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ission Title: [Recent Development of THz Amplifier and Low Complexity Beamforming Sch

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act: [The research group at Korea University, Tera Hz LAN/PAN Wireless System Group (thing) presents the recent deve
plifier and the low compelxity beamforming schemes which are critical in making the THz system feasible.]

se: [Information of feasibility of THz hardware from our recent development of the THz am
w complexity beamforming.]

Recent Development of THz Amplifier and Low Complexity Beamforming Schemes

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- Introduction of THz Wireless LAN/PAN Sys. Group at Korea University
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- Conclusion

. THz Wireless LAN/PAN System Group Korea University

- Project title
  - Development of THz Wireless LAN/PAN System
- Member
  - 6 Faculty member and 15 MS/Ph.D students in Korea University
    - Director: Prof. Chulhee Kang
    - PHY layer: Prof. Jun Heo and Prof. Young-Chai Ko
    - MAC layer: Prof. Sangheon Pack
    - Antenna/Amplifer: Prof. Moon-Il Kim
    - RFIC: Prof. Jae-Sung Rhie
- Project
  - 5 year project from 2008-2012
  - Supported by Korea Government Funding Agency, IITA (0.5m USD/year)

On-Going Research Topics

- PHY area
  - Techniques to overcome NLOS channel environment
    - Relay schemes
    - Beamforming with low complexity
- MAC area
  - Improved MAC process to support 20-40 Gbps data rate such as in THz comm system
  - Distributed relay MAC protocol
- Antenna/RFIC
  - Linear amplifiers and power amplifiers as basic building blocks
  - Mixers and VCOs to complete the transceiver systems
  - Lens waveguide system
  - Dichroic plates and metamaterial filters

2. Development of THz Amplifier

Background

- Conventional RF signal generation → Diode-base multiplier chain
  1) Unavailable to fabricate planar circuit - Impossible for mass production
  2) Impossible to design amplifiers - High noise figure
- Recently, THz transistor device is being developed
- Circuit design method is needed proper to THz transistor device process

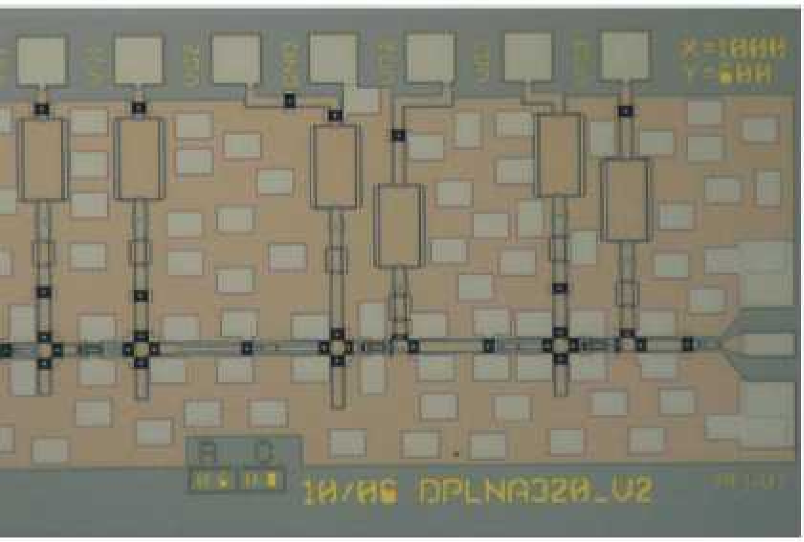
Approach

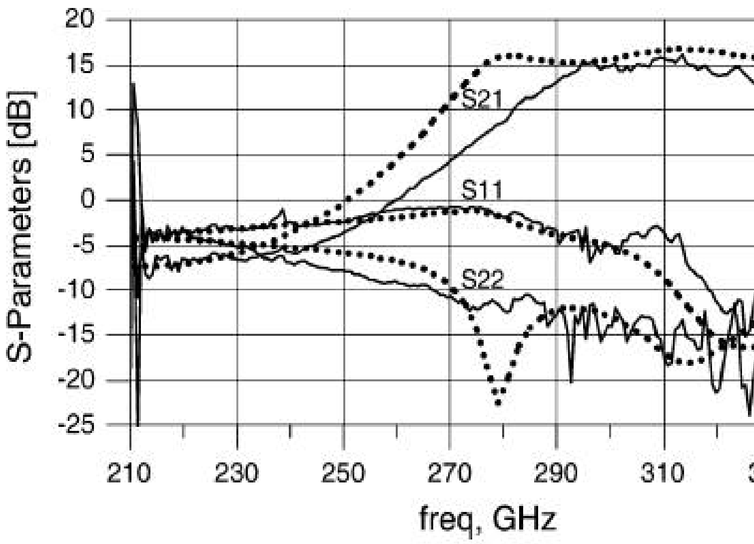
- Cooperation with Teledyne, one of the THz device manufacturers
- Design 10dB amplifier at 300GHz using Teledyne 0.25um InP HBT* process
- Special circuit design scheme
  (ex. negative feedback circuit, bias network)

* Heterojunction Bipolar Tr

(Trend) Research of Other Group

2008 “Submillimeter-Wave InP MMIC Amplifiers From 300–345 GHz”





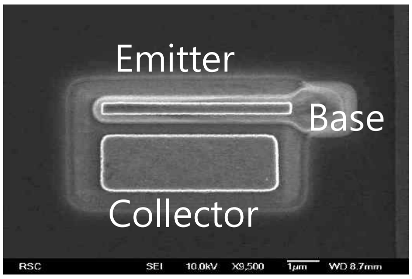
- Northrop 35nm InP HEMT* process is used
- Three-stage common-source type: 15dB at 310GHz
- Circuit size: 1.0x0.6 mm^2

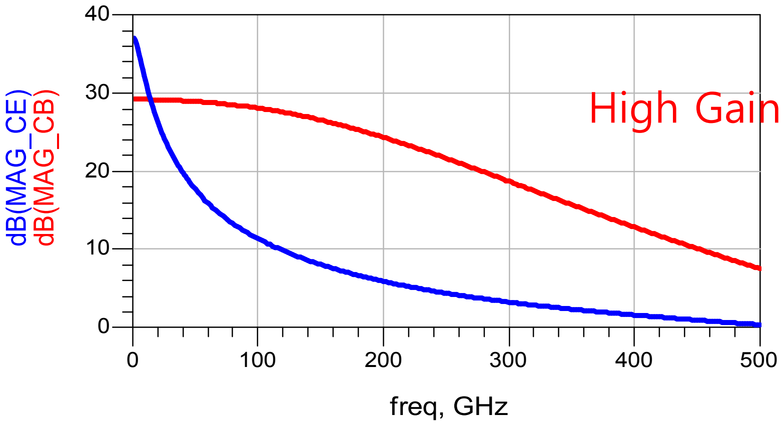
* High Electron Mobility Tran

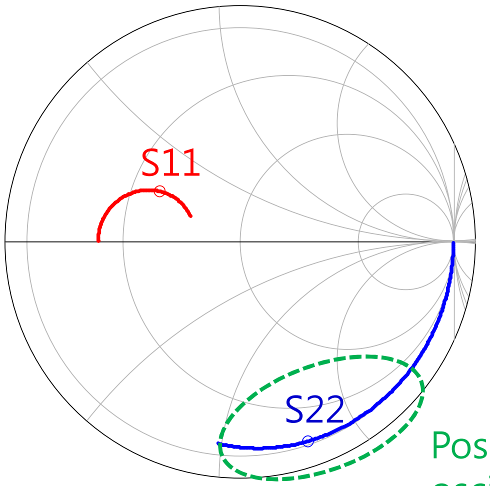
Device Analysis for Basic Amp Configuration

DC Bias: Ic=10mA, Vce=1.5V

<Common Base(CB) configuration>

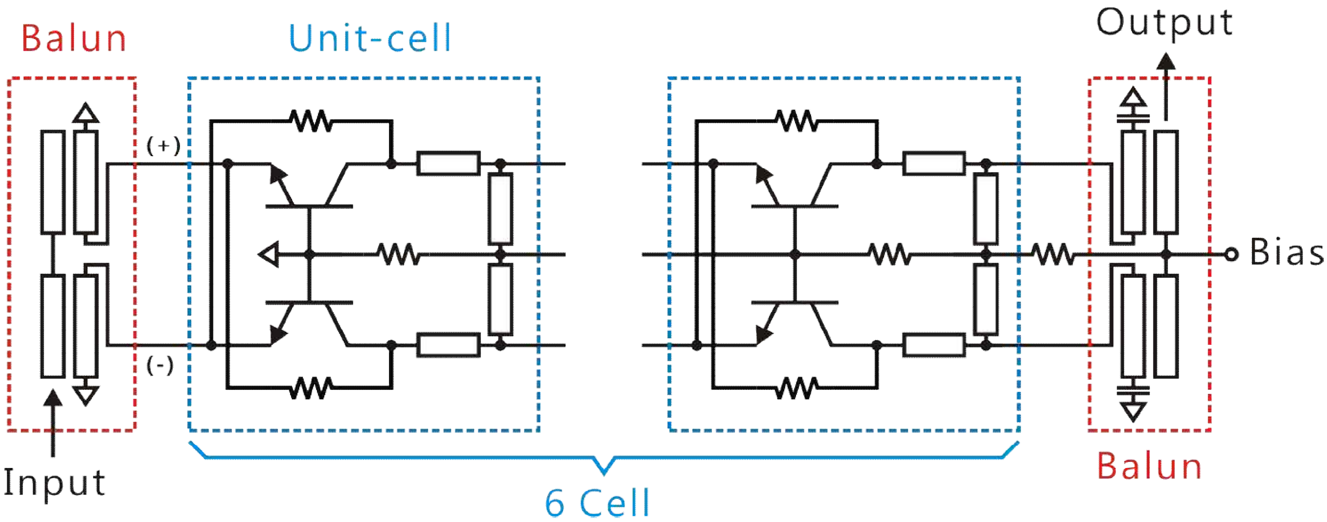


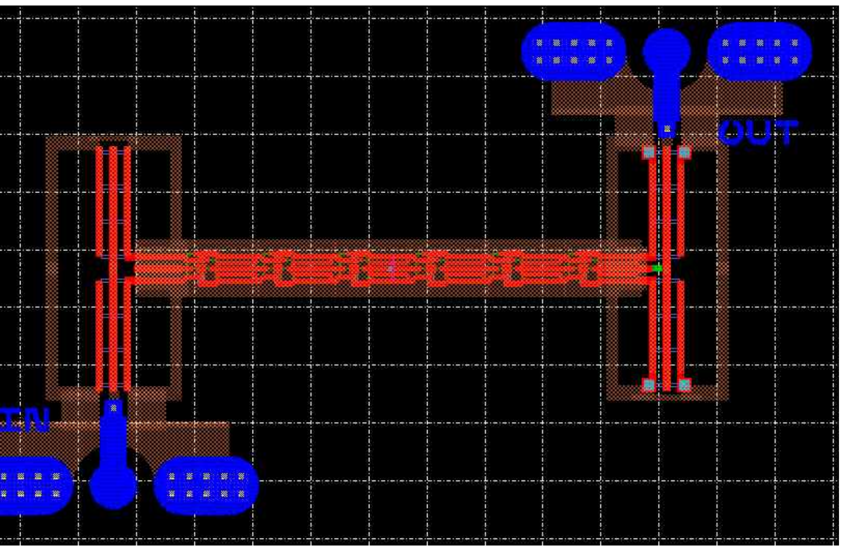




- For high gain
  - Multistage and common-base configuration
- Oscillation suppression
  - Negative feedback resistor with 180° phase change

300GHz Amplifier Design

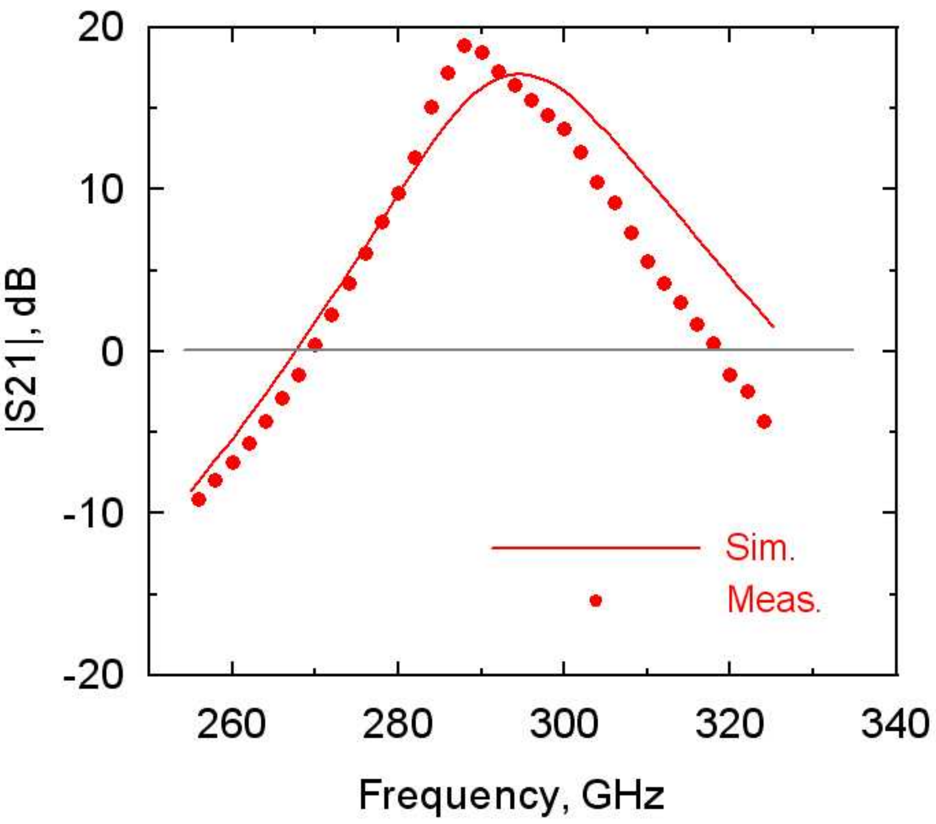


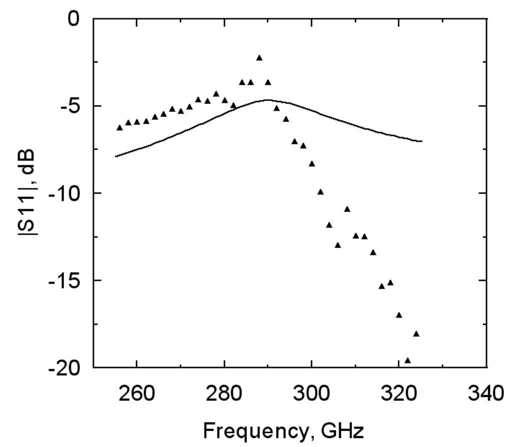


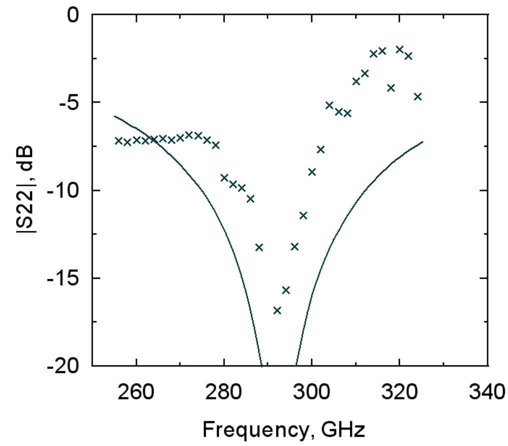
- 6-stage Differential Common-Bas Amplifier
- Cross-connected (180° phase cha negative feedback resistor is used
- Total circuit size (with pads) is 0.73 x 0.45 mm^2

Measurement Results

18.5 dB peak gain @ 289 GHz, 14 dB gain @ 300 GHz
Input and output are well-matched and no oscillation







3. Low Complexity Beamforming

Beamforming

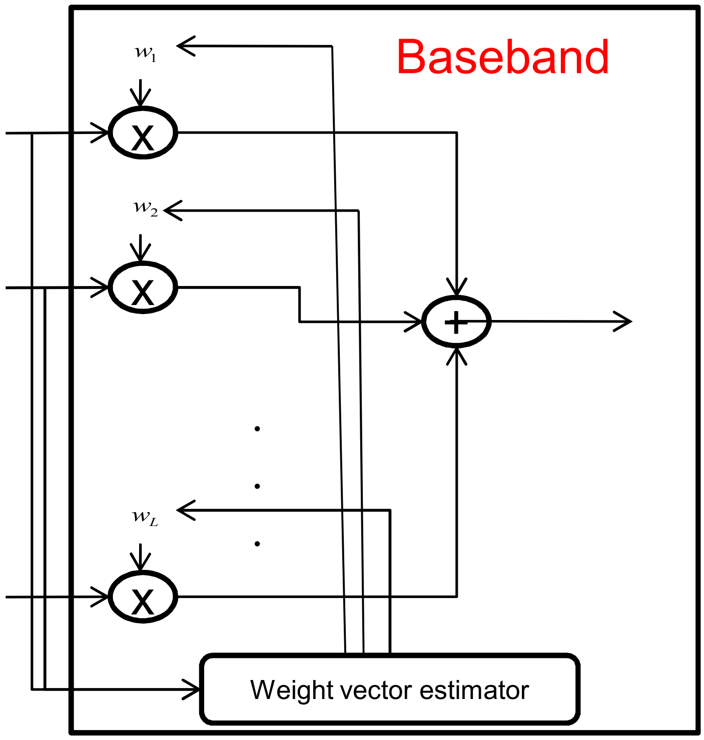
- Using the multiple antennas to obtain high antenna gain
- In Tera Hz system, BF must be employed due to high path loss.

Issues

- Conventional Beamforming is based on the signal combining at the baseband the multiple RF chains (the same number of antennas).
- Having multiple RF chains including the ADC/DAC for the implementation of beamforming might be not feasible in THz system due to complexity, which r very high data rate system with very large bandwidth.
- For example, 20Gbps using OOK modulation requires 40Gsamples/sec in the baseband. For beamforming with 2 antenna systems (i.e., two RF chains), the baseband might need to be running 80Gsample/sec to aggregate the sample from each RF chain.

Conventional Baseband Beamforming

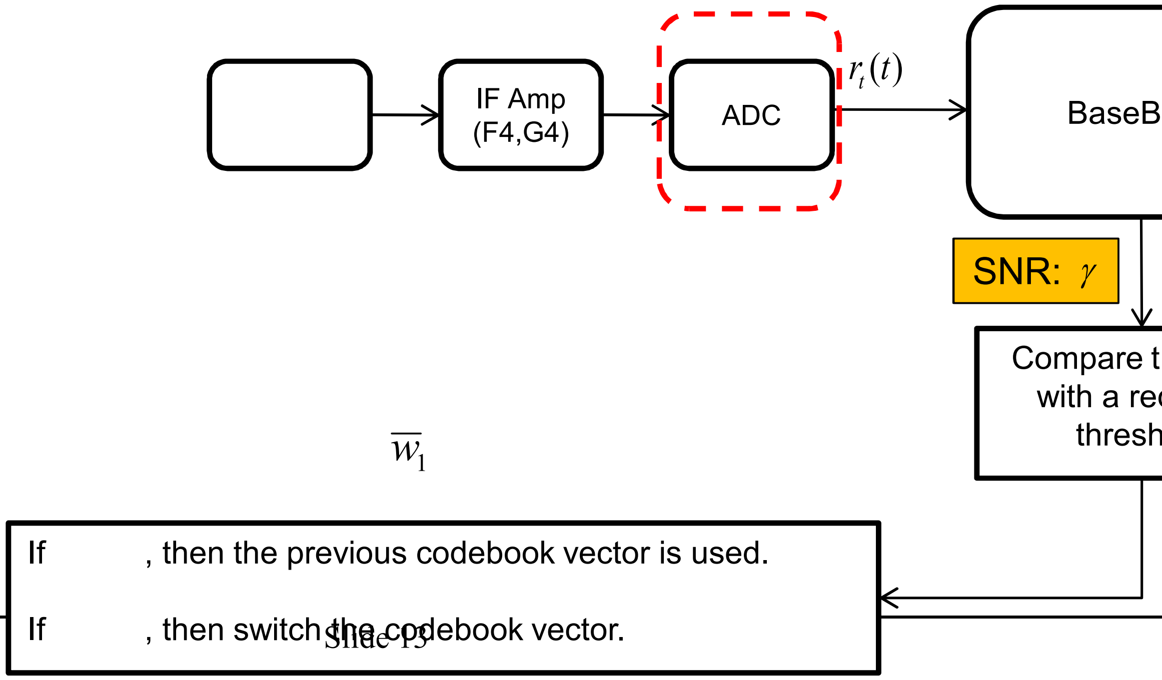
- Structure



- Complexity
  - Very high due to multiple RF chains (the same as the number of antennas)
  - Processing time of BB based on TDM is very high due to multiple ADC/DACs

RF Beamforming

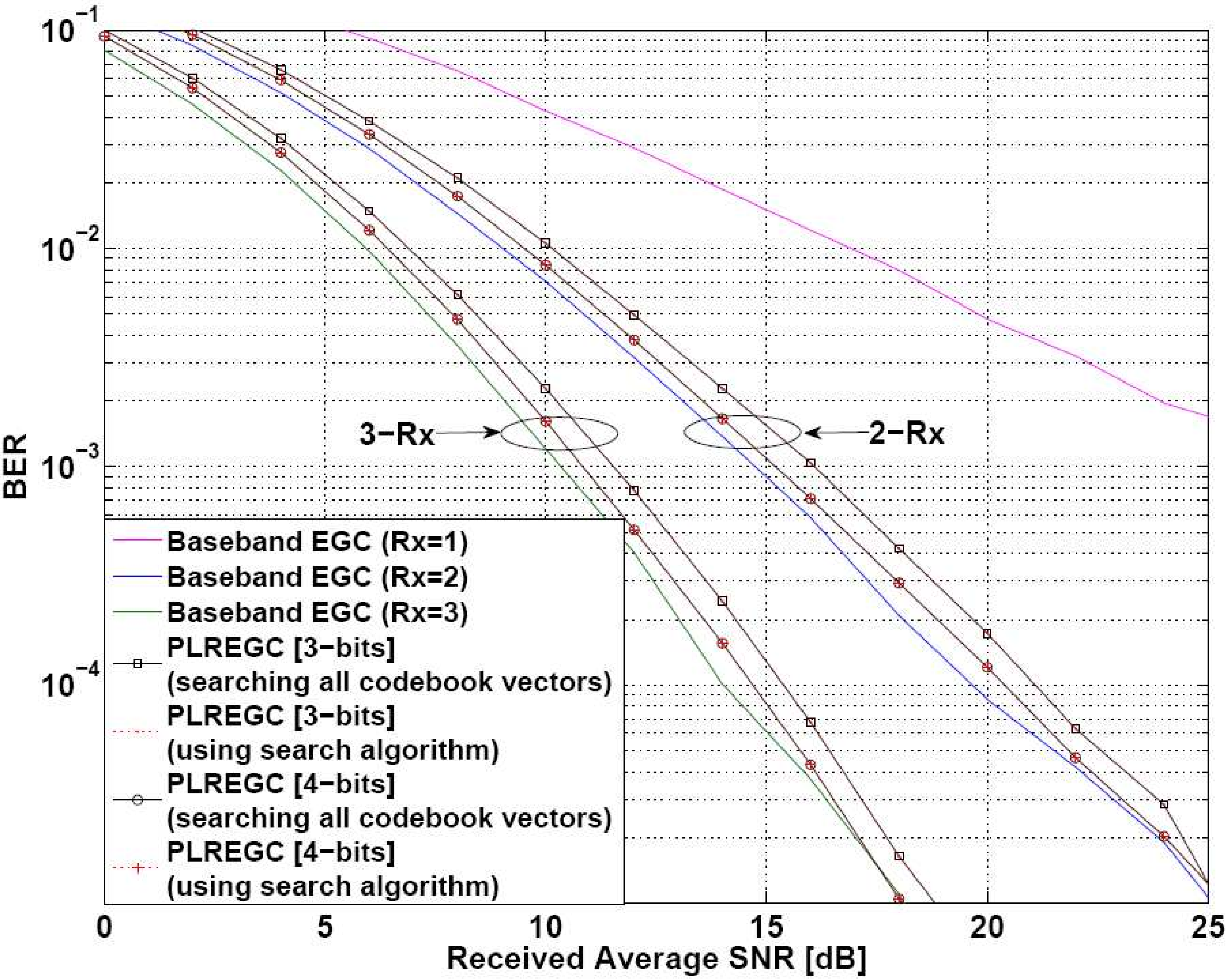
- Motivation
  - Single ADC/DAC and the minimal usage of RF components
- Equal gain Beamforming (only phase control) was presented at Globecom'2009



Characteristics of RF Beamforming

- Phase shifter
  - Phase information is provided from the channel estimation of the Baseband.
- Combining
  - Combiner is located after LNA to reduce the overall noise figure.
- Phase information
  - Since the input signal to baseband is the combined signal (or beam formed signal), the accurate phase information of each antenna path is not possible.
  - We proposed codebook vector switching algorithm for the phase information in Globecom'09.
    - There exists a certain predefined codebook set (or matrix).
    - Arbitrary selected codebook vector is selected and tested to see if the received SNR of the signal meets a certain threshold. If it meets, the weight vector search is stopped. Otherwise, it switches to the other codebook vector and follow the same procedure.

Numerical Examples



Conclusion

- THz Amplifier
  - Based on advanced HBT device technology developed by Teledyne Scientific, better than 20 dB of small signal gain over 60 GHz bandwidth centered at 300 GHz has recently been achieved.
  - With better than 15dB of small signal gain, first ever power measurement is being attempted at 325 GHz.
- Low complexity Beamforming
  - Single RF chain and single ADC/DAC BF is proposed as well as the beam tracking algorithm.