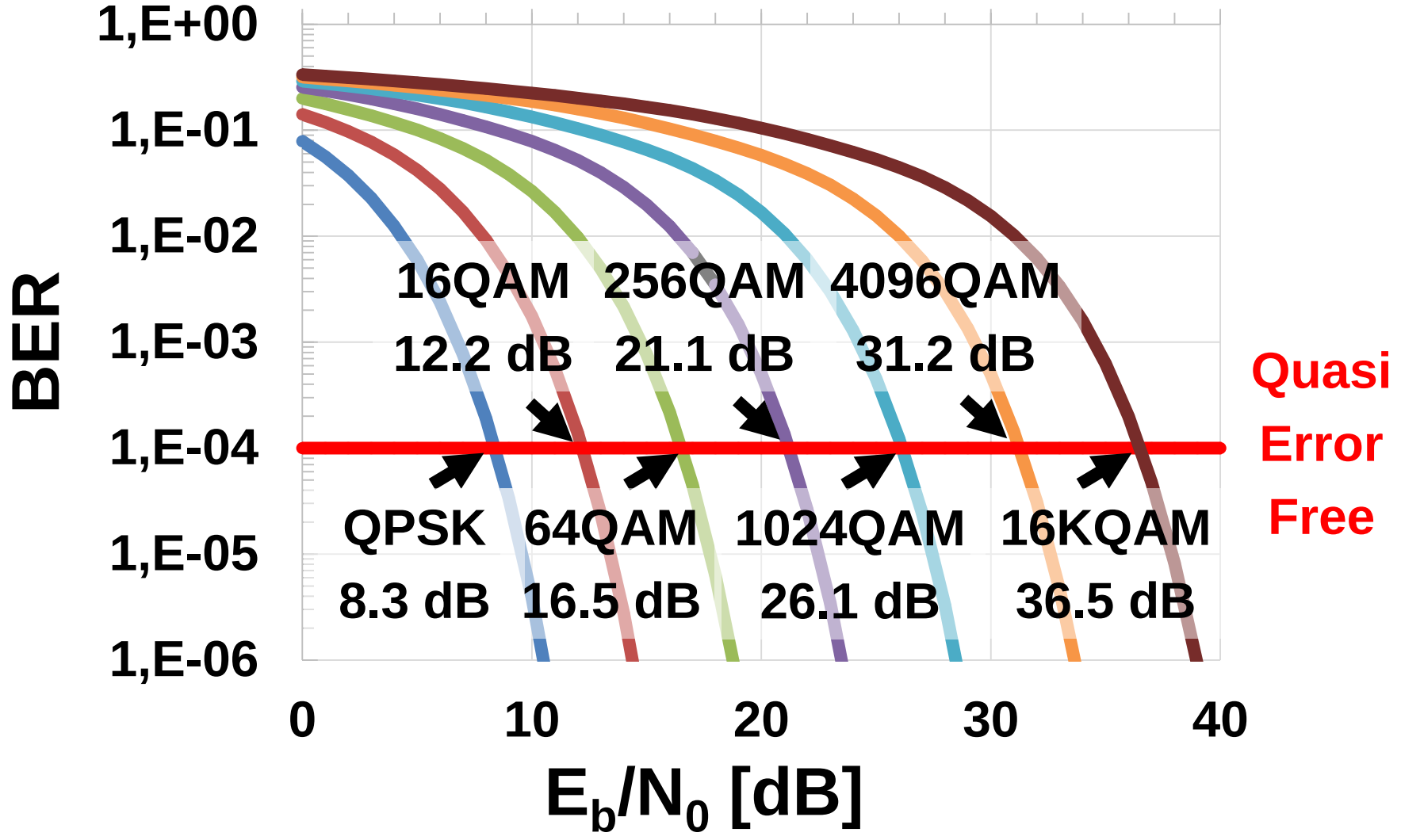
$E_b/N_0 = C/N * BW/R_s \times m$






M.A.ABDEL 15D14048

Matsuzawa & Okada Lab.

# Digital Television Evolution



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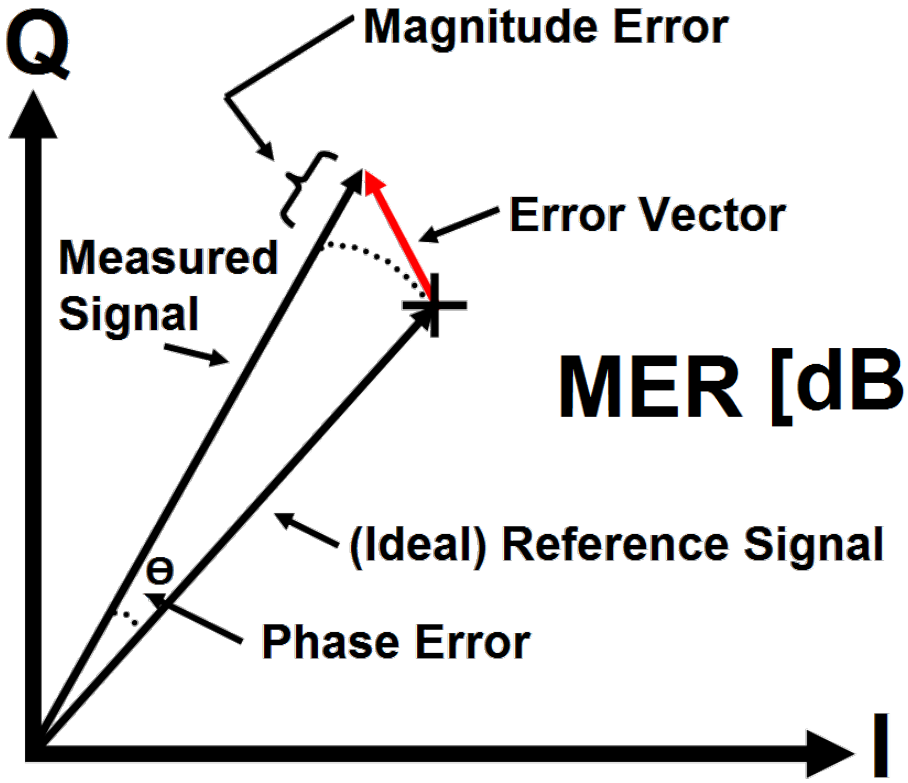
| Standard | Modulation | | Data Rate [Mb/s] | BW [MHz] | Required C/N [dB] (spec) | TxMER [dB] (typical) |
|---|---|---|---|---|---|---|
| DVB-S | QPSK | SC | 45.4 | 36 | > 8.4 | > 38 |
| DVB-S2 | 8PSK | SC | 65 | 36 | > 7.9 | > 38 |
| DVB-S2X | 16APSK | SC | 89 | 36 | > 12 | > 42 |
| DVB-C | 64QAM | SC | 38.1 | 8 | > 26 | > 40 |
| DVB-C2 | 4096QAM | OFDM | 79.5 | 8 | > 34.8 | > 40 |
| DTMB | 64QAM | OFDM | 24.3 | 8 | > 14.9 | > 40 |
| DTMB-A | 256- APSK | OFDM | 49.6 | 8 | > 22.8 | - |
| ISDBT-T/Tb | 64QAM | OFDM | 23.2 | 6 | > 22 | > 40 |
| 8K Super Hi-Vision | 4096QAM | OFDM | 91.8 | 6 | > 35.7* | > 45* |

***From "Super Hi-Vision Terrestrial Transmission Test". NHK STRL. 2013.***

# TxMER degradation








$$\text{MER [dB]} = 10\log_{10}\left[\frac{\sum_{j=1}^{N}\left(I_j^2+Q_j^2\right)}{\sum_{j=1}^{N}\left(\delta I_j^2+\delta Q_j^2\right)}\right]$$

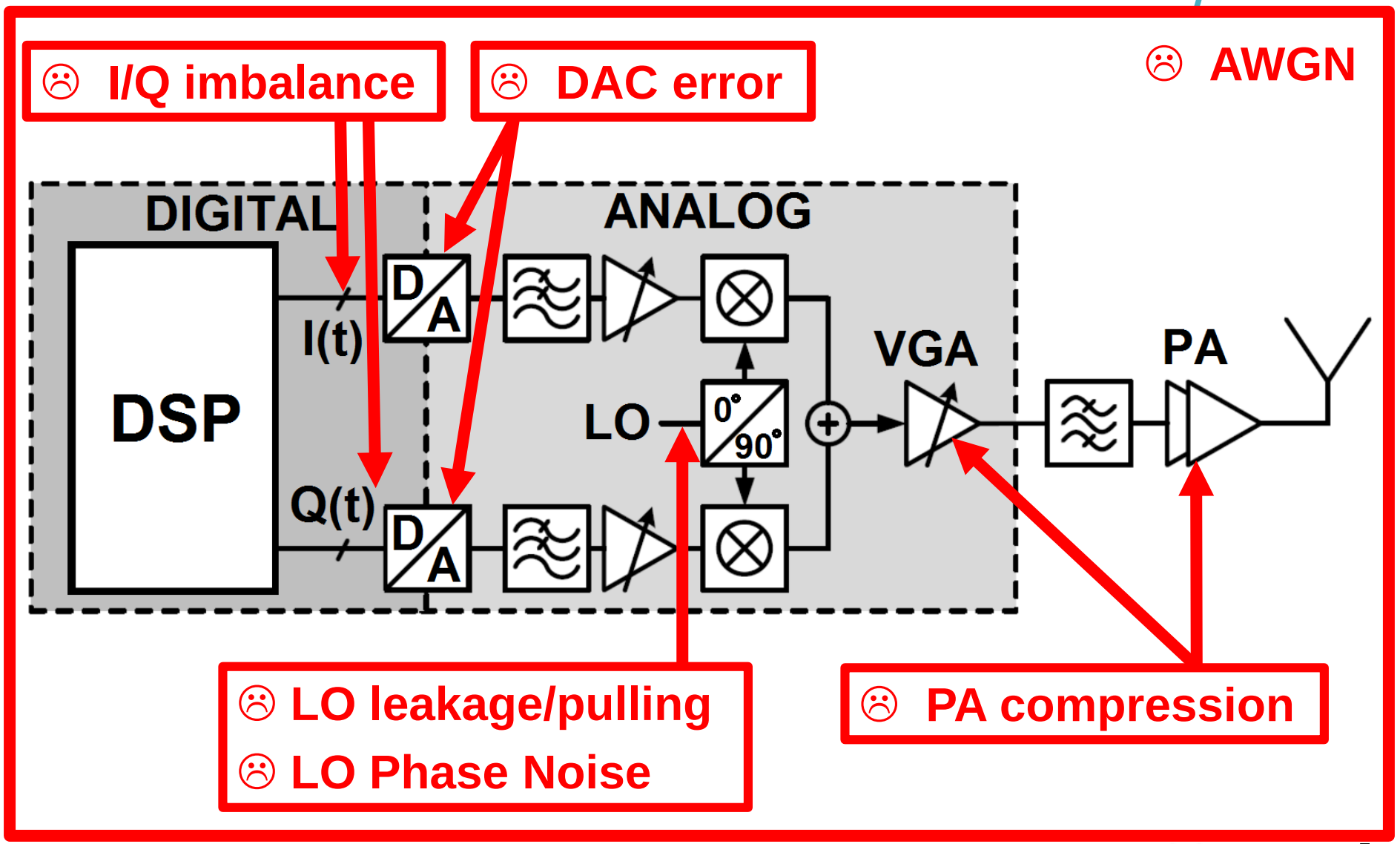
## Tx error sources:

- ☹ AWGN
- ☹ LO Phase Noise
- ☹ I/Q imbalance
- ☹ LO leakage/pulling
- ☹ DAC error
- ☹ PA compression

# Direct Conversion Modulator



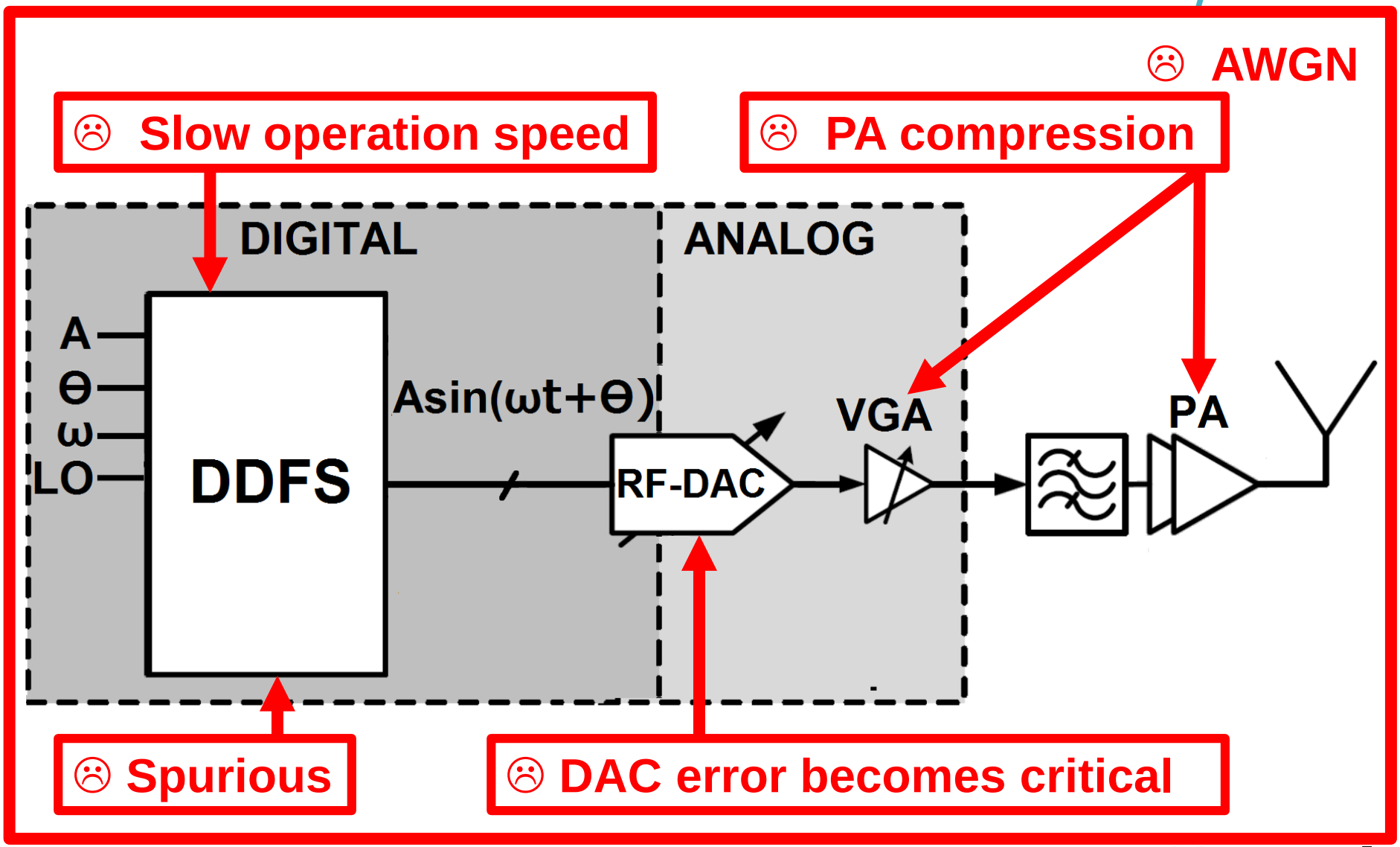




# Direct Polar Modulator







# Direct Polar Modulator



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## Advantages:

- No I/Q mismatch
- Low Phase Noise
- Low LO leakage/pulling

} ↑ TxMER

- Supports effortless digital modulation
- Better scaling with CMOS technology

## Challenges:

- 50 MHz - 2660 MHz band operation
- DAC errors becomes critical
- Spurious performance

} ↓ TxMER

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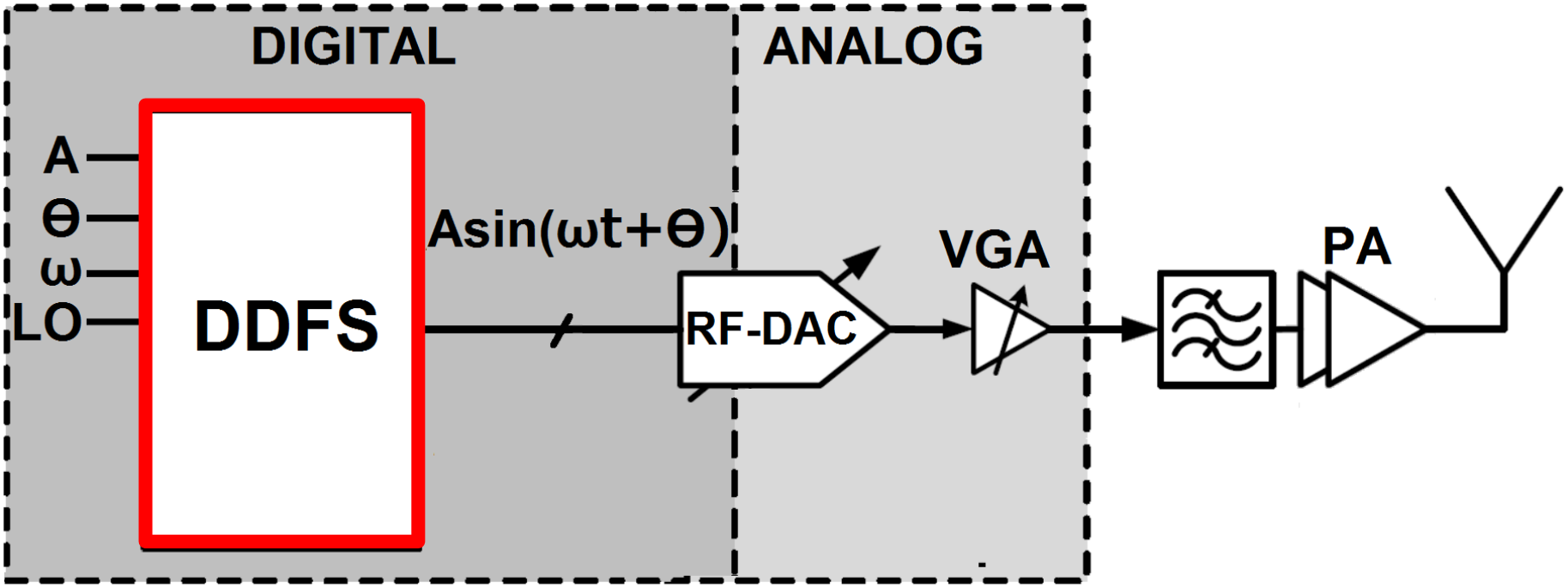
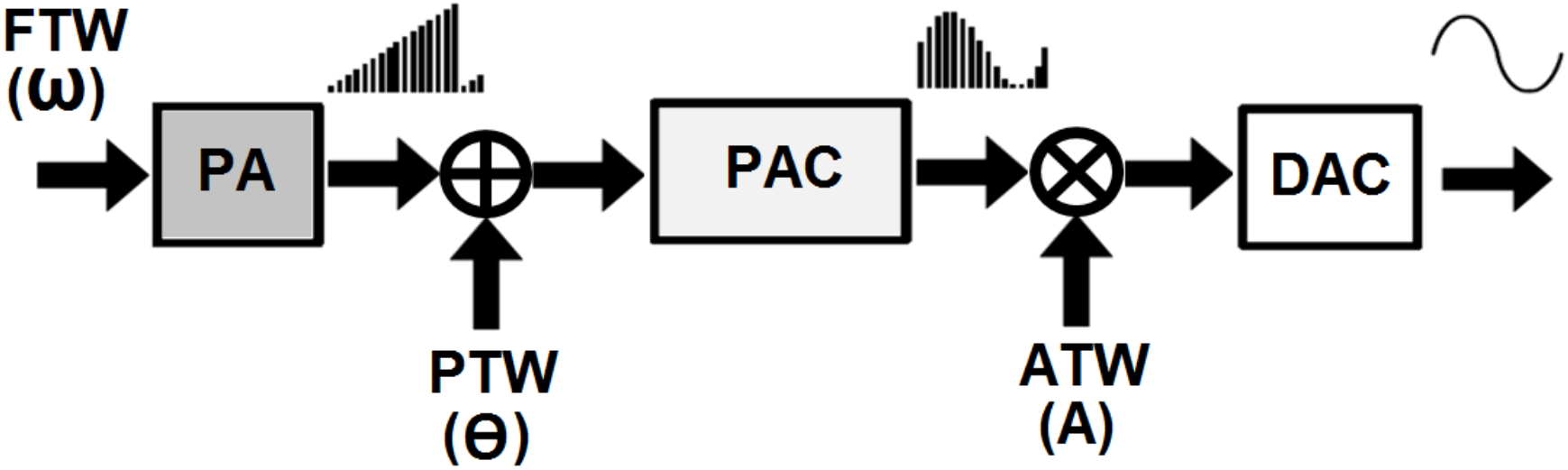
# Direct Polar Modulator

## RF-DDFS Design:



# RF-DDFS Design

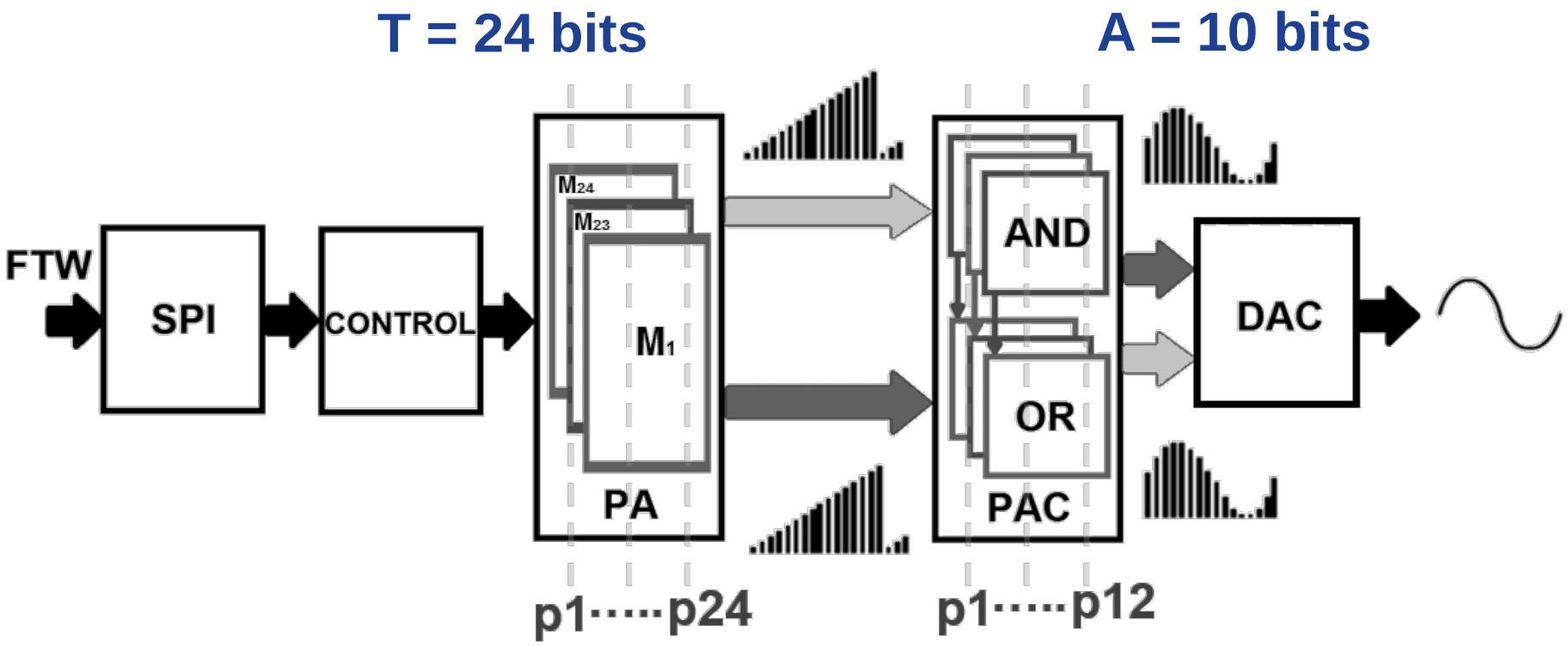
## Classic Digital Mapping DDFS:




$$DDFS_{out} = A*\sin(\omega t + \Theta)\ [2]$$

# RF-DDFS Design

## Proposed Complementary Dual Phase Latch-Based (CDPL) DDFS:



# RF-DDFS Design

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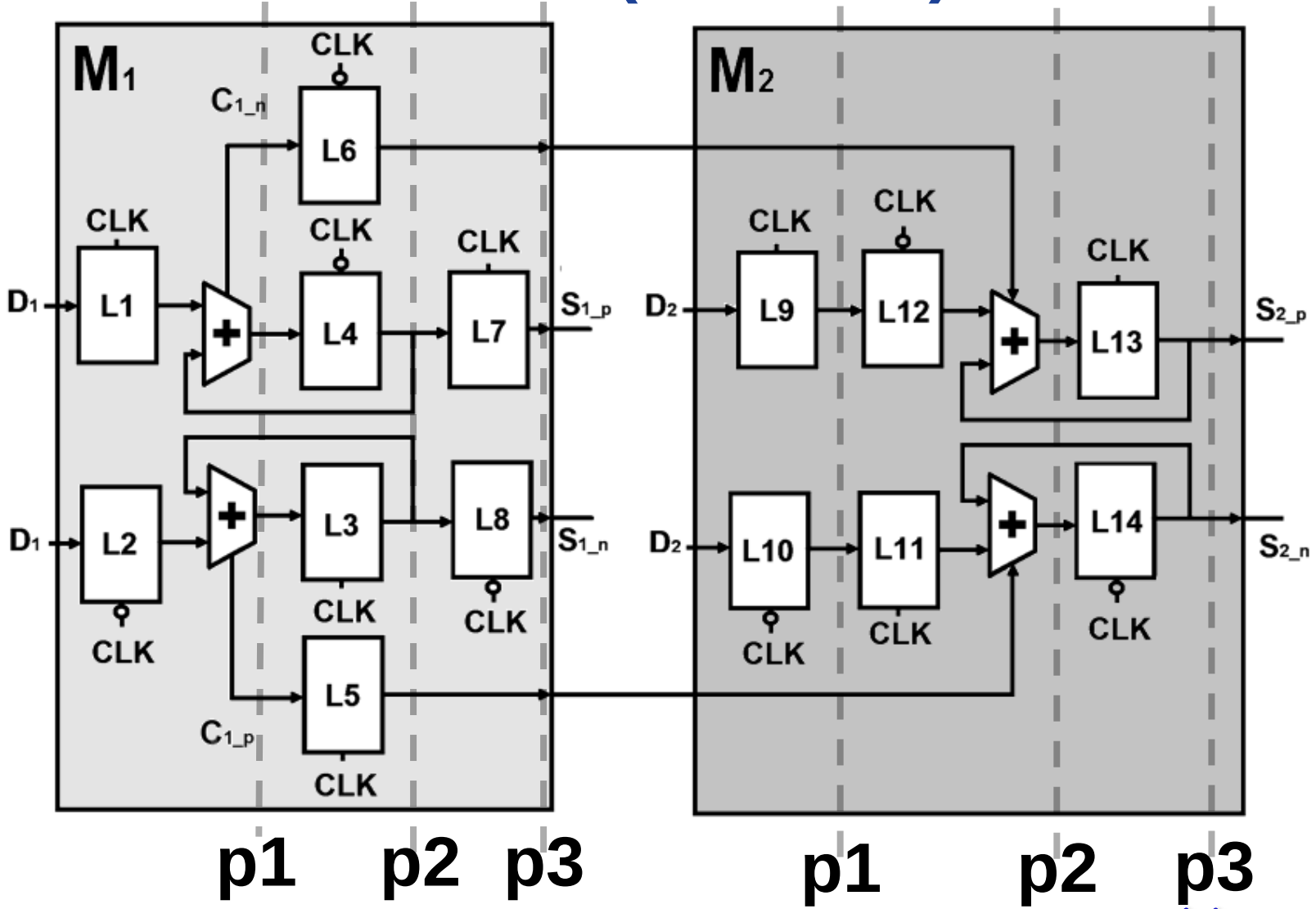
## Phase Accumulator (PA 2 bits) :



# RF-DDFS Design

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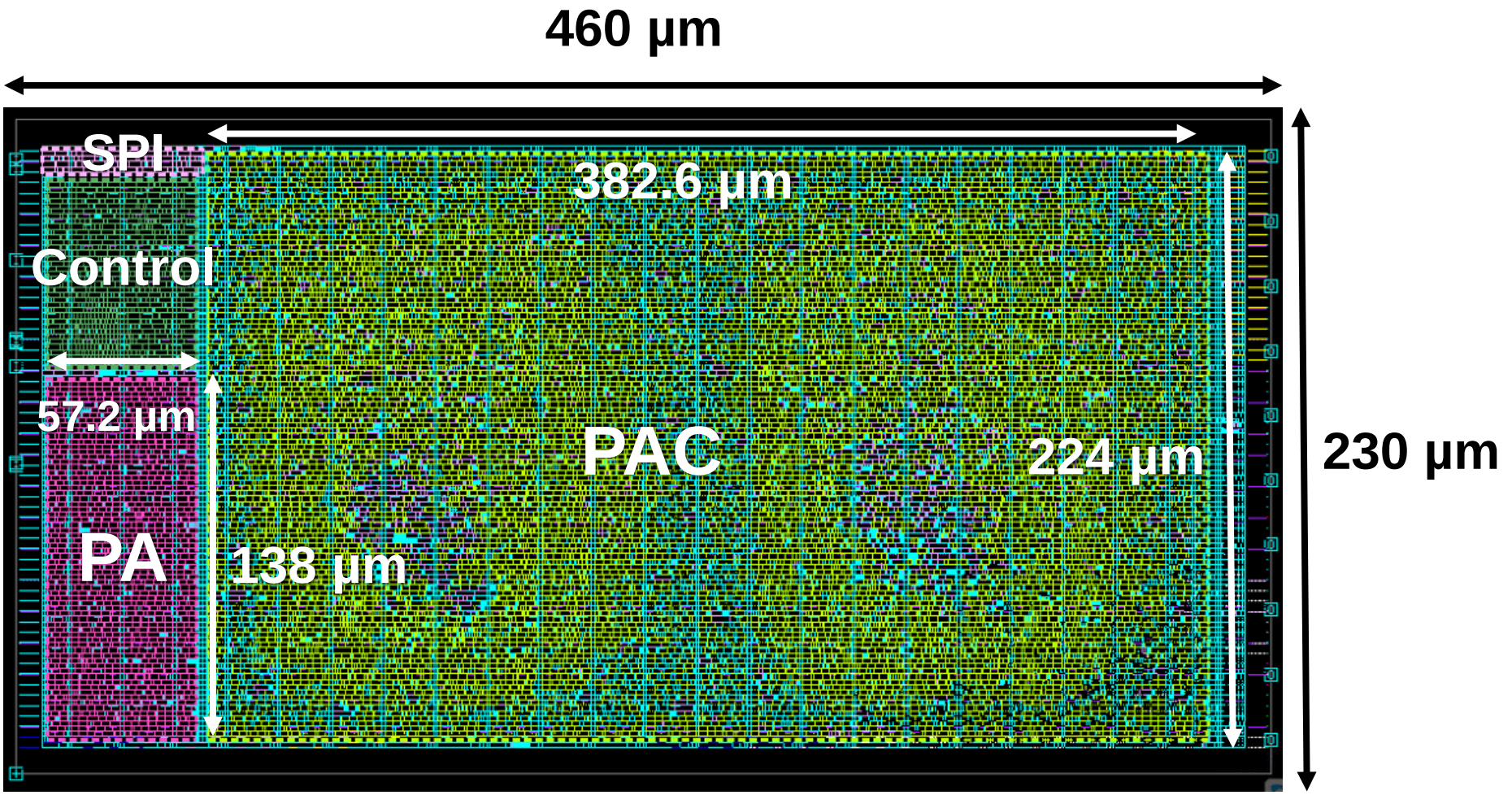
## Floorplan view (CMOS 65nm)



# RF-DDFS Design

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## Performance Comparison:

| Reference | Arch. | T | P | A | Technology | Sampling Rate (GS/s) | Area ($mm^2$) | Power (mW) |
|---|---|---|---|---|---|---|---|---|
| FF DDFS | Digital Mapping | 24 | 14 | 10 | CMOS 65 nm | 3.9 | 0.114 | 238 |
| CDPL DDFS | Digital Mapping | 24 | 14 | 10 | CMOS 65 nm | **6.8** | 0.105 | **145** |

**CDPL-DDFS can achieve a higher sampling rate and lower power consumption when compared with a Flip-Flop approach.**

# RF-DDFS Design



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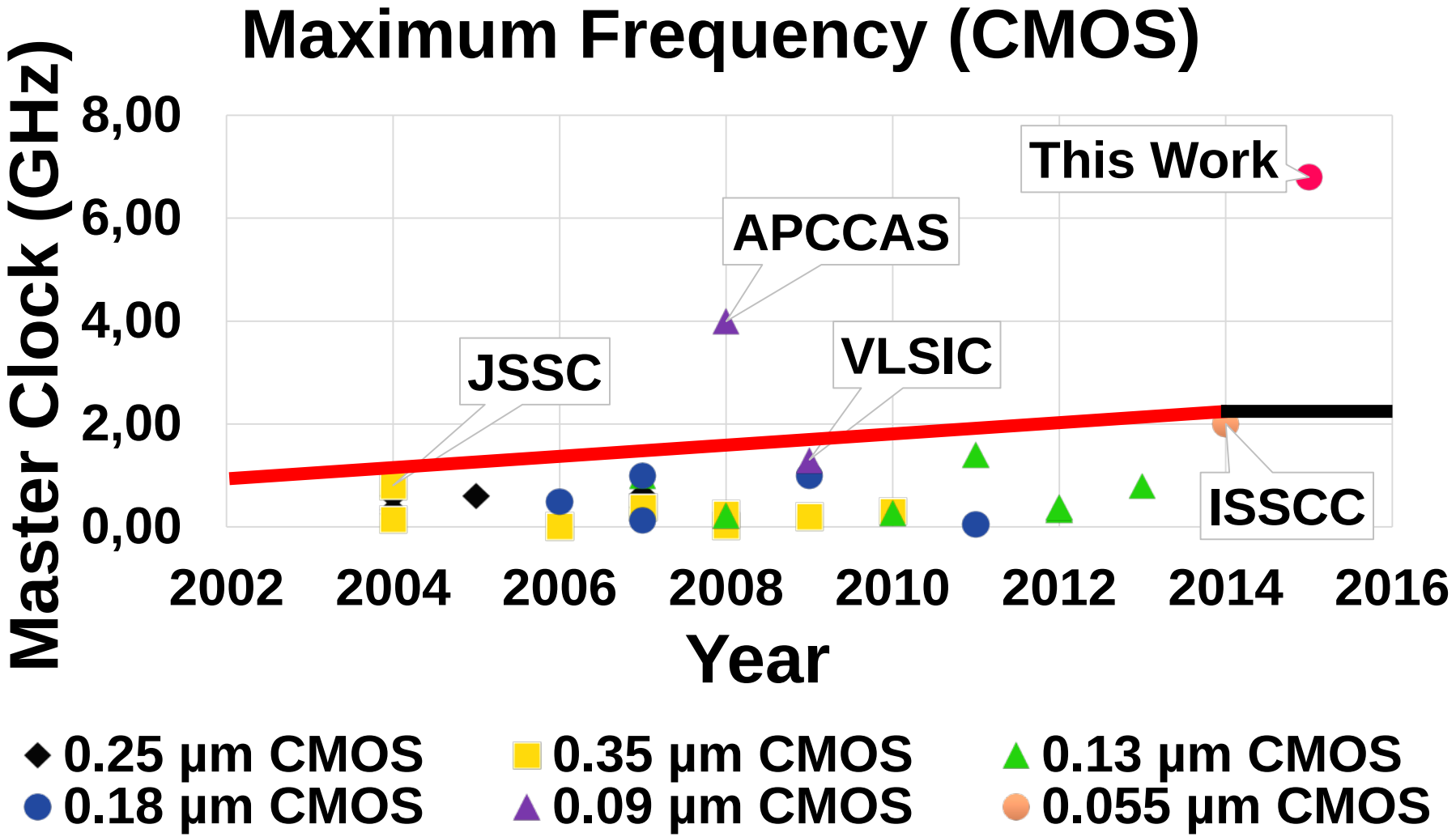

# RF-DDFS Design

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## Performance Comparison:

| Reference | Arch. | T (PA bits) | A (DAC bits) | CMOS Technology | Sampling Rate (GS/s) | Area ($mm^2$) | PE (W/GS/s) | SFDR (dBc) |
|---|---|---|---|---|---|---|---|---|
| JSSC'04 | Digital Mapping | 32 | 9 | 0.35 µm | 0.8 | 1.47 | 0.217 | 55 |
| *APCCAS '08 | Nonlinear DAC | 12 | 7 | 90 nm | 4 | N/A | 0.1155 | 44 |
| VLSIC'09 | Nonlinear DAC | 24 | 11 | 90 nm | 1.3 | 2 | 0.26 | 52 |
| *TCSI'11 (Without DAC) | Digital Mapping | 24 | 9 | 0.13 µm | 1.4 | 0.006 | 0.005 | 62 |
| ISSCC'14 | Nonlinear DAC | **32** | **9** | **55 nm** | **2** | **0.1** | **0.065** | **55.1** |
| This Work (Without DAC) | Digital Mapping | 24 | 10 | 65 nm | 6.8 | 0.1 | 0.022 | 45.3 |

# Direct Polar Modulator



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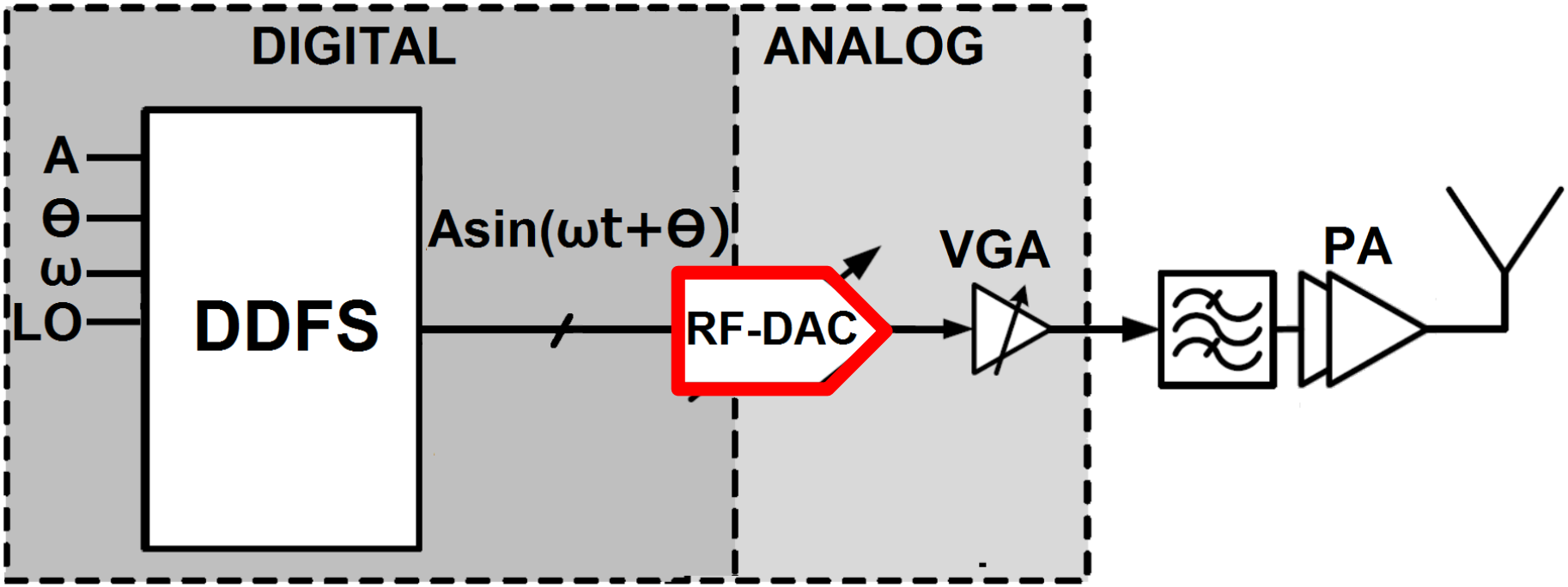
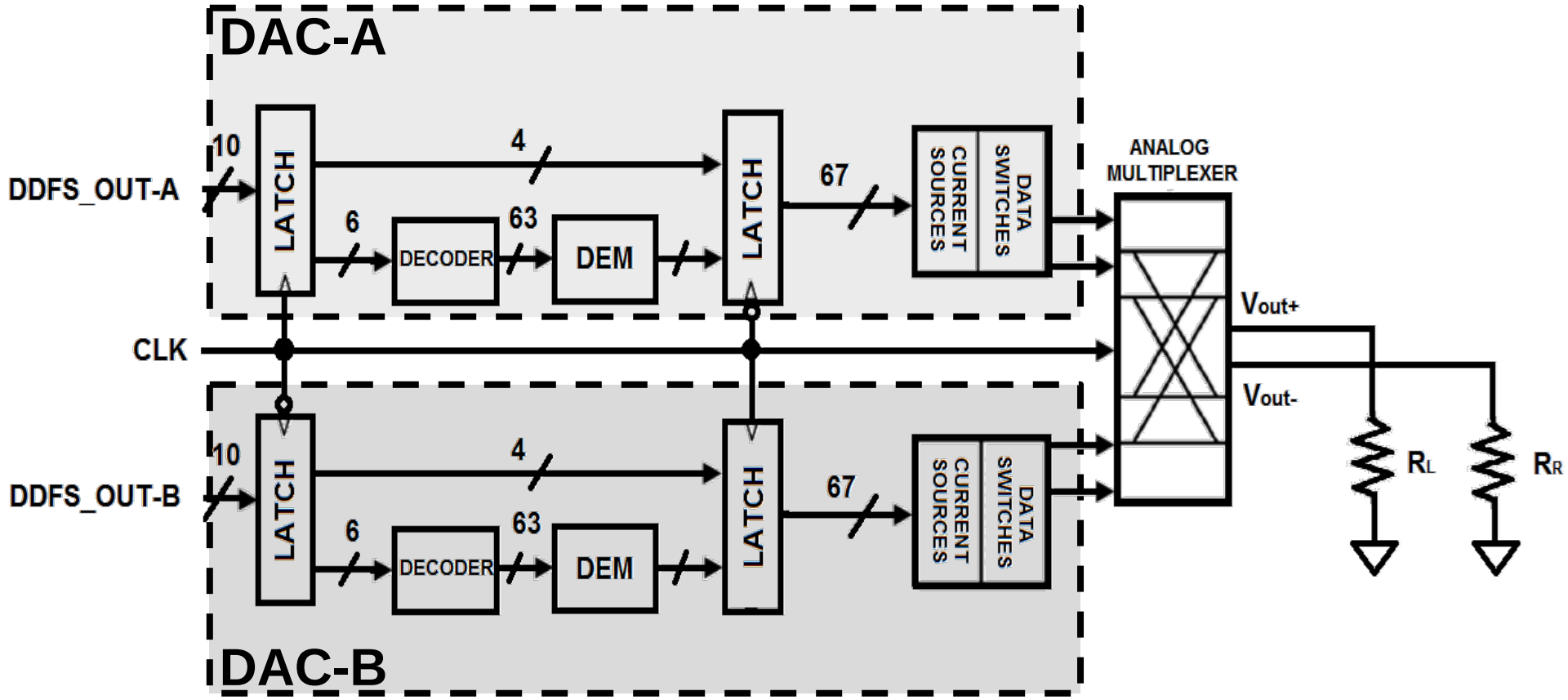
## RF-DAC Design:



# RF-DAC Design

## Interleaved DAC architecture:



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# Conclusions



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1. 4K and 8K ultra-high-definition video technology is already making inroads into broadcasting.
2. Integrated All-Standard-All-Band Modulator is proposed:
   - High TxMER Direct Polar Modulator (TxMER > 45 dB).
   - Complementary Dual-Phase Latch-Based DDFS ($F_{out}$ = 2.7 GHz).
   - Interleaving RF-DAC. ($F_{out}$ = 2.7 GHz).

# References



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[1] D. ANALOG. “3.5 GSPS Direct Digital Synthesizer with 12-Bit DAC”, 2014.

[2] G. Ken. “DDS simplifies polar modulation”, EDN Network, 2004.

[3] D. ANALOG. “A Technical Tutorial on Digital Signal Synthesis”. Web site: http://www.analog.com, 1999.

[4] M. Shin, *et al*., “The feasibility Study on the 4K-UHD Satellite Broadcasting Service in Ka-Band”, ICCE, 2013.

[5] European Telecommunications Standards Institute. EN 302 755 V1.3.1, 2012.

[6] Digital Broadcasting Experts Group. ABNT NBR 15601, 2009.

[7] Advanced Television Systems Committee. ATSC Digital Television Standard, 2007.

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