行政院國家科學委員會專題研究計畫 期中進度報告

60 GHz 無線生醫感測網路晶片系統(1/3)
期中進度報告(精簡版)

計 畫 類 別 ：個別型
計 畫 編 號 ：NSC 95-2218-E-002-042-
執 行 期 間 ：95 年 02 月 01 日至 96 年 01 月 31 日
執 行 單 位 ：國立臺灣大學電機工程學系暨研究所

計 畫 主 持 人：呂學士
共 同 主 持 人：王晉良、張守進、羅錦興、孟慶宗、林裕城
黃榮山、莊英宗、張大強

報 告 附 件 ：國際合作計畫研究心得報告

處 理 方 式 ：本計畫可公開查詢

中 華 民 國 96 年 01 月 15 日

行政院國家科學委員會補助專題研究計畫 □ 成 果 報 告
■期中進度報告

60 GHz 無線生醫感測網路晶片系統

計畫類別：■ 個別型計畫 □ 整合型計畫
計畫編號：NSC 95－2218－ E － 002 － 042 －
執行期間： 95 年 2 月 1 日至 96 年 1 月 31 日

計畫主持人：國立臺灣大學電機工程學系暨研究所 呂學士 教授
共同主持人：國立臺灣大學應用力學研究所 黃榮山 副教授
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財團法人國家實驗研究院國家晶片系統設計中心 張大強 副研究員
計畫參與人員：

成果報告類型(依經費核定清單規定繳交)：■精簡報告 □完整報告

中 華 民 國 96 年 1 月 15 日

行政院國家科學委員會專題研究計畫進度報告

計畫編號：NSC 95-2218-E-002-042

執行期限： 95 年 2 月 1 日至 96 年 1 月 31 日

主持人：呂學士 博士 台灣大學電子所教授

計畫參與人員：陳筱青、陳春豪、林宥佐、汪濤、廖芳仁、陳憲穀

台灣大學電子所博士班研究生

一、中文摘要

我們進行對 ASK 調變接收機的系統分析，發現該接收機在 10 MHz 頻寬下可達成約 -87.2dBm 的靈敏度。此外我們對於在金氧半製程裡的整合式晶片天線進行 S 參數的模擬及量測。並對於這些晶片式天線的增益和場形做進一步的研究。由於矽基板的導電性，晶片式天線的增益一般上約為-7.5 dB 至 -8.5 dB。我們也發現量測時在待測物下方的金屬地板會對晶片式天線的導向性與增益有極大的影響，必須要將此地板排除。

關鍵詞: 天線，金氧半製程，接收機

Abstract

The system analysis of a ASK receiver was performed. With a given noise bandwidth of 10 MHz and a required SNR of 10 dB, the receiver can achieve a sensitivity of -87.2 dBm. In addition, the simulation / measurement of S-parameters for integrated antennas in CMOS processes were performed. The gain and pattern for these chip-antennas were also investigated. Due to silicon-substrate conductivity, the chip-antennas exhibited gain of -7.5 dB to -8.5 dB. It was also found that the grounded metal plate under the device-under-test during the measurement would have large impact on the directivity and gain of the antenna, which should be prevented.

Key Words: Antenna, CMOS, Receiver

二、研究目的

由於本計畫要建造一個操作於 60-GHz 的無線單晶收發系統，必須先對整個系統做一完整的分析。在本年度我們先針對收發機的靈敏度去考慮，並依此訂出各個子電路的規格。此外 CMOS 的晶片式天線技術尚未成熟，我們也必須要先對此種天線的特性做一深入的探討，並依此得出最佳的解決方案。

三、研究內容

ASK receiver system analysis

The architecture of our 60-GHz receiver is shown in Fig.1. The ASK modulation was chosen to implement the system for its advantages of simplicity and power-saving. The receiver consists of a LNA, a sub-harmonic mixer and a demodulator. All the circuit performances are provided by the designers of these circuits, based on their simulation.

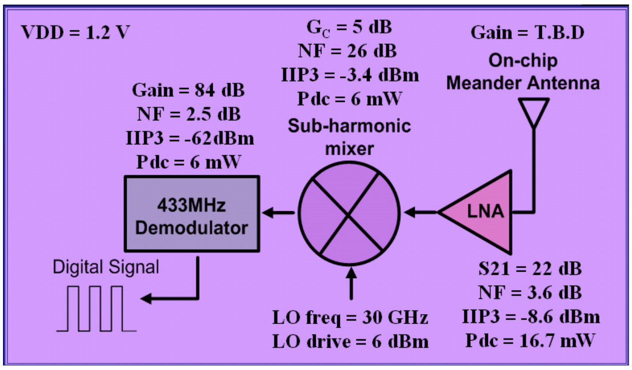
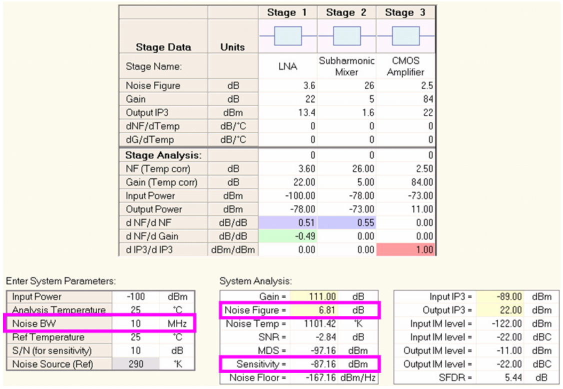


Fig. 1 The ASK receiver block diagram

A system analysis has been performed with the receiver chain as shown in Fig.2. The cascade noise figure is 6.8 dB. For ASK modulation, to achieve bit-error-rate of 10^{-3}, the required SNR is 10 dB. With a given noise bandwidth of 10 MHz and a required SNR of 10 dB, the receiver can achieve a sensitivity of -87.2 dBm. However, poor linearity or the lack of channel filter would degrade the sensitivity.



Stage Data	Units	Stage 1	Stage 2	Stage 3
Stage Name:		LNA	Subharmonic Mixer	CMOS Amplifier
Noise Figure	dB	3.6	26	2.5
Gain	dB	22	5	84
Output IP3	dBm	13.4	1.6	22
dNF/dTemp	dB/°C	0	0	0
dG/dTemp	dB/°C	0	0	0
Stage Analysis:		0	0	0
NF (Temp corr)	dB	3.60	26.00	2.50
Gain (Temp corr)	dB	22.00	5.00	84.00
Input Power	dBm	-100.00	-78.00	-73.00
Output Power	dBm	-78.00	-73.00	11.00
d NF/d NF	dB/dB	0.51	0.55	0.00
d NF/d Gain	dB/dB	-0.49	0.00	0.00
d IP3/d IP3	dBm/dBm	0.00	0.00	1.00

Enter System Parameters:

Input Power	-100	dBm
Analysis Temperature	25	°C
Noise BW	10	MHz
Ref Temperature	25	°C
S/N (for sensitivity)	10	dB
Noise Source (Ref)	290	°K

System Analysis:

Gain =	111.00	dB
Noise Figure =	6.81	dB
Noise Temp =	1101.42	°K
SNR =	-2.84	dB
MDS =	-97.16	dBm
Sensitivity =	-87.16	dBm
Noise Floor =	-167.16	dBm/Hz

Input IP3 =	-89.00	dBm
Output IP3 =	22.00	dBm
Input IM level =	-122.00	dBm
Input IM level =	-22.00	dBC
Output IM level =	-11.00	dBm
Output IM level =	-22.00	dBC
SFDR =	5.44	dB

Fig. 2 The ASK receiver system analysis

Bond-wire characterization for antenna pattern measurement

To measure the antenna pattern, the antenna chip will be mounted on a ceramic evaluation board and fed with CPW. The interconnection will be bond-wires. Therefore, EM-simulations by ADS-momentum have been performed to check if there is any undesired radiation due to those bond-wires. The layout used in the EM-simulation is shown in Fig. 3. The length of each bond-wire is 500-um. CPW-mode is applied at both sides by using the slot-method. Two different cases were considered: In the first case, there's only one wire used as interconnection while in the second case, there're three. The reason why we considered using more wires is the bond-wire lead to certain parasitic inductance. By increasing the number of parallel connected wires to 3, this effect could be minimized from 1.1 nH to 0.39 nH. However, matching network would be still required between the bond-wire and the CPW-feed. By examining the s-parameters obtained in the EM-simulation, we can find out if the bond-wire radiates.

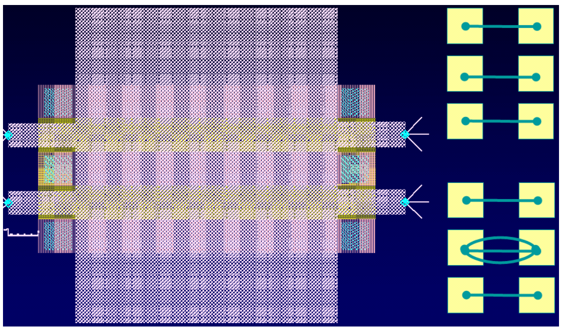


Fig. 3 Layout of bond-wire in EM-simulation

As shown in Fig.4, the summation of reflection and insertion coefficient is almost 1. Namely, the energy of the incident power is either reflected back to the input or transferred to the output. Therefore, we can say that the energy radiated from the bond-wires is negligible or can be ignored.

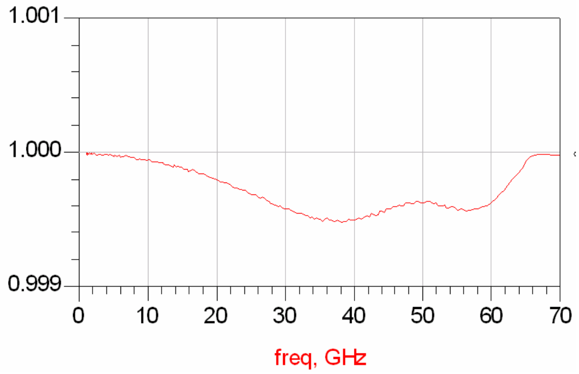


Fig. 4 The summation of reflection and insertion coefficient

On-chip antenna simulation

By scaling the dimension of an antenna in a referenced work [1], a few meander antennas were designed as shown in Fig. 5 and fabricated in UMC 0.18-um CMOS process. The measurement of S11 has been performed and the optimal input match occurred at 71.5-GHz and 40.0GHz for meander antennas with total length of 403 um and 694 um, respectively.

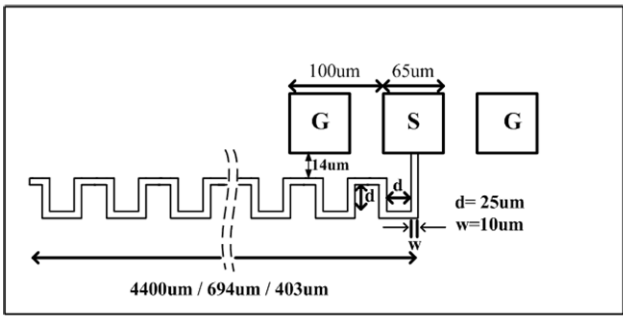


Fig.5 The schematic of on-chip meander antennas

The simulation results for meander antennas would be organized as follows:

1. The meander antenna with length of 694 um in UMC 0.18um CMOS process
    a. Measured S11 of chip antennas before / after post process
    b. Simulated S11 of chip antenna on

grounded metal plate
    c. Simulated S11 and pattern of chip antenna on PCB
2. The meander antenna with length of 403 um in UMC 0.18um CMOS process
    a. Simulated S11 of chip antenna on grounded metal plate
    b. Simulated S11 of chip antenna in free space
    c. Simulated S11 of chip antenna with thinned substrate in free space
    d. Link-budget consideration for antenna in 2-c
3. The meander antenna with length of 337 um in TSMC 0.13um CMOS process
    a. Simulated S11 of chip antenna on grounded metal plate

Meander antenna with length of 694 um by UMC CMOS 0.18um 1P6M

The S11 measurement results of meander antenna with length of 694 um before and after inductively-couple-plasma (ICP) post process were both shown in Fig. 6. S11 was measured with the chip put on the metal plate which is connected to ground.

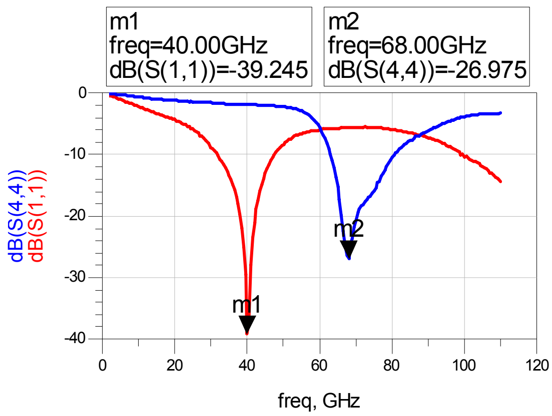


Fig. 6 The measured S11 of the meander antenna with a total length of 694 um

Due to the frequency limit of the measurement, the radiation pattern of the meander antenna with a total length of 694 um would be measured first. The following simulation was done for this antenna and would be compared with the measurement in the future. The layout used in the simulation is shown in the Fig. 7.

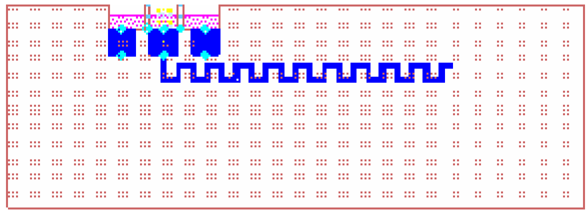


Fig. 7 Layout view in the ADS momentum simulation

First, a simulation was performed with the chip put on the metal plate as in the measurement. It can be found in Fig.8 that the simulation result agreed with the measurement in terms of S11. However, the gain was pretty poor.

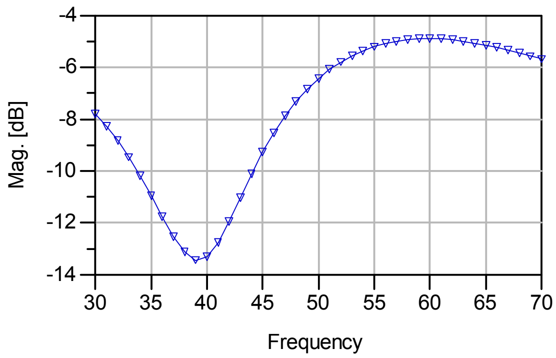


Fig. 8 The simulated S11 for meander antenna with length of 694 um on the grounded metal plate of the probe station

The antenna parameters obtained are as follows; D~ 5dB, Gain ~ -20dB @ 40GHz. The antenna chip will be mounted on a printed board for the pattern measurement and a corresponding simulation was performed. As shown in Fig. 9, the optimal frequency of S11 was shifted to 36 GHz. In addition, the gain was improved from -20 dB to -11.3 dB.

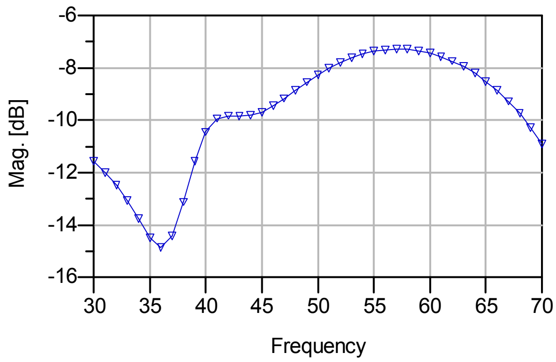


Fig. 9 The simulated S11 for meander antenna with length of 694 um on a dielectric layer (thickness=254 um, dielectric constant=9.9)

The antenna-parameters obtain from the EM simulation are as follows: D~ 5.8dB, Gain ~ -13.1dB @ 36 GHz D~ 5.7dB, Gain ~ -11.3dB @ 40 GHz. The following graphs are simulated radiation pattern for this meander antenna.

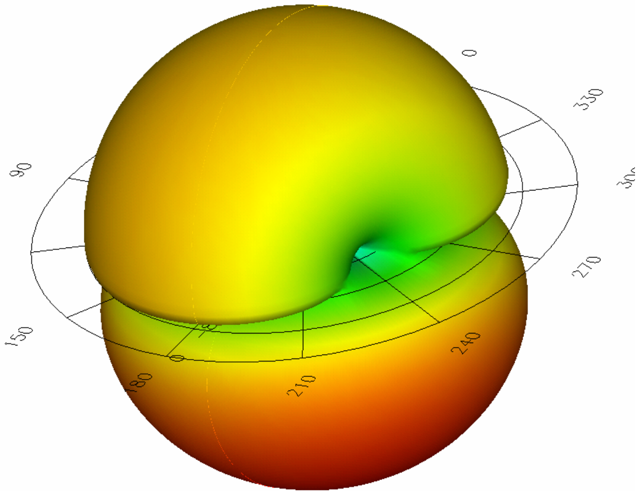


Fig.10 (a) 3-D antenna pattern

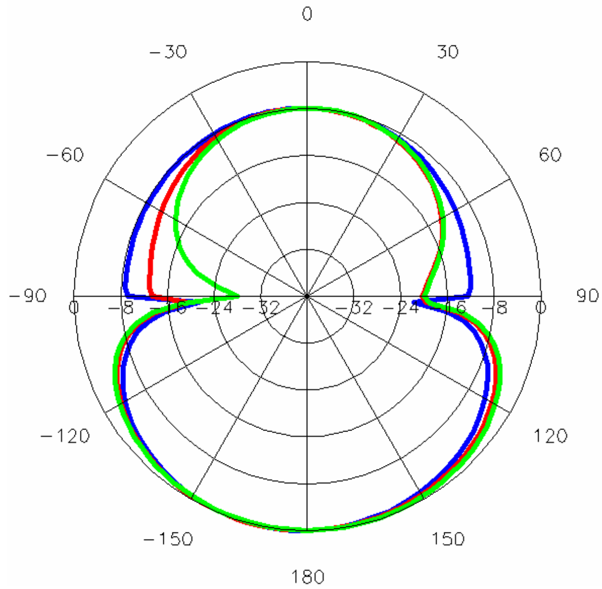


Fig.10 (d) 2-D cut antenna pattern

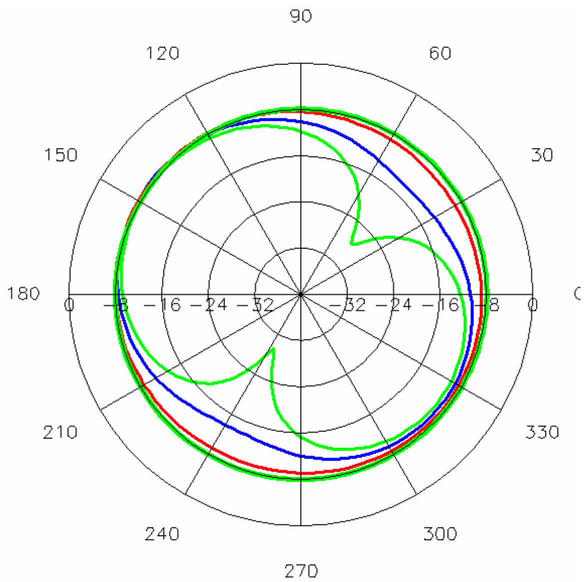


Fig.10 (b) 2-D cut antenna pattern

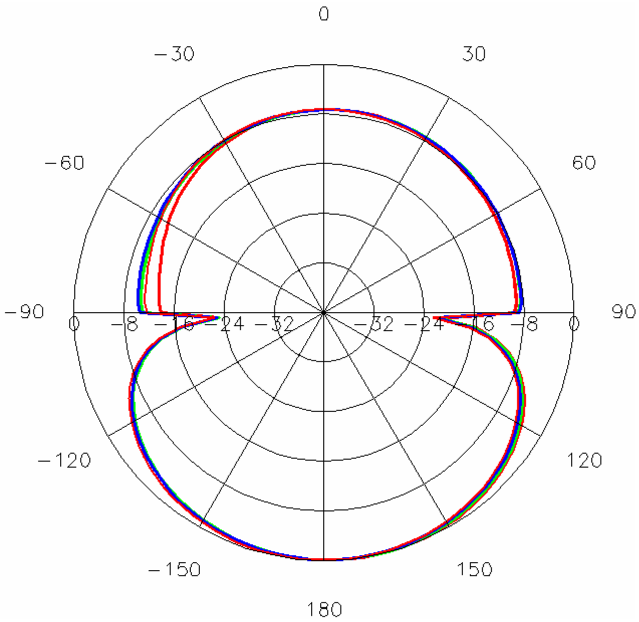


Fig.10 (e) 2-D cut antenna pattern

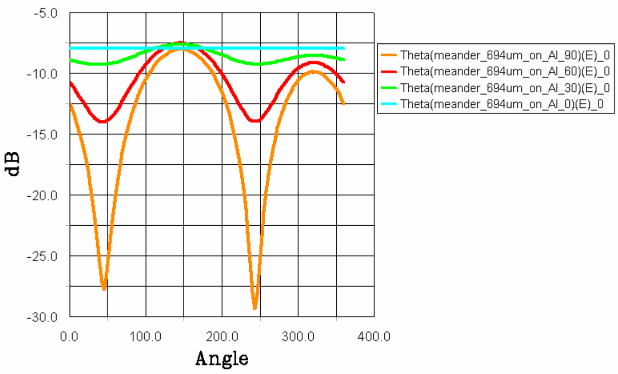


Fig.10 (c) 2-D cut antenna pattern

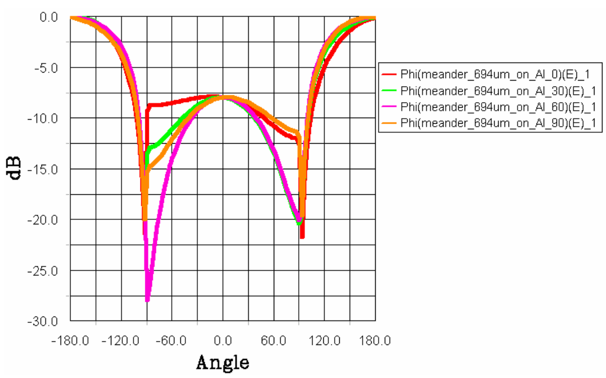


Fig.10 (f) 2-D cut antenna pattern

Meander antenna with length of 403 um by UMC CMOS 0.18um 1P6M

S11 was measured with the chip put on a metal plate which is part of the probe station and connected to ground. In fact, the chip can be put on glass or other dielectric materials. Again, a simulation was performed with the chip put on the metal plate as in the measurement. It was found that the simulation result agreed with the measurement in terms of S11. And then a similar simulation was performed with the chip in free space. It was found the gain was improved from -20.3 dB to -8.5 dB by removing the metal layer under the chip.

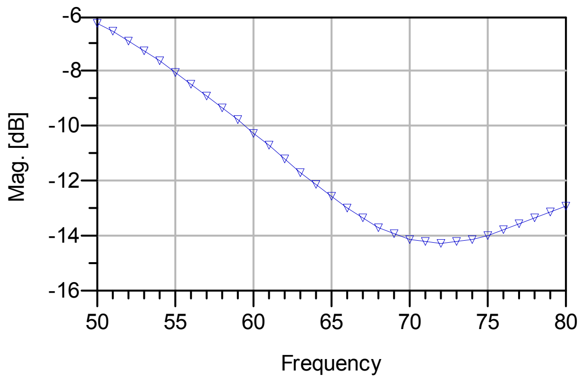


Fig.11 The simulated S11 for meander antenna

Chip in free space, silicon substrate thickness=320um, D=5.2 dB, Gain=-8.5 dB

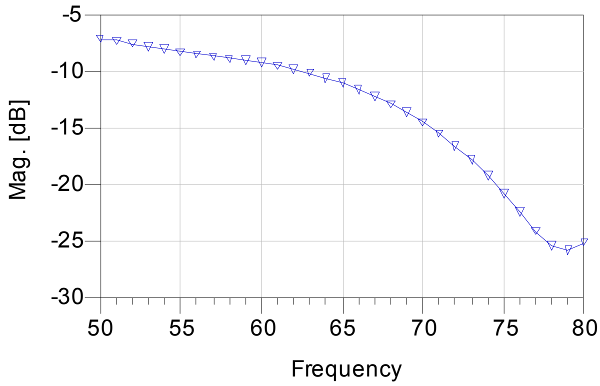


Fig.12 The simulated S11 for meander antenna

And then, another simulation was performed to see the effect of the silicon substrate thinning by inductively coupled plasma (ICP) post process. It was found the gain could be improved while the antenna became less directive and probably more suitable for in-door applications.

Sample in free space, silicon substrate thickness=50um → D=2.4 dB, Gain=-7.5 dB

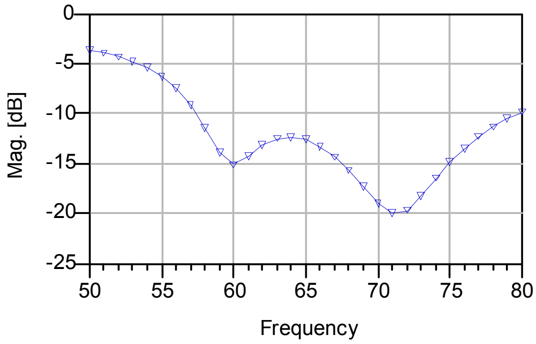


Fig.13 The simulated S11 for meander antenna

If the sensor nodes are at a distance of 1 meter, the received power can be estimated as follows:
Pr = Pt (dBm) + TX-Antenna-Gain (dB) + RX-Antenna-Gain (dB) – Path Loss
Assuming that the transmitted power Pt is around 0 dBm and the path loss at 60 GHz in free space is 68 dB for 1 meter. A received power of at least -84 dBm can be obtained, which leaves 3 dB margins for our system. To achieve larger coverage, either the transmitted power or the number of sensor nodes should be increased for the given receiver sensitivity.

Chip in free space, silicon substrate thickness=320um, D=5.8 dB, Gain=-13.5 dB

Using the process parameters of TSMC 0.13um CMOS, a meander antenna was simulated. To achieve input matching at 60-GHz, the total length should be reduced.

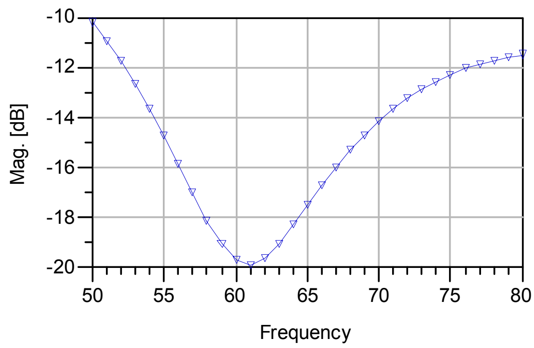


Fig.14 The simulated S11 for meander antenna

四、參考文獻

[1] M. Sun, Y. P. Zhang and G. X. Zheng, "Modeling and Measurement of the On-chip Meander Antenna Pair", APMC 2005.

台加雙邊國際合作會議報告

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[a]國立台灣大學電子所暨電機系
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一、參加會議經過

二○○六年台加雙邊生醫暨環境無線感測會議於十月十八日在加拿大渥太華舉行，有來自台灣大學電機系呂學士教授、台灣大學應力所黃榮山教授、成功大學張守進教授、已來CRC二個月技術合作的三名學生(台大一名，清大一名和成大一名)及加拿大通訊研究中心（Communication Research Center）地面通訊所 Gerry Chan 所長、Dr.Valek 及工程師、TECO的葉楚懿小姐等共二十人與會。此次會議 TECO 負責幫忙接待台灣人員至CRC 開會。會議爲時一天，議程如下附件一所示。

二、會議討論內容

會議由上午九點開始，首先由台灣的三位學生報告在 CRC 二個月所進行的合作計劃進度及討論剩餘的一個月及回台灣後的計劃進行方向（見附件二）。接著由台灣來的四位老師報告生醫無線感應器進度（見附件三）。短暫休息後由 CRC 的 William Wang 和Ibrahim Haroun 進行環境無線感應器進度（見附件四）。此合作計劃乃是針對無線感應器，台灣聚焦於生醫的應用而加拿大 CRC 則具焦於環境的應用。學生方面由於 CRC 的技術協助，已完成了 60GHZ 天線，CMOS 低雜訊放大器及 CMOS 傳輸線的設計。CRC則提出了整個系統架構的規劃，台灣老師方面提出了生醫感應器、無線電路及低頻生醫無線感應器的成果，從而對於台灣和 CRC 的相互了解及合作，可說是邁進了一大步。(至此上午的會議結束)。

三、結論

下午的會議乃交換意見，主要結論如下：明年台灣將再送三名學生（台大、清大和成大各一名）至CRC研究三個月，CIC也將送一名研究人員至CRC做短期研究。明年度的進度討論會約在十月於台灣舉行，從而CRC會率團來訪。另CRC希望能有台積電的設計套件(design kit)，但台積電目前仍不願提供予CRC。台灣老師將再度反應給CIC，請其繼續向台積電爭取。另CRC將多雇用一人，專心於MOS 60GHZ射頻電路設計。會議於圓滿的氣氛結束，大家互道明年臺灣見。

附件一

NTU-CRC Program Review Meeting on
Wireless Sensors for
Biomedical and Environmental Applications

October 18,2006
Location: Room 220, Building76
Time:9:00am-3:00pm

9:00-9:10 Welcoming Remarks,Agenda Review Gerry Chan
9:10-10:00 Student Presentations:
Hsiao-Chin Chen,Yin-Ho Lee,Hung-Chin Wang
10:00-10:40 Wireless Biomedical Sensors:
Shey-Shi Lu,Shoou-Jin Chang,Chin-Chun Meng,Long-Sun Huang
10:40-11:00 Coffee Break
11:00-11:40 Wireless Environmental Sensors
William Wong,Ibrahim Haroun
11:40-1:00 Lunch in Cafeteria Dining Room
1:00-2:45 Discussion:

-Update on Status of Amendment to MOU
-NTU-CRC Agreement
-R&D Plans/Schedule of Activities for next year
-Update of CIC-CRC activities
-Outstanding issues:
  -Availability of TSMC Design Kit
  -Other

2:45-3:00 Identification of Action Items and Concluding Remarks

附件二

Research Activities at CRC for the 60-GHz Biomedical Sensor System

Hsiao-Chin Chen (Nicole)
Graduate Institute of Electronics
National Taiwan University

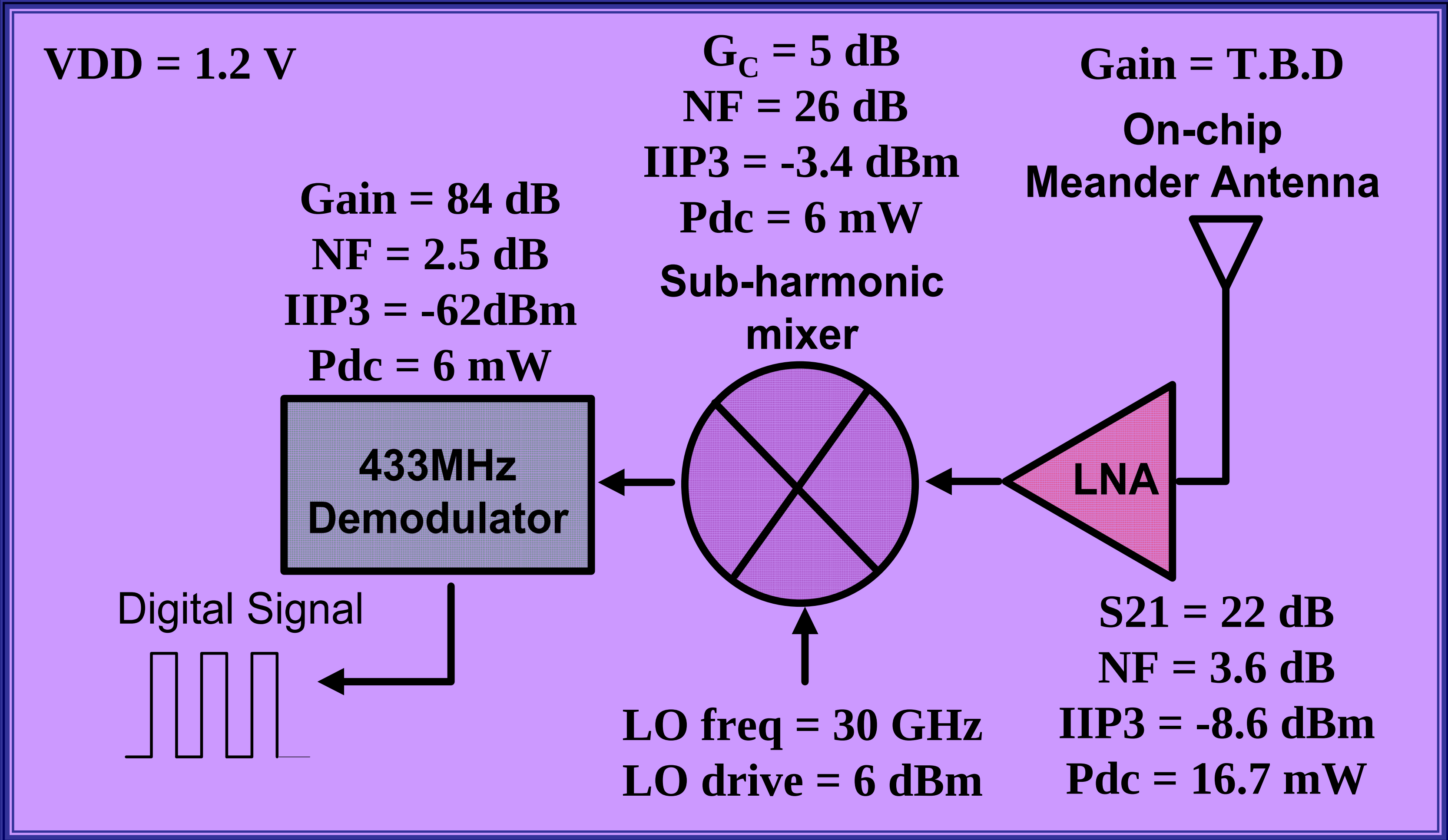
October 18 , 2006
Ottawa, Canada

Outline

- ASK receiver system analysis
- Integrated antennas in CMOS processes
- 60-GHz CMOS LNA Design for wireless sensor applications
- Summary

ASK Receiver System Analysis

60-GHz **ASK** Receiver Architecture



Block and Level System Analysis of the 60-GHz ASK Receiver

Stage Data	Units	Stage 1	Stage 2	Stage 3
Stage Name:		LNA	Subharmonic Mixer	CMOS Amplifier
Noise Figure	dB	3.6	26	2.5
Gain	dB	22	5	84
Output IP3	dBm	13.4	1.6	22
dNF/dTemp	dB/°C	0	0	0
dG/dTemp	dB/°C	0	0	0
Stage Analysis:		0	0	0
NF (Temp corr)	dB	3.60	26.00	2.50
Gain (Temp corr)	dB	22.00	5.00	84.00
Input Power	dBm	-100.00	-78.00	-73.00
Output Power	dBm	-78.00	-73.00	11.00
d NF/d NF	dB/dB	0.51	0.55	0.00
d NF/d Gain	dB/dB	-0.49	0.00	0.00
d IP3/d IP3	dBm/dBm	0.00	0.00	1.00

Enter System Parameters:

Input Power	-100	dBm
Analysis Temperature	25	°C
Noise BW	10	MHz
Ref Temperature	25	°C
S/N (for sensitivity)	10	dB
Noise Source (Ref)	290	°K

System Analysis:

Gain =	111.00	dB
Noise Figure =	6.81	dB
Noise Temp =	1101.42	°K
SNR =	-2.84	dB
MDS =	-97.16	dBm
Sensitivity =	-87.16	dBm
Noise Floor =	-167.16	dBm/Hz

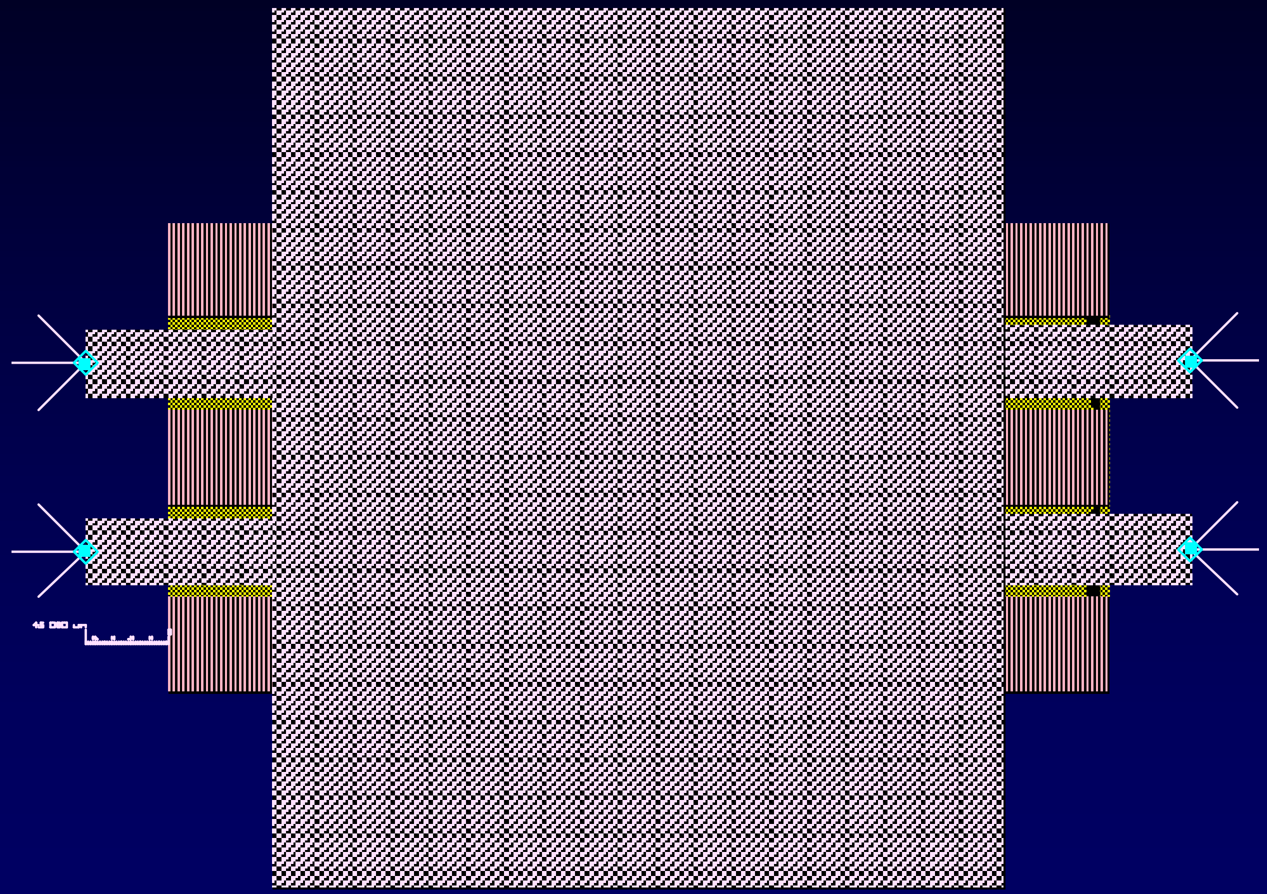
Input IP3 =	-89.00	dBm
Output IP3 =	22.00	dBm
Input IM level =	-122.00	dBm
Input IM level =	-22.00	dBC
Output IM level =	-11.00	dBm
Output IM level =	-22.00	dBC
SFDR =	5.44	dB

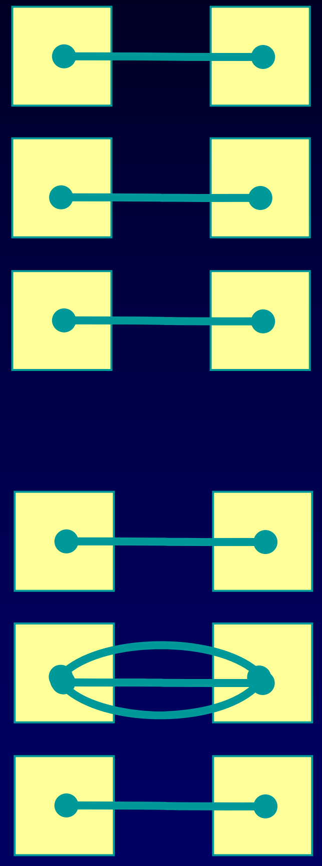
Integrated Antennas in CMOS Processes

Antenna Pattern Measurement

Antenna Simulation

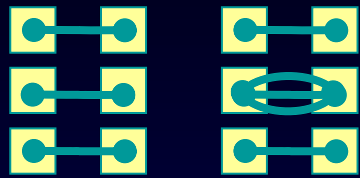
Bond-wire Simulation Layout

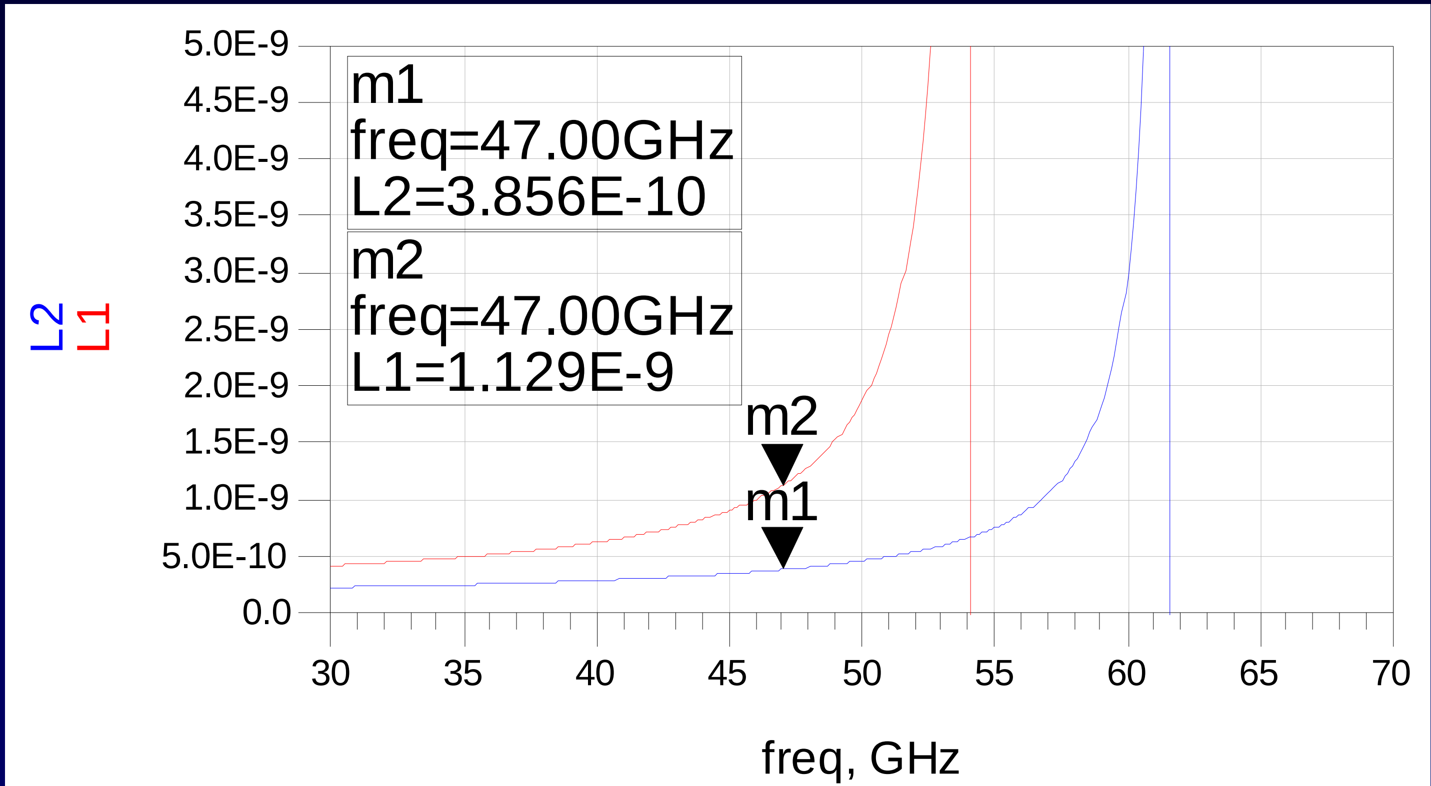




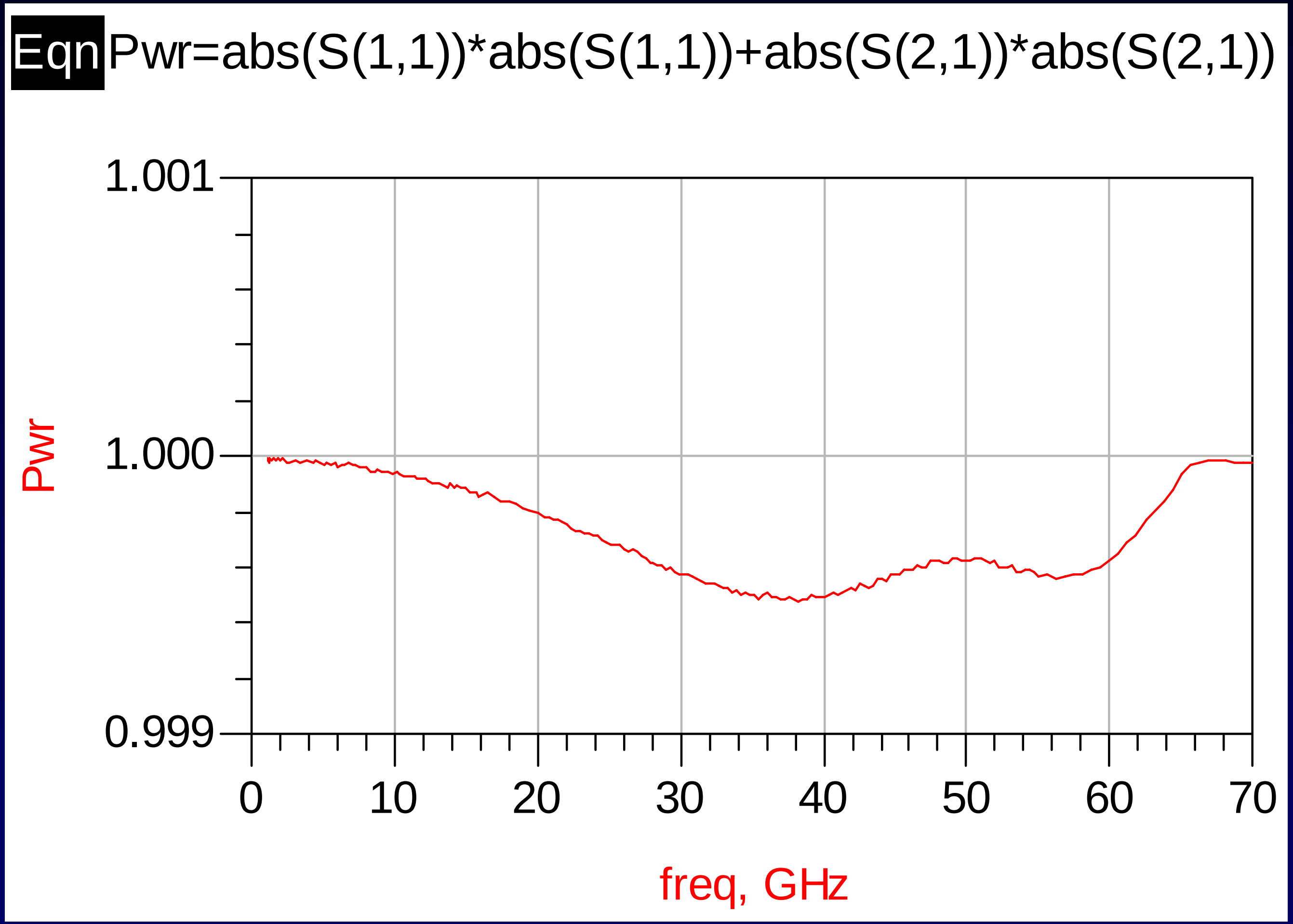
Simulated Results of the Bond-wire Parasitic Inductances

L1 : one bond-wire only , ~ 1.1 nH
L2 : three bond-wires in parallel , ~ 0.39 nH





Simulated Results of the Bond-wire Radiation

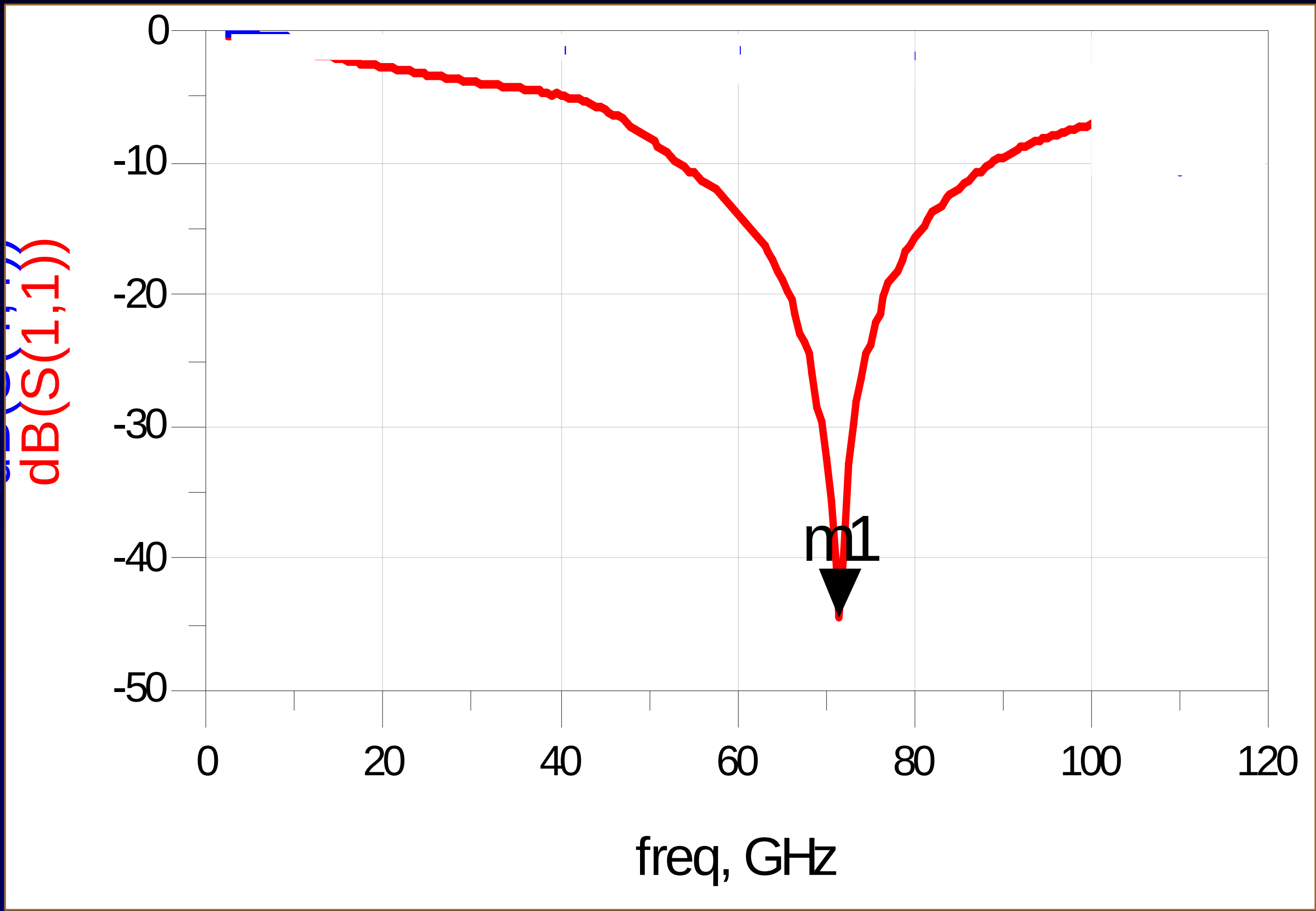


Integrated Antennas in CMOS Processes

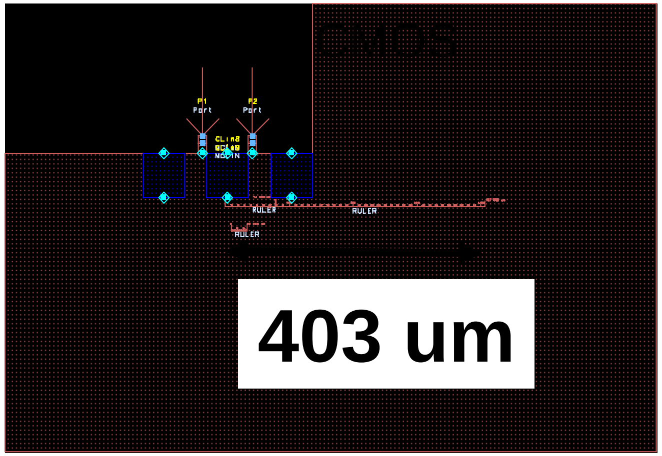
Antenna Pattern Measurement

Antenna Simulation

Measured S11 of the On-Silicon Meander Antenna



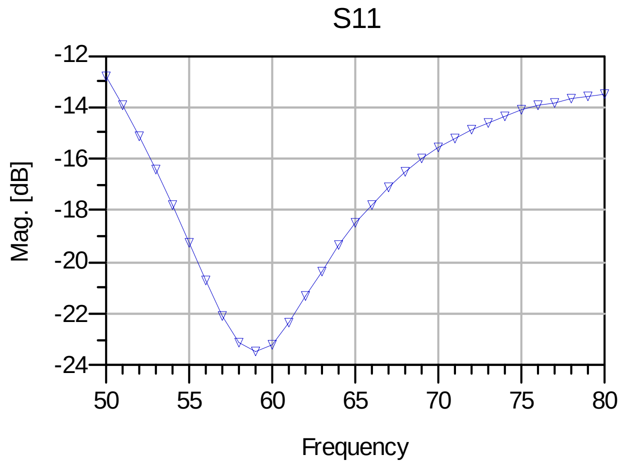
Layout and Simulation S11 of On-Silicon Meander Antenna

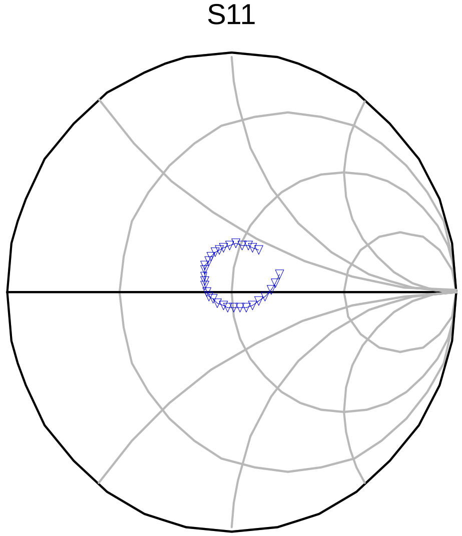


Directivity = 5.55 dB

Gain = -12.62 dB

Why is there such a discrepancy between simulation and measurement?



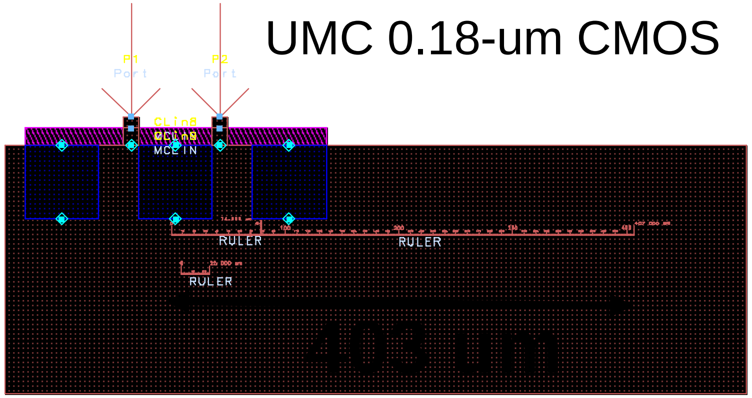


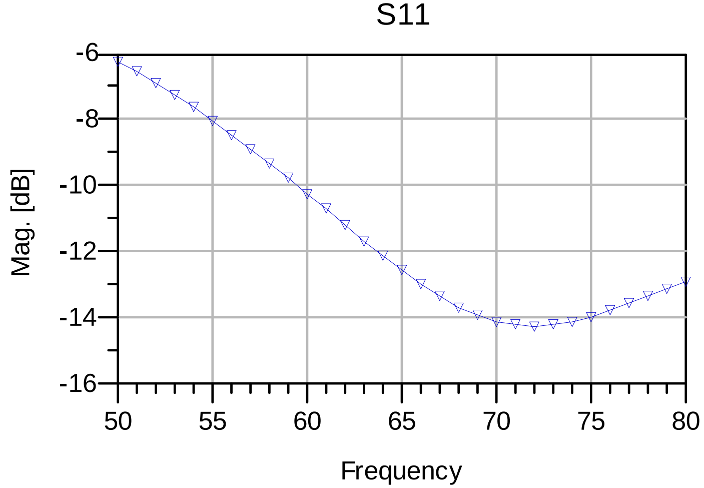
Layout and Simulation S11 of On-Silicon Meander Antenna (cont.)

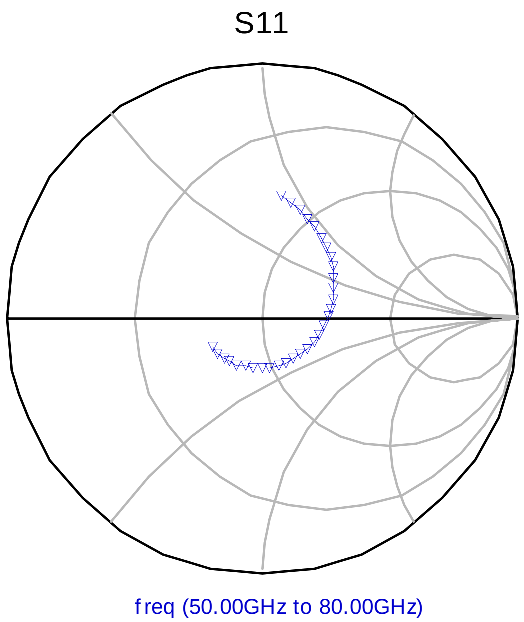
UMC 0.18-um CMOS

Directivity = 5.15 dB

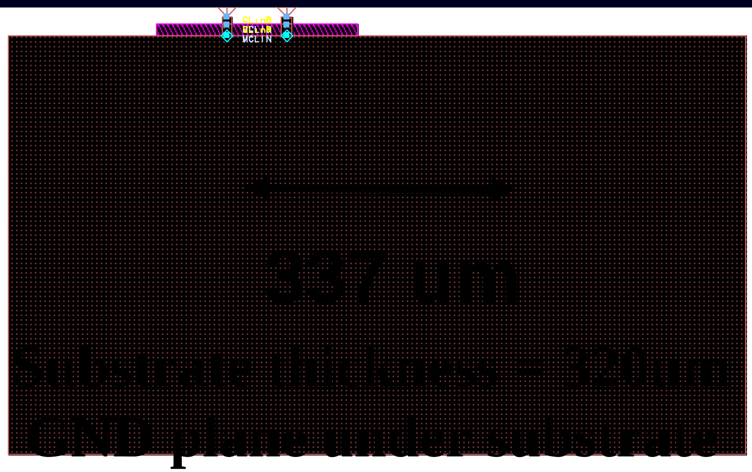
Gain = -20.34 dB







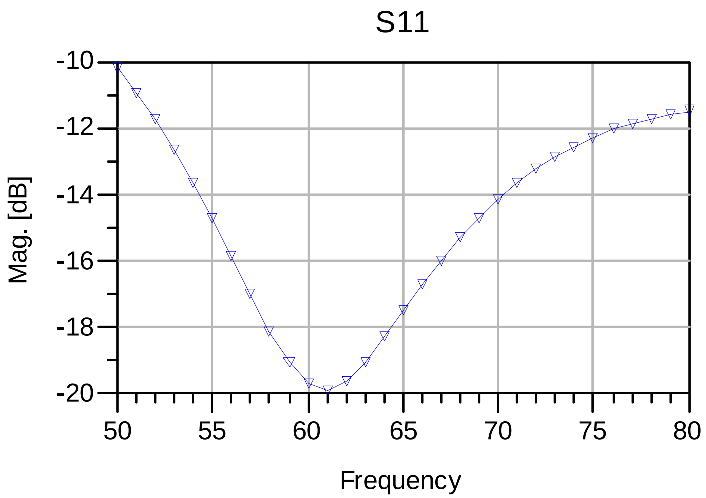
Layout and Simulation S11 of On-Silicon Meander Antenna (cont.)

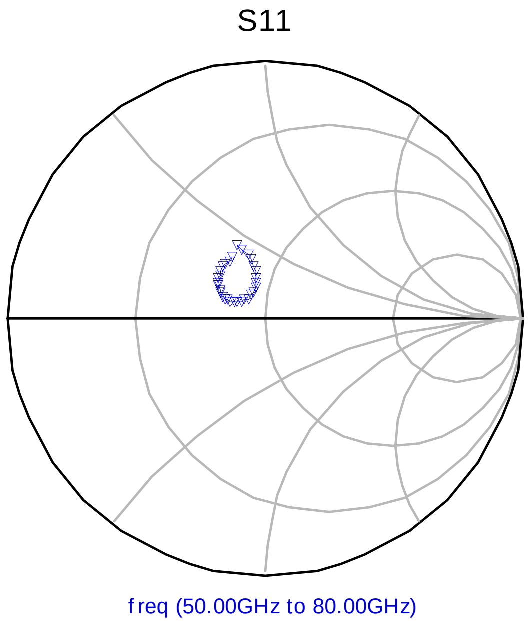


Directivity = 5.75 dB

Gain = -13.47 dB

TSMC 0.13-um CMOS



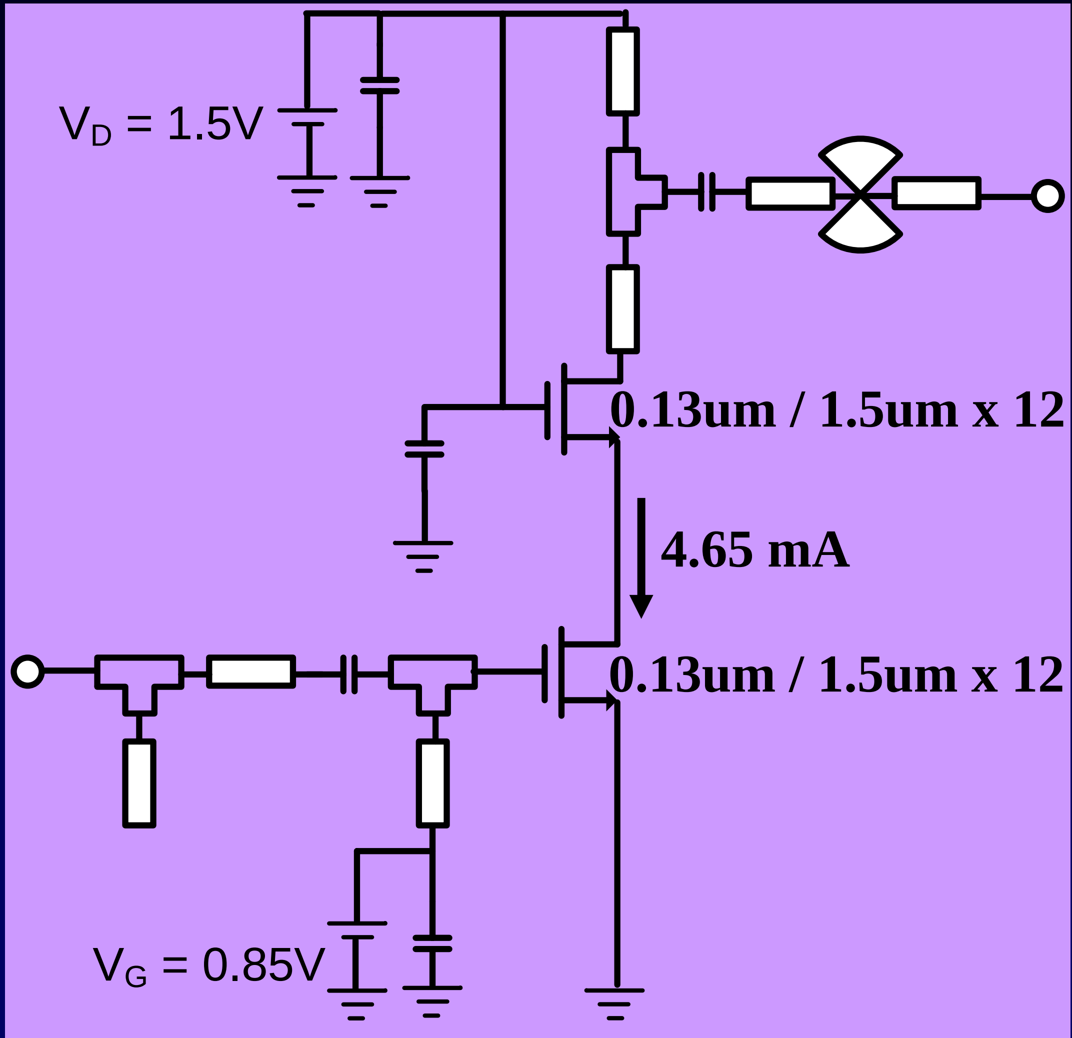


60-GHz CMOS LNA Design for Wireless Sensor Applications

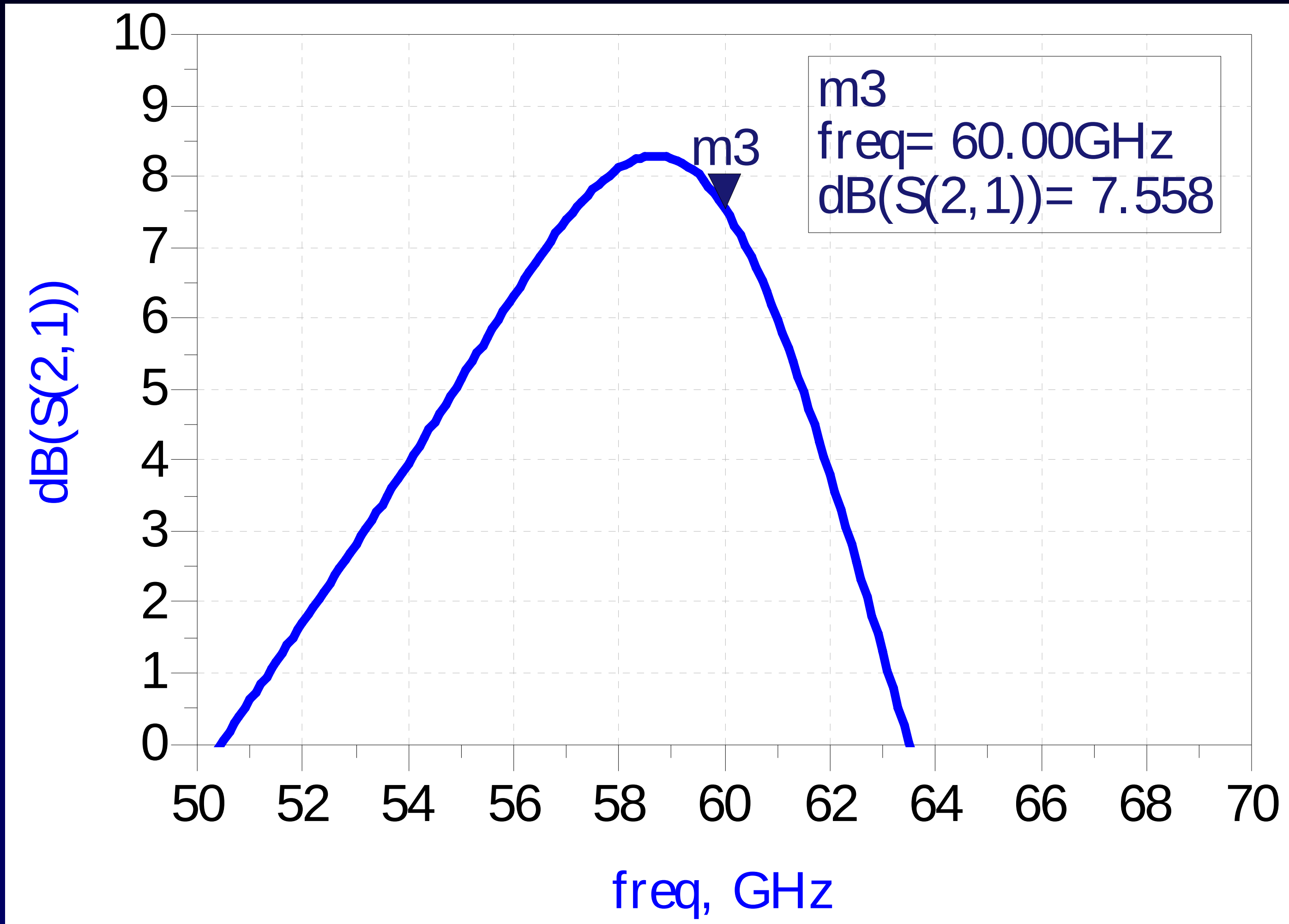
60-GHz LNA Specification

60-GHz LNA in 0.13-um CMOS process	
Supply	= 1.5 V
Current consumption	< 15 mA
Power Gain	> 15 dB
Noise Figure	< 8.5 dB
IIP_3	> -15 dBm
Input /Output Return Loss	< -15 dB < -15 dB
Unconditionally stable !!	

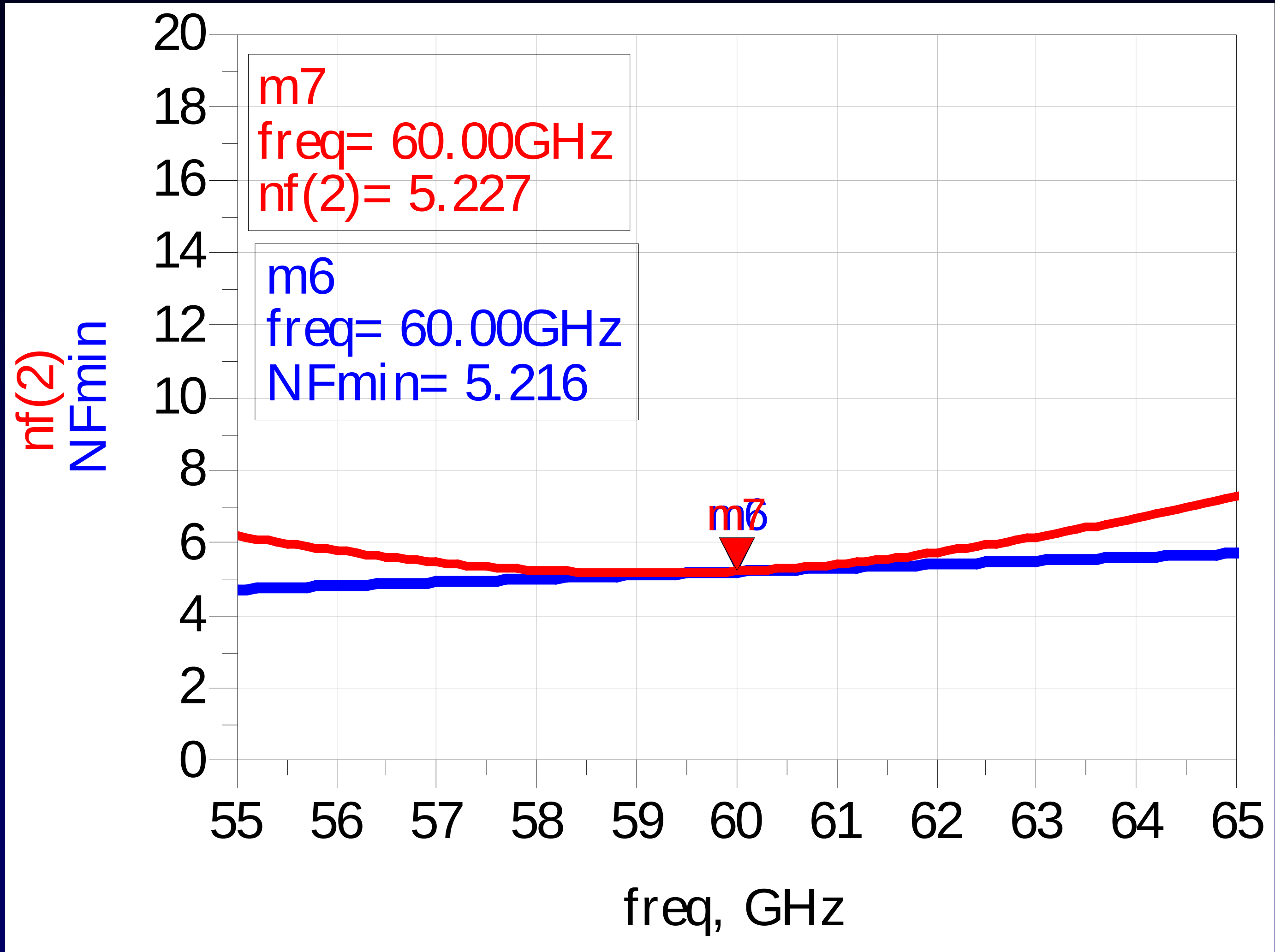
Design Topology of the Single Stage 60-GHz LNA



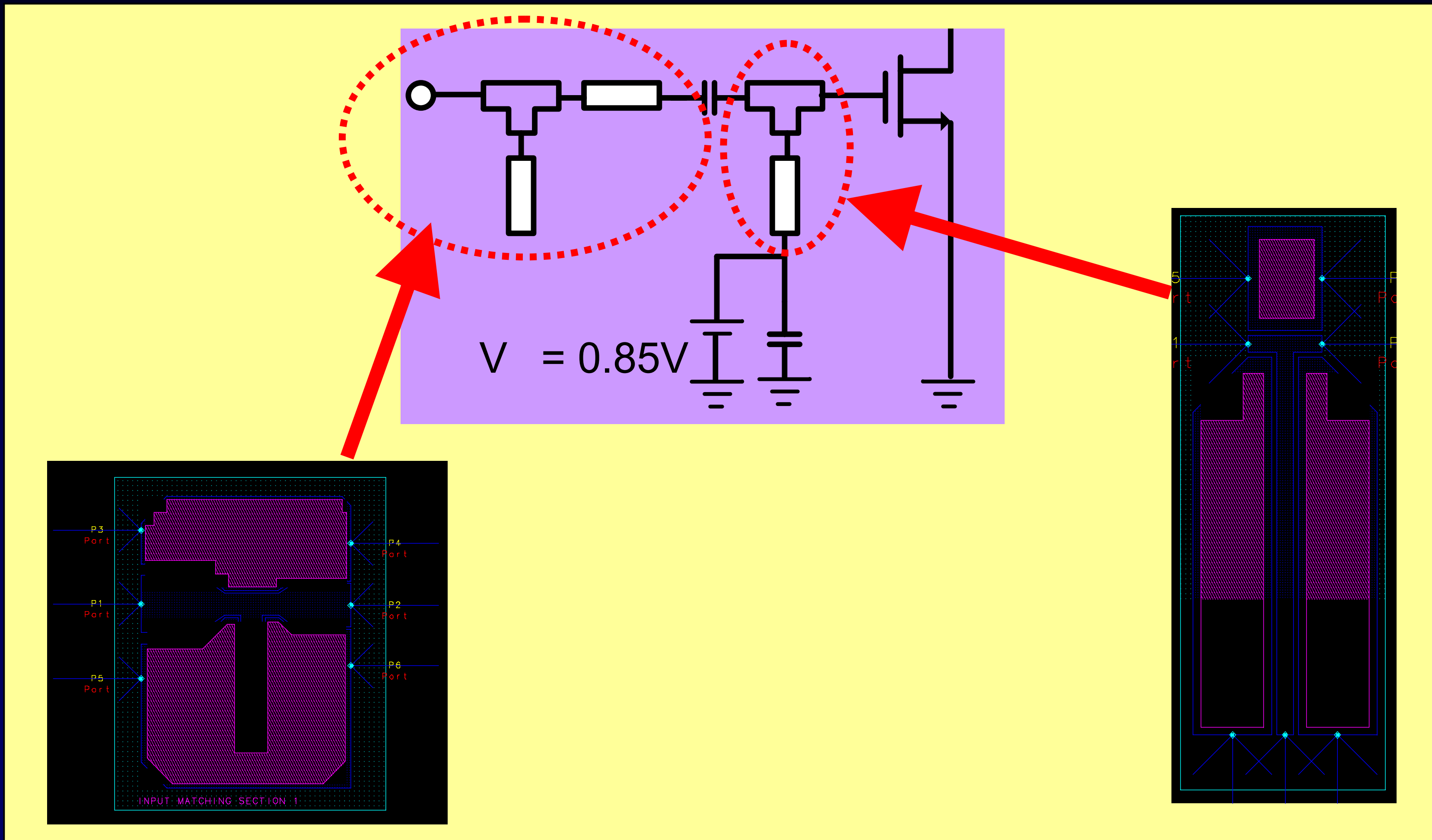
Power Gain of Single Stage Cascode LNA with ideal transmission line



Noise Figure of Single Stage Cascode LNA with ideal transmission line

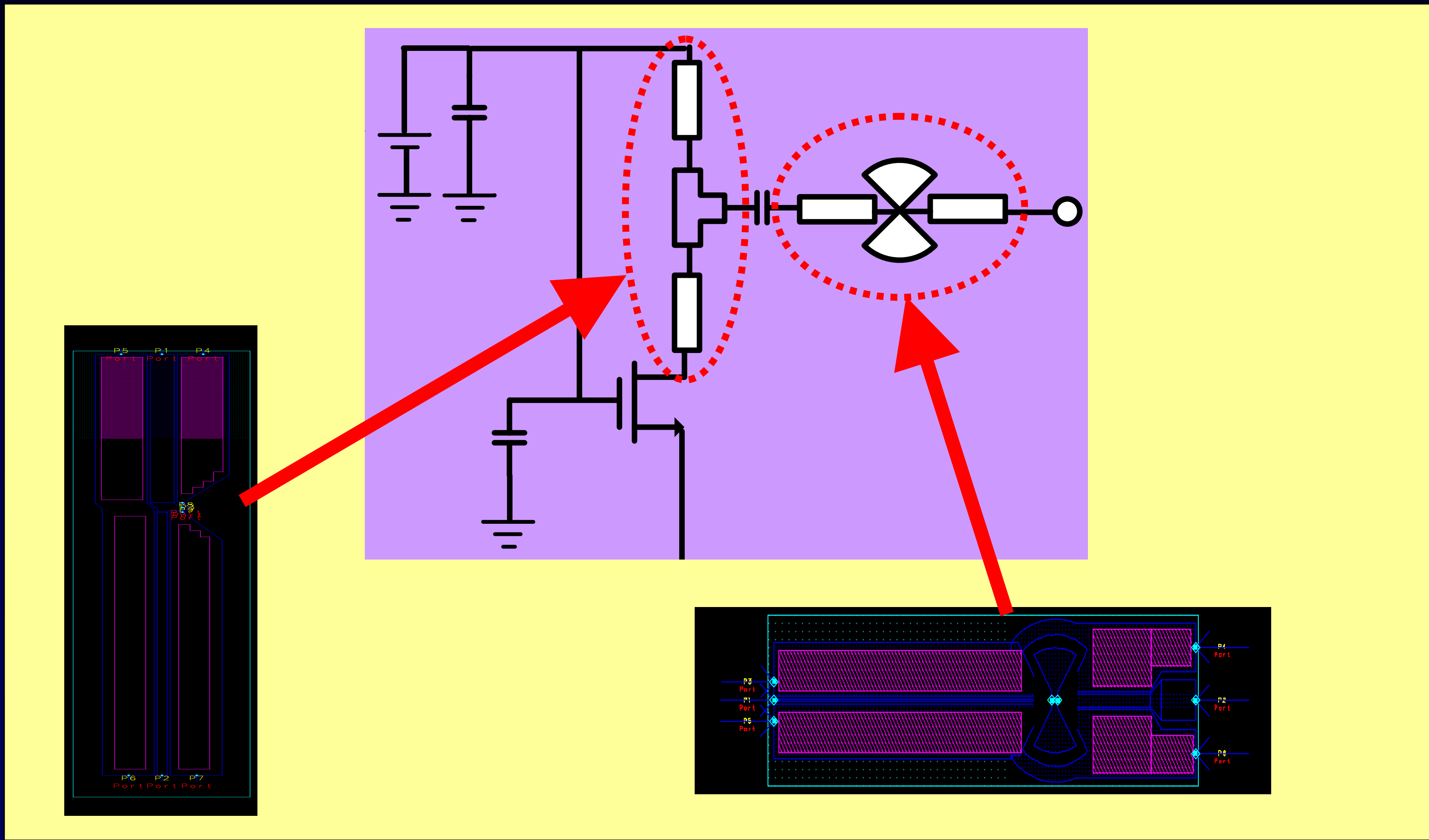


Layout of CPWG Matching Elements Based on EM-Simulation (input)

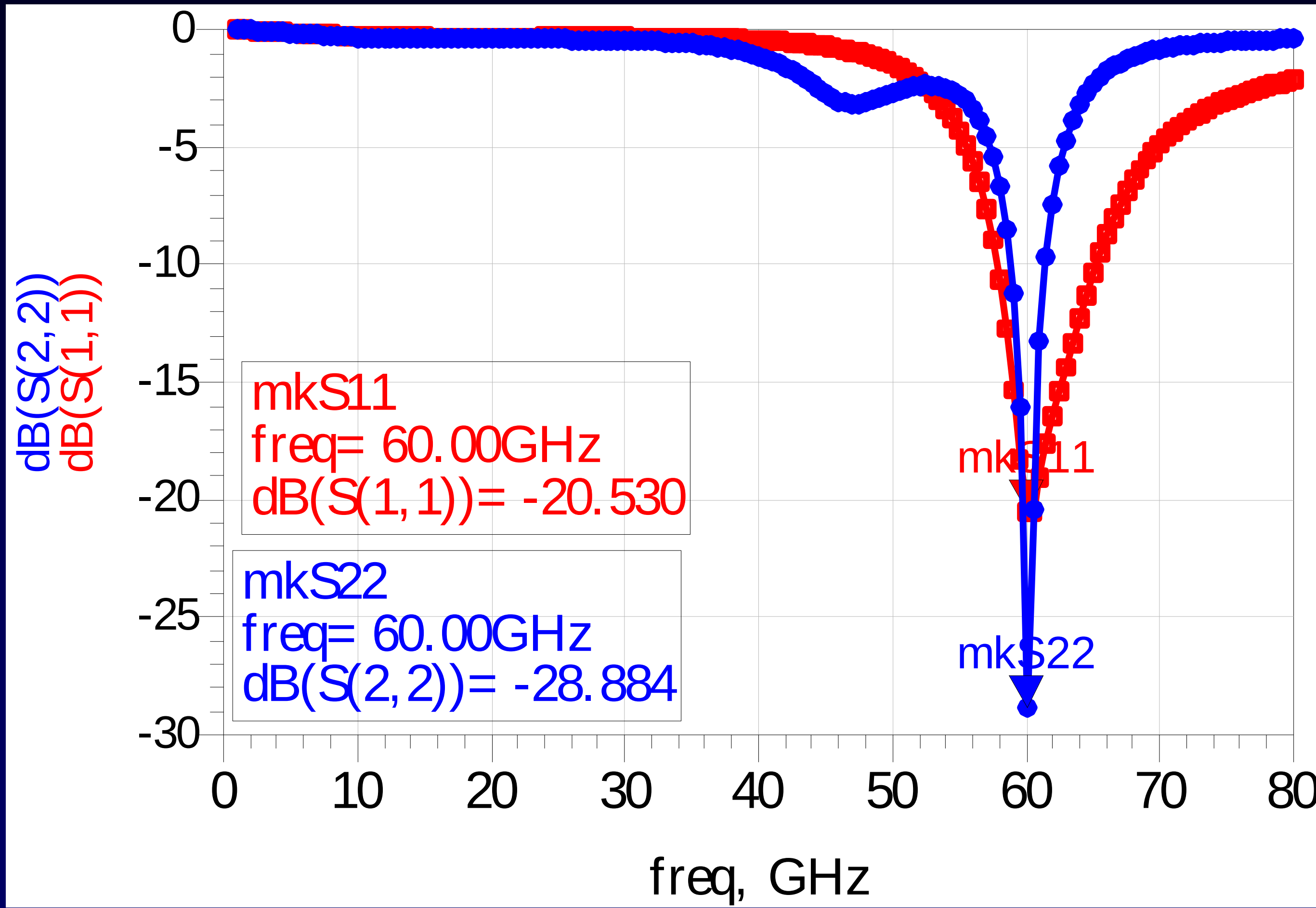


G

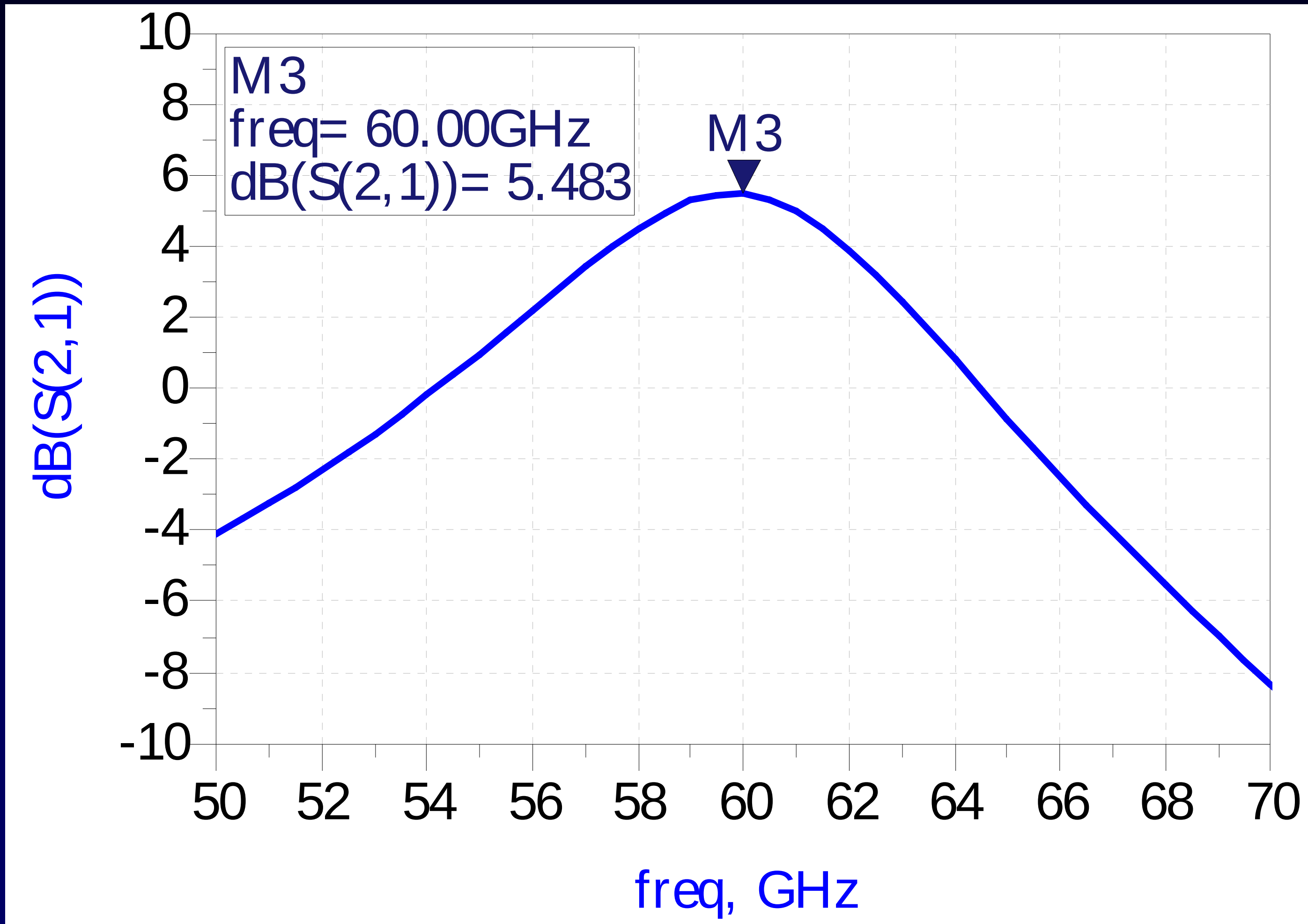
Layout of CPWG Matching Elements Based on EM-Simulation (output)



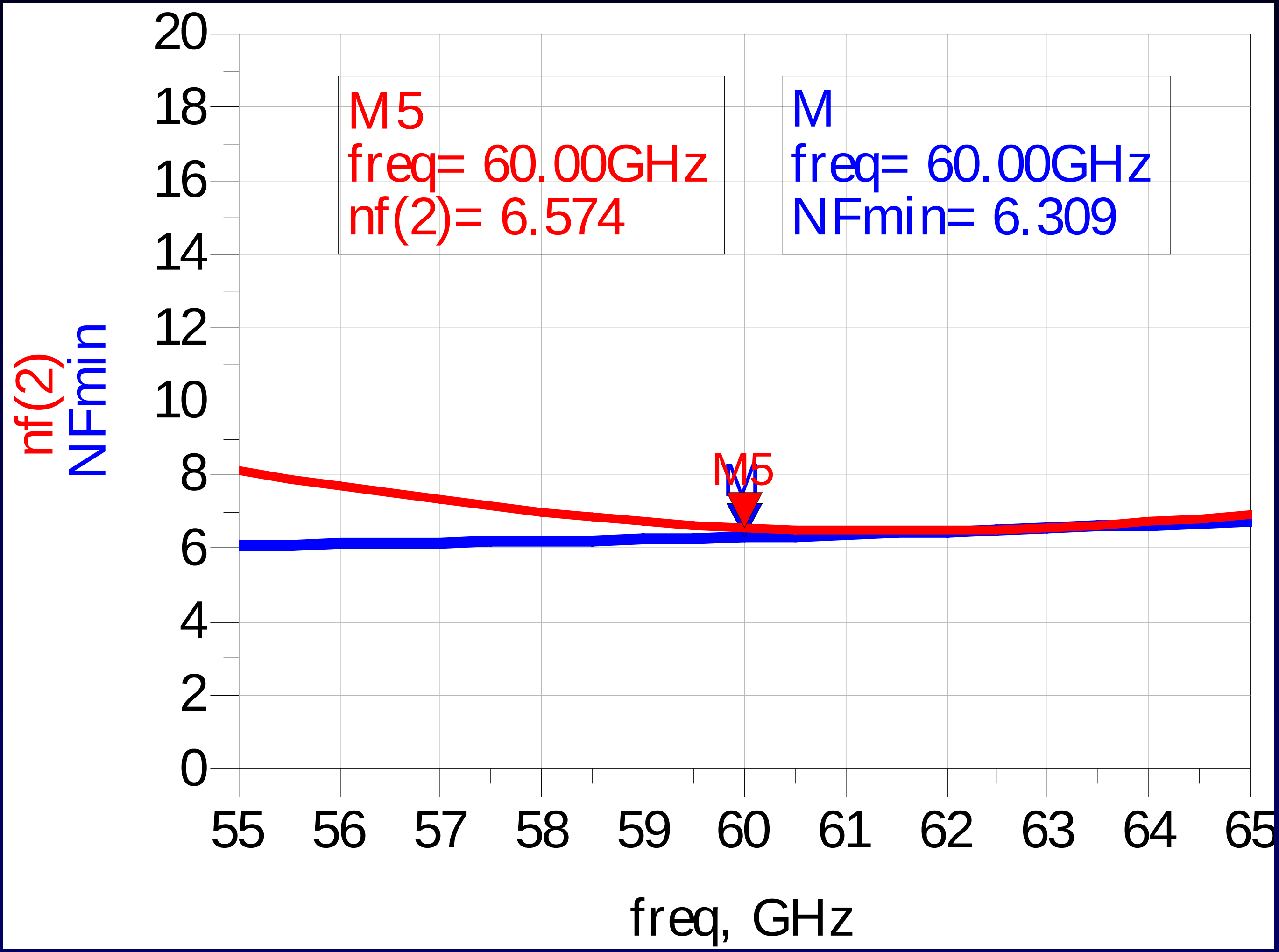
S11 / S22 of Single Stage Cascode LNA with Modeled CPWG



Power Gain of Single Stage Cascode LNA with Modeled CPWG



Noise Figure of Single Stage Cascode LNA with Modeled CPWG



Summary

- Based on the simulation results, the ASK Rx exhibits cascade noise figure of 6.81 dB and sensitivity of -87.2 dBm.
- As the interconnections between the CPW feed and the antenna chip, bond-wires don't radiate much but they cause considerable inductance.
- The gain/efficiency of integrated antennas would be affected by objects around them.
- The simulated single stage 60-GHz LNA with CPWG as matching elements and interconnection achieved gain of 5.5 dB, noise figure of 6.6 dB, input/output return loss less than -20 dB and unconditionally stable.

Acknowledgement

- This research is a team effort by Taiwan team which includes Anson (Ho-Yin Lee) and myself along with CRC team which includes Ibrahim Haroun, Khelifa Hettak and Malcolm Stubbs.

Thank you!

Hsiao-Chin Chen

d92943025@ntu.edu.tw

附件三

CRC-Taiwan Program Review Meeting on Wireless Sensors for Bio/Environmental Appl.

Shey-shi Lu

National Taiwan University

Outline

- **Project Outline**

- **What we have done**

  - 5GHz CMOS RF front-end (Nicole, accepted by JSSC)

  - Fractional frequency synthesizer (Arein, to be published at JSSC Nov. 2006)

  - 433 MHz bio wireless sensor (LS Huang/SS Lu, presented at ISSCC Feb. 2006)

- **Help needed from CRC**

  - System Planning/Design

  - Antenna Design

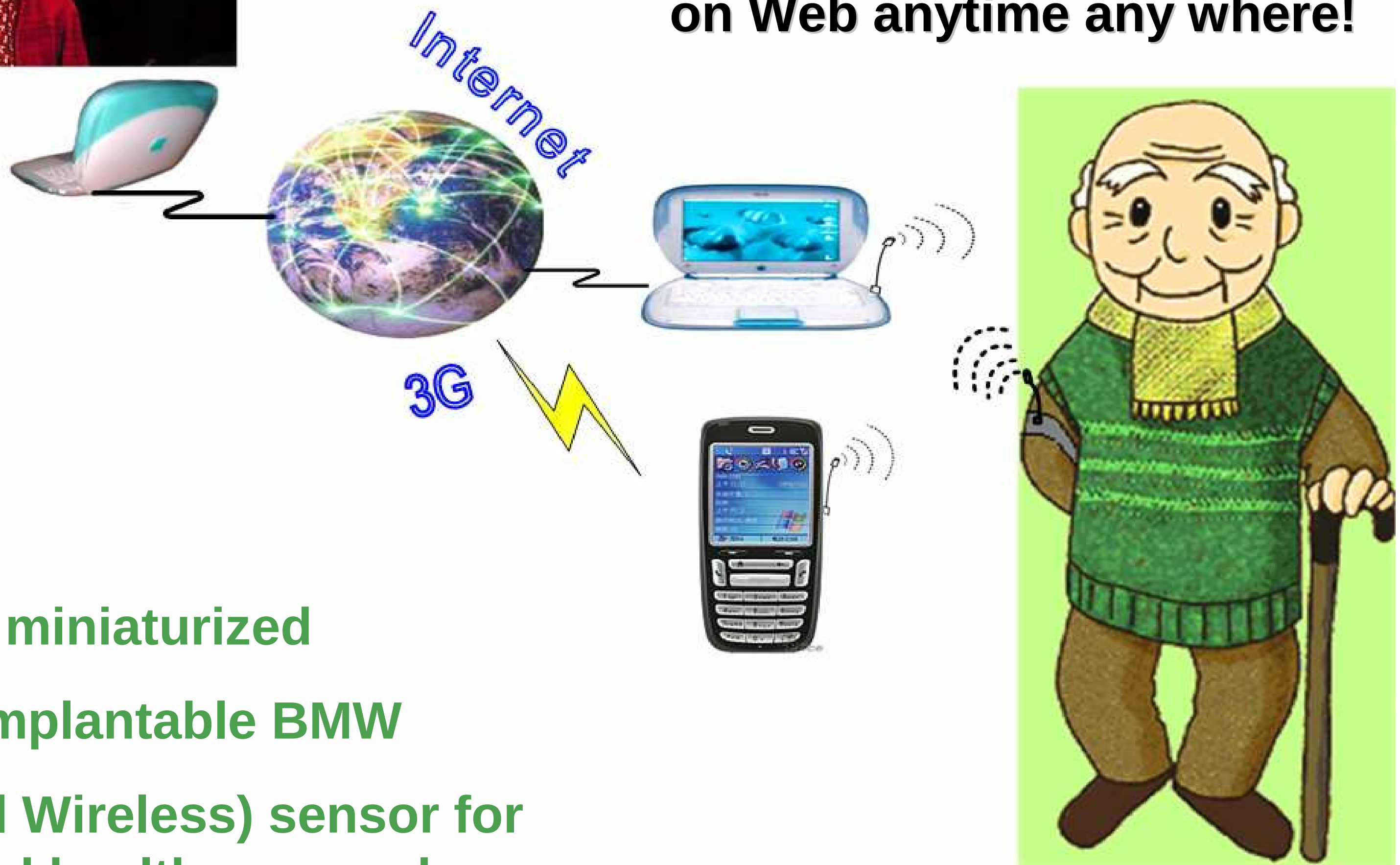
  - Milli-meter wave circuit design

- **Discussions**

Our Vision and Goal

You can check out your beloved persons' health conditions

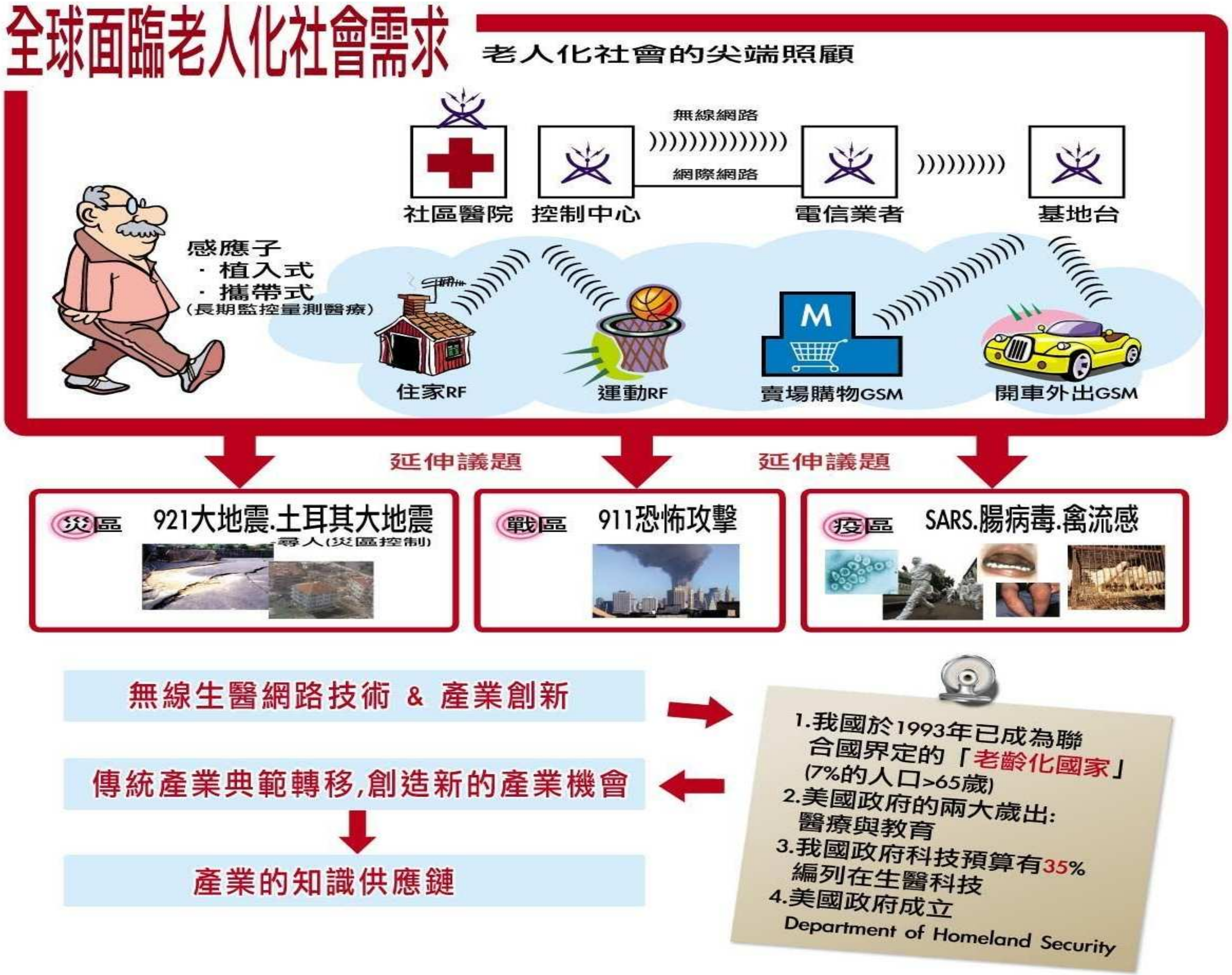
on Web anytime any where!



To develop miniaturized

wearable/implantable BMW

(BioMedical Wireless) sensor for personalized health care and beyond-hospital applications.


全球面臨老人化社會需求
老人化社會的尖端照顧
無線網路
網際網路
社區醫院
控制中心
電信業者
基地台
感應子
· 植入式
· 攜帶式
(長期監控量測醫療)
住家RF
運動RF
賣場購物GSM
開車外出GSM
延伸議題
延伸議題
災區 921大地震.土耳其大地震
尋人(災區控制)
戰區 911恐怖攻擊
疫區 SARS.腸病毒.禽流感
無線生醫網路技術 & 產業創新
傳統產業典範轉移,創造新的產業機會
產業的知識供應鏈
1.我國於1993年已成為聯合國界定的「老齡化國家」(7%的人口>65歲)
2.美國政府的兩大歲出:醫療與教育
3.我國政府科技預算有35%編列在生醫科技
4.美國政府成立 Department of Homeland Security

Three Year Work Plan

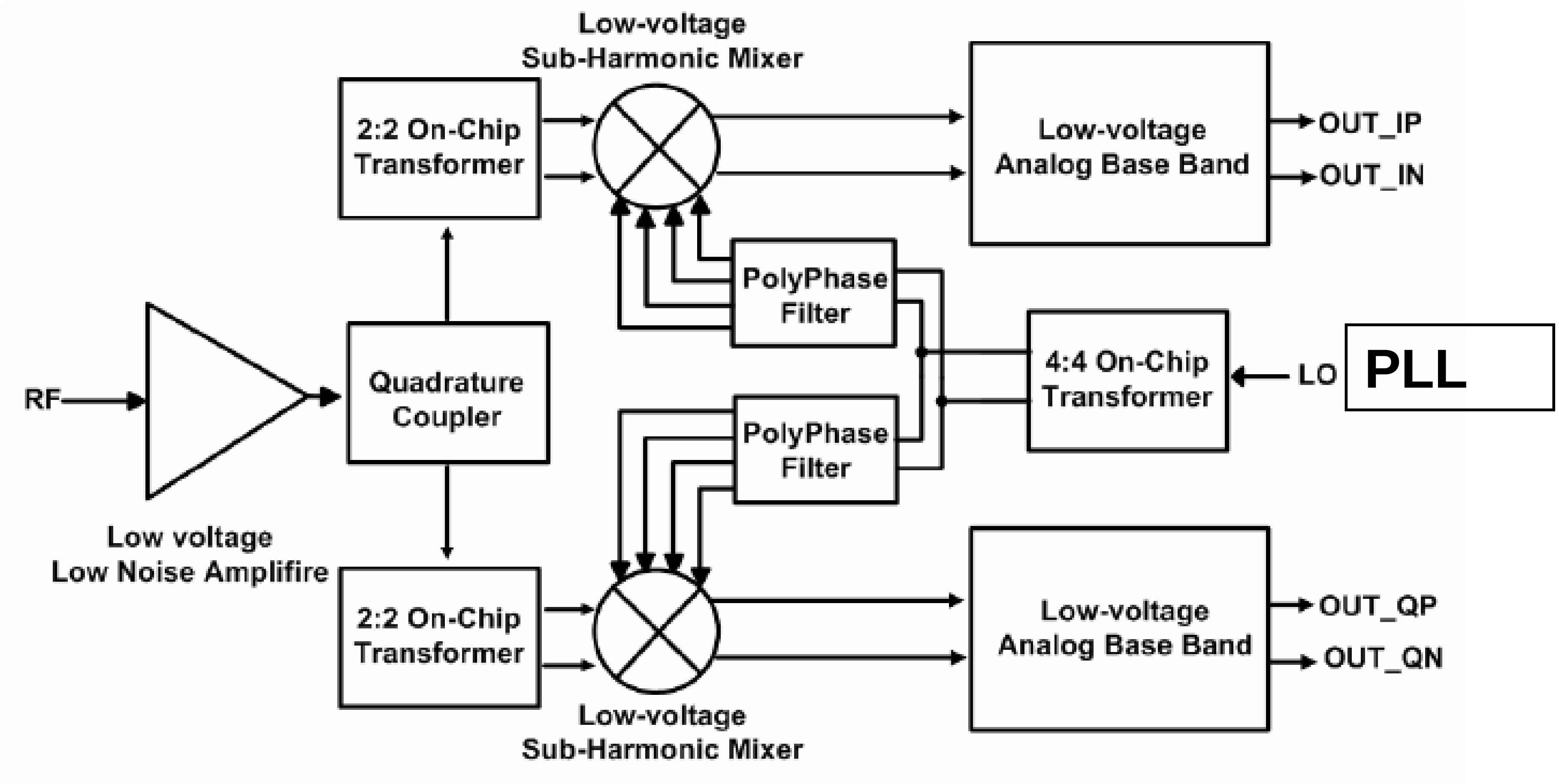
- **Year 1:**
  - (i) Identify applications (bio and environmental sensors).
  - (ii) Establish & discuss system parameters – meeting .
  - (iii) CRC & NSC: run test structures (i.e. RFIC, MMIC, LTCC) with CIC.
  - (iv)Jointly organize and chair special session on Wireless Sensors at the 2006 IEEE VTC conference in Montreal.
  - (v)NSC: Possible placement of 2 Ph.D. students at CRC.
  - (vi)CIC: 1 researcher placed at CRC to learn LTCC high frequency design techniques.
  - (vii)NSC & CRC: Possible placement of one Ph.D. student at CRC to perform R&D relevant to the establishment of wireless sensor test platform in Taiwan.

- **Year 2:**
  - (i) Review meeting.
  - (ii) Design circuits and test structures.
  - (iii) Fabricate ICs and LTCC packages/structures.
  - (iv) Conduct testing.
  - (v) Exchange of researchers.
  - (vi) NSC: Possible placement of 2 Ph.D. students at CRC.
  - (vii) NSC & CRC: Possible placement of one Ph.D. student at CRC to perform R&D relevant to the establishment of wireless sensor test platform in Taiwan. (4)
  - (viii) CIC: 1 researcher placed at CRC to learn LTCC high frequency design techniques.

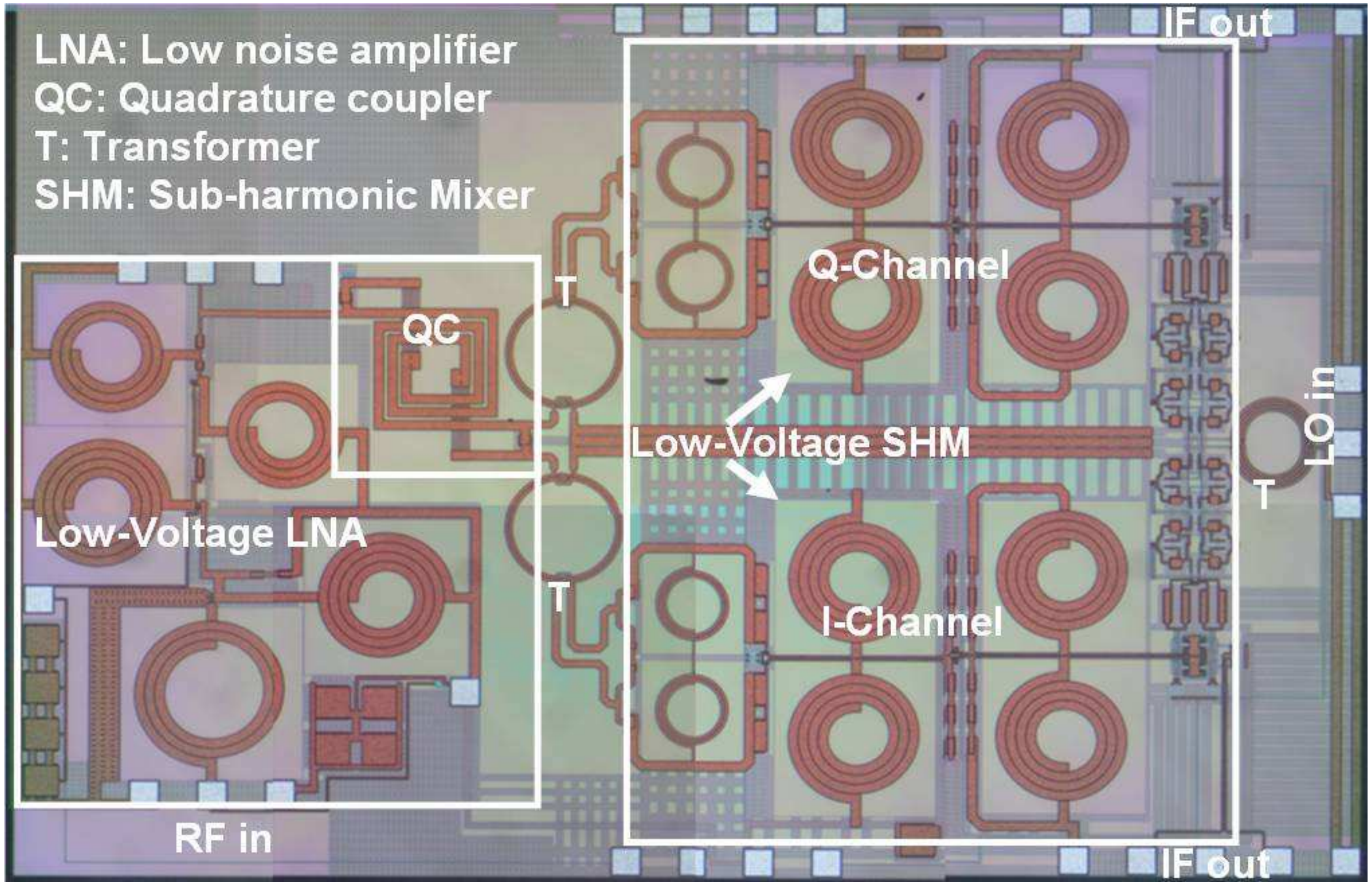
– **Year 3:**

- (i) Design ICs.
- (ii) Exchange of researchers.
- (iii) Fabricate ICs and LTCC packages.
- (iv) Conduct IC testing, integrated testing
- (v) Meeting to review results.
- (vi) NSC: Possible placement of 2 Ph.D. students at CRC.
- (vii) NSC & CRC: Possible placement of one Ph.D. student at CRC to perform R&D relevant to the establishment of wireless sensor test platform in Taiwan. Conduct tests on wireless sensor platform in Taiwan.
- (viii) CIC: 1 researcher placed at CRC to learn LTCC high frequency design techniques.

5 GHz RF front end by Nicole/Arein to be published in J. Solid State Ckt

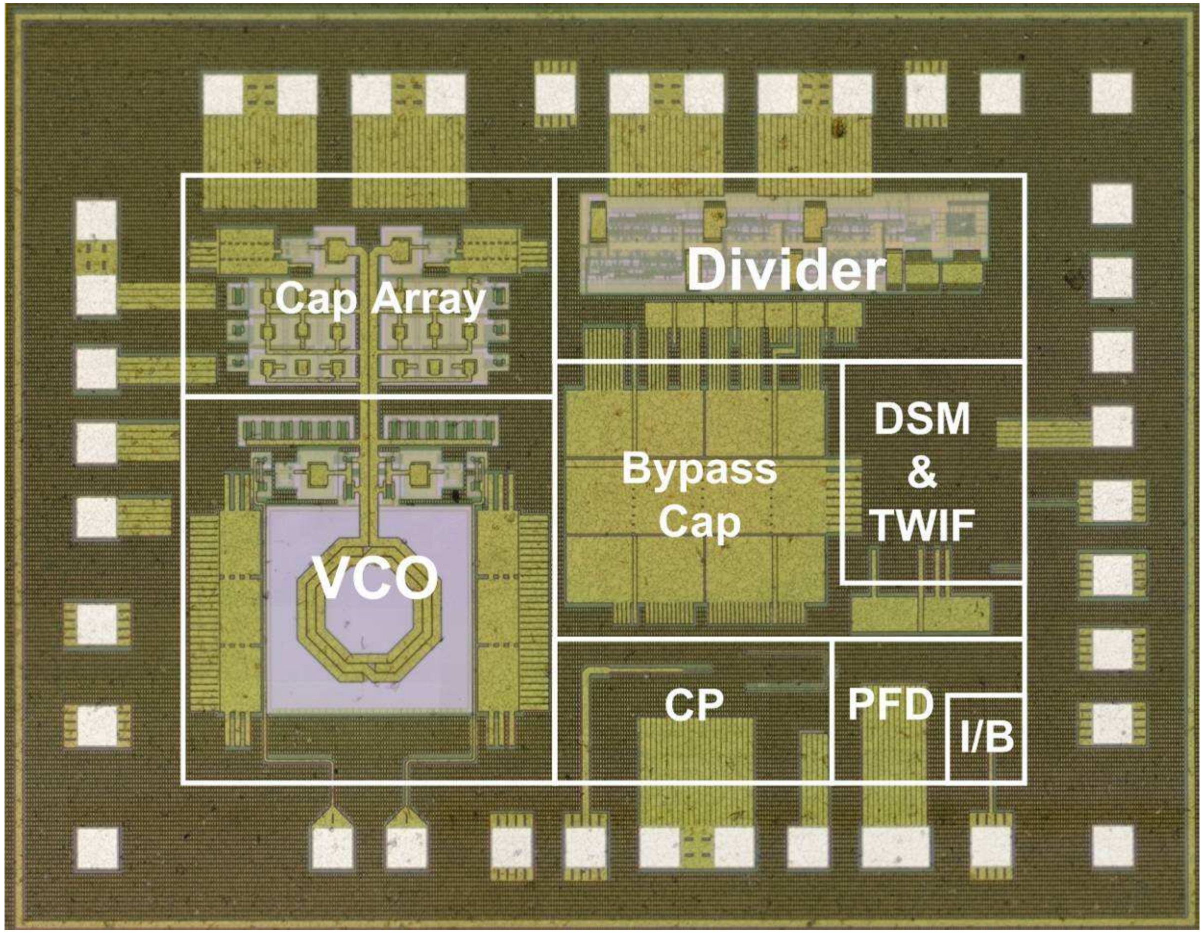


1 V 5 GHz RF Front-end



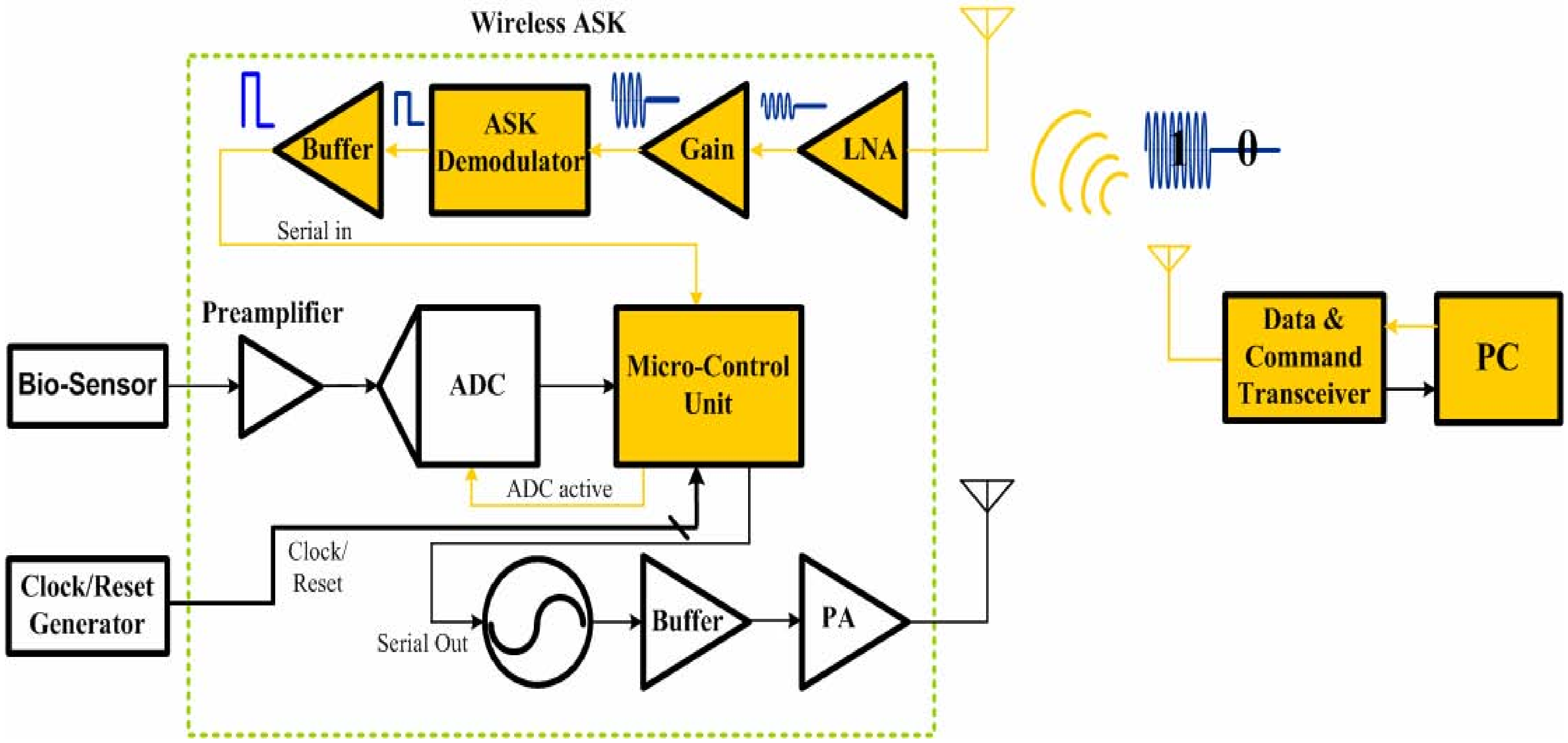
To be published in J. Solid State Circuits

Frequency Synthesizer (VCO+PLL)

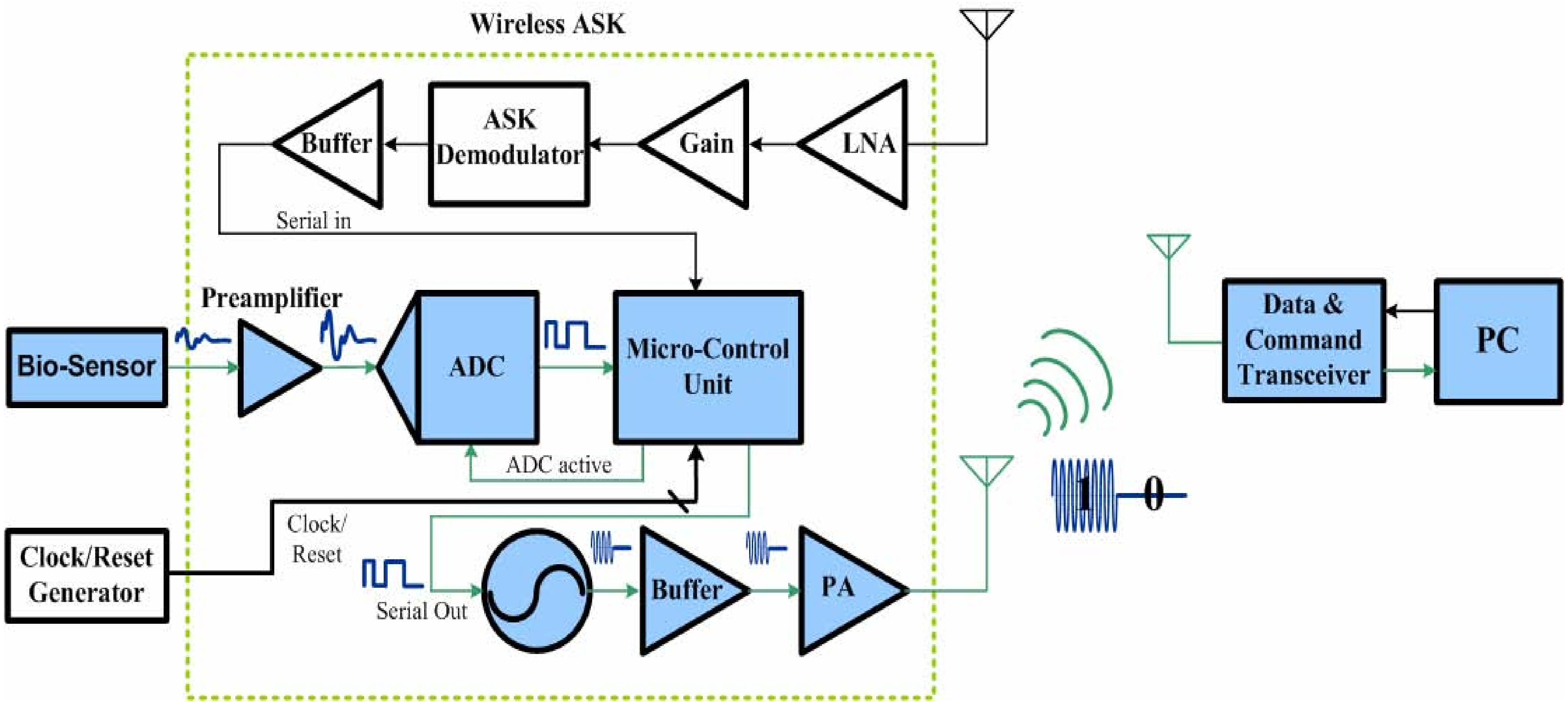


To be published in J. Solid State Circuits

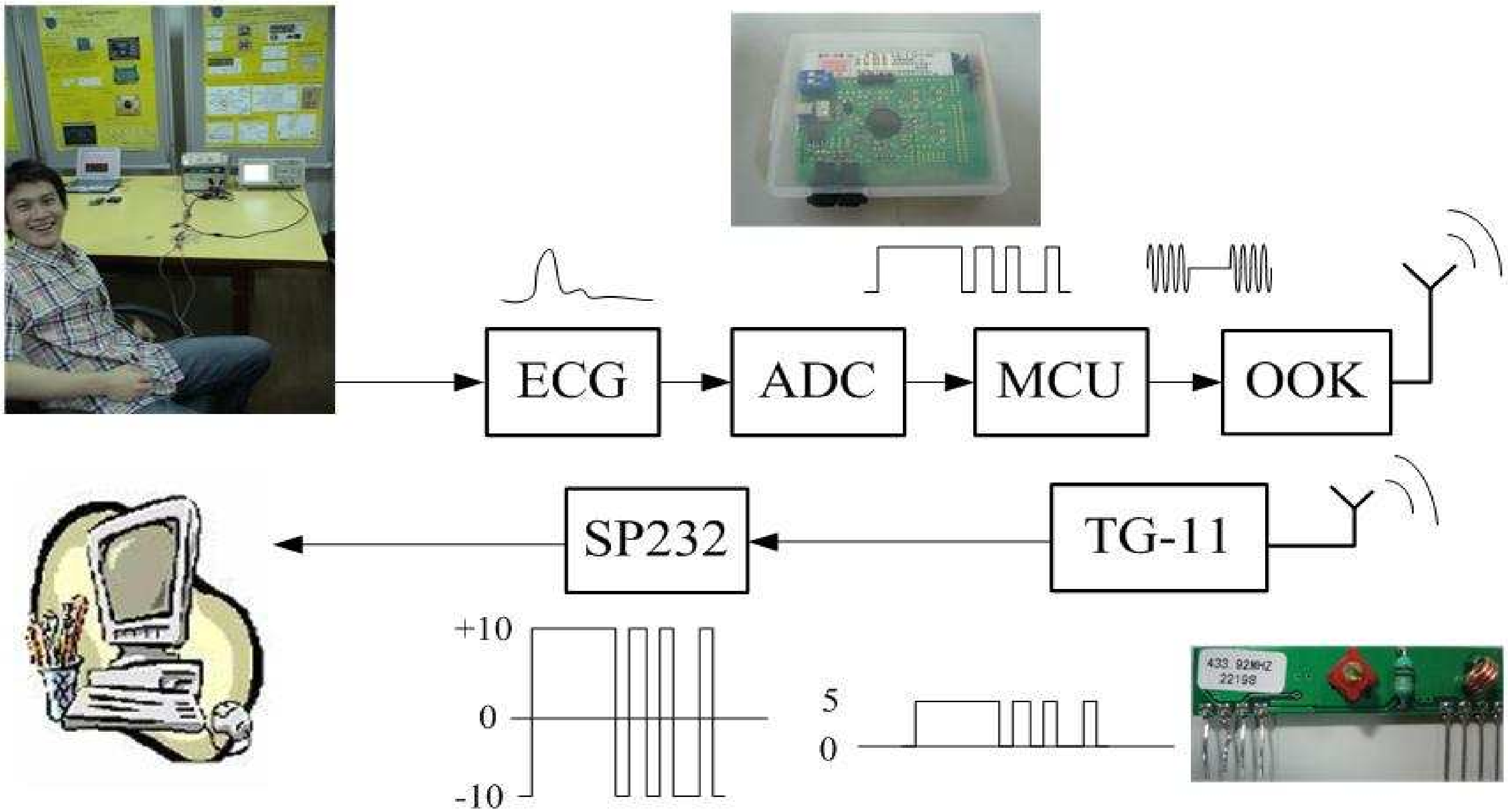
433 MHZ SOC:Command Mode



433MHz SOC:Readout Mode



ECG Experiment Setup



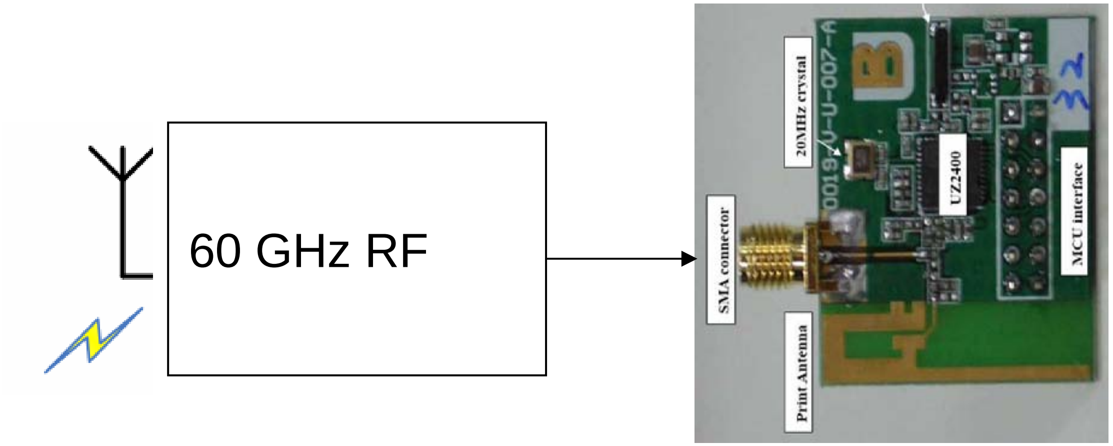
ECG Waveform Recovered on PC

ECG on PDA

Preliminary architectures for 60 GHz wireless sensor

- Non-SOC solution: 60 GHz RF front end

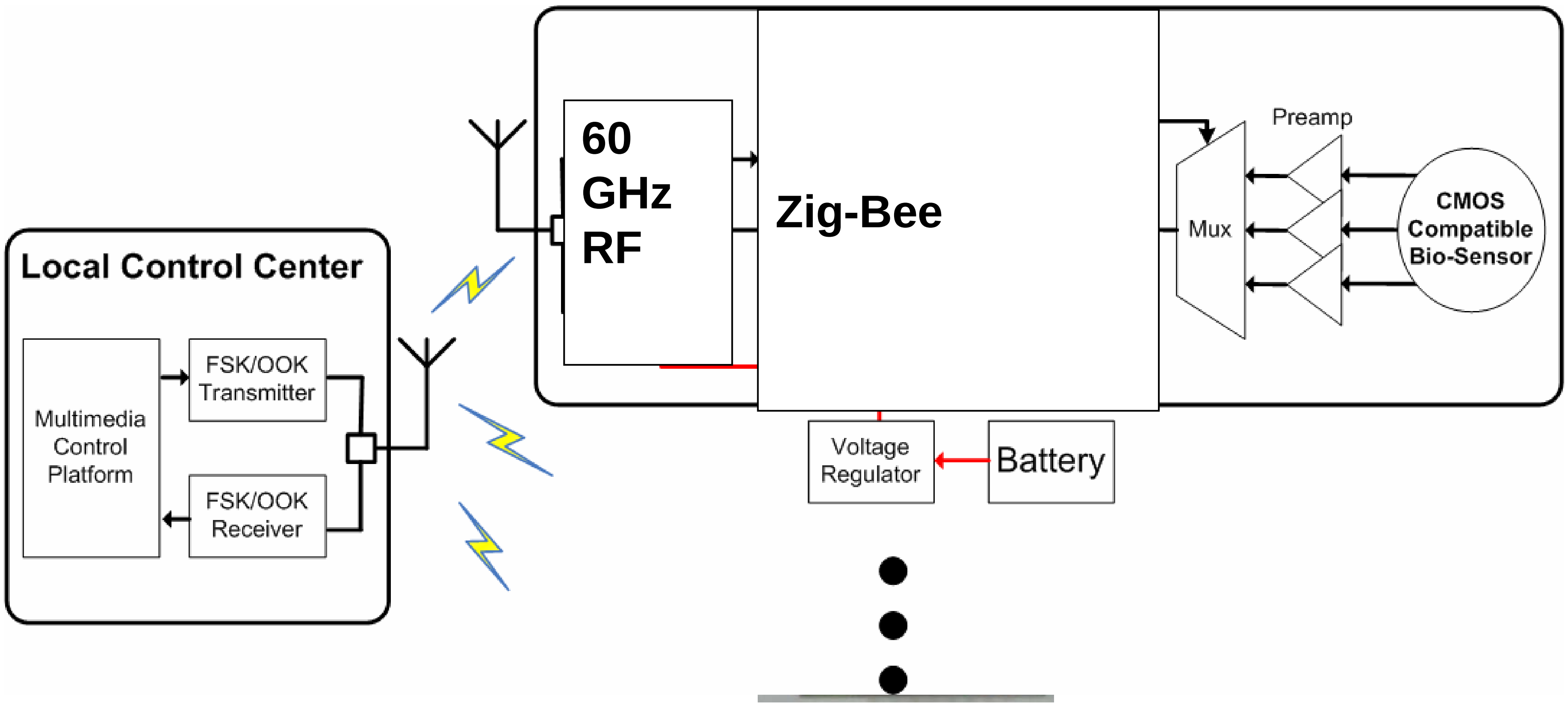
(GaAs or CMOS) + the commercially available Zig-Bee



Zig-Bee

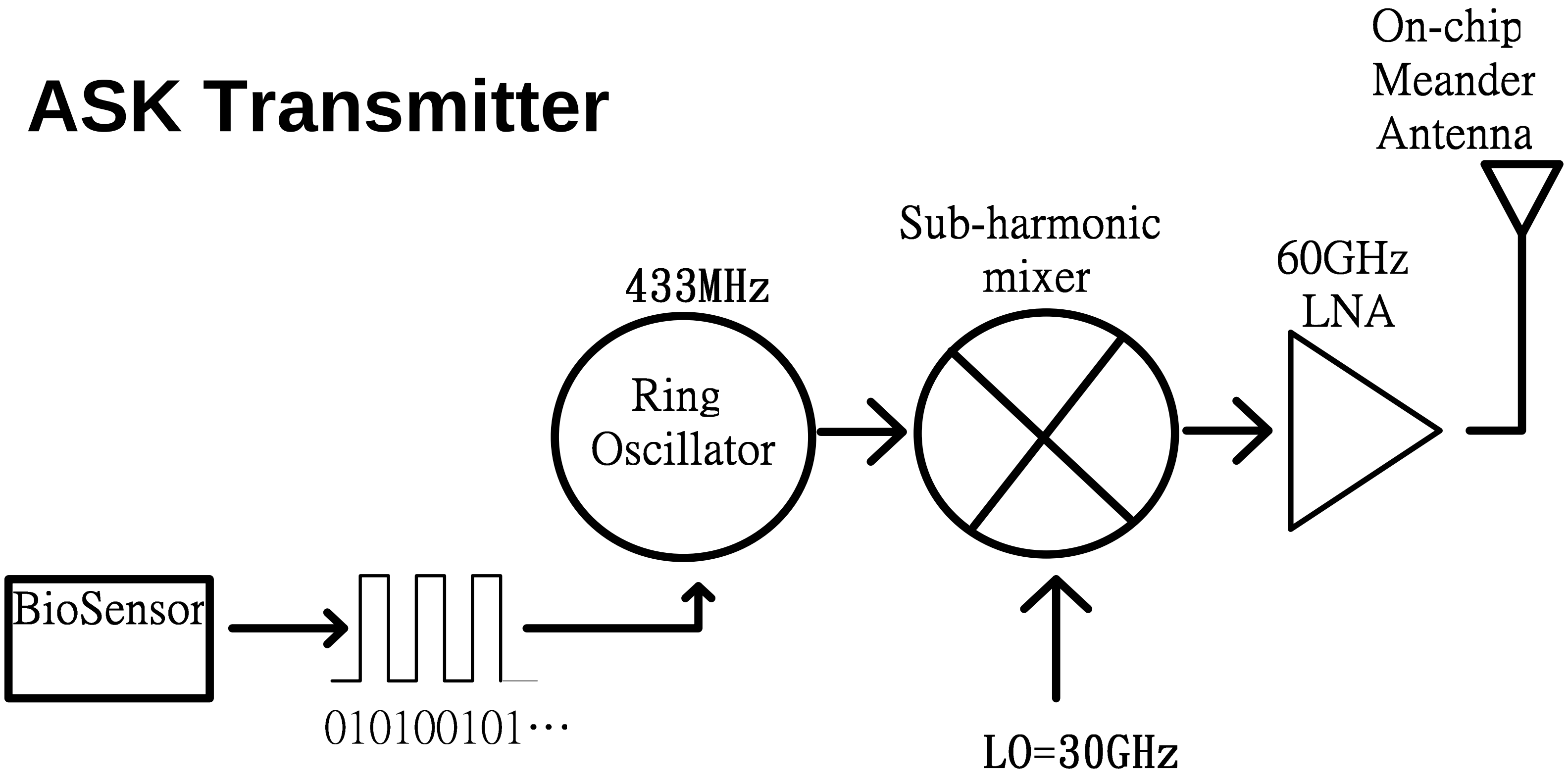
- SOC solution: all CMOS

Non-SOC solution: more practical

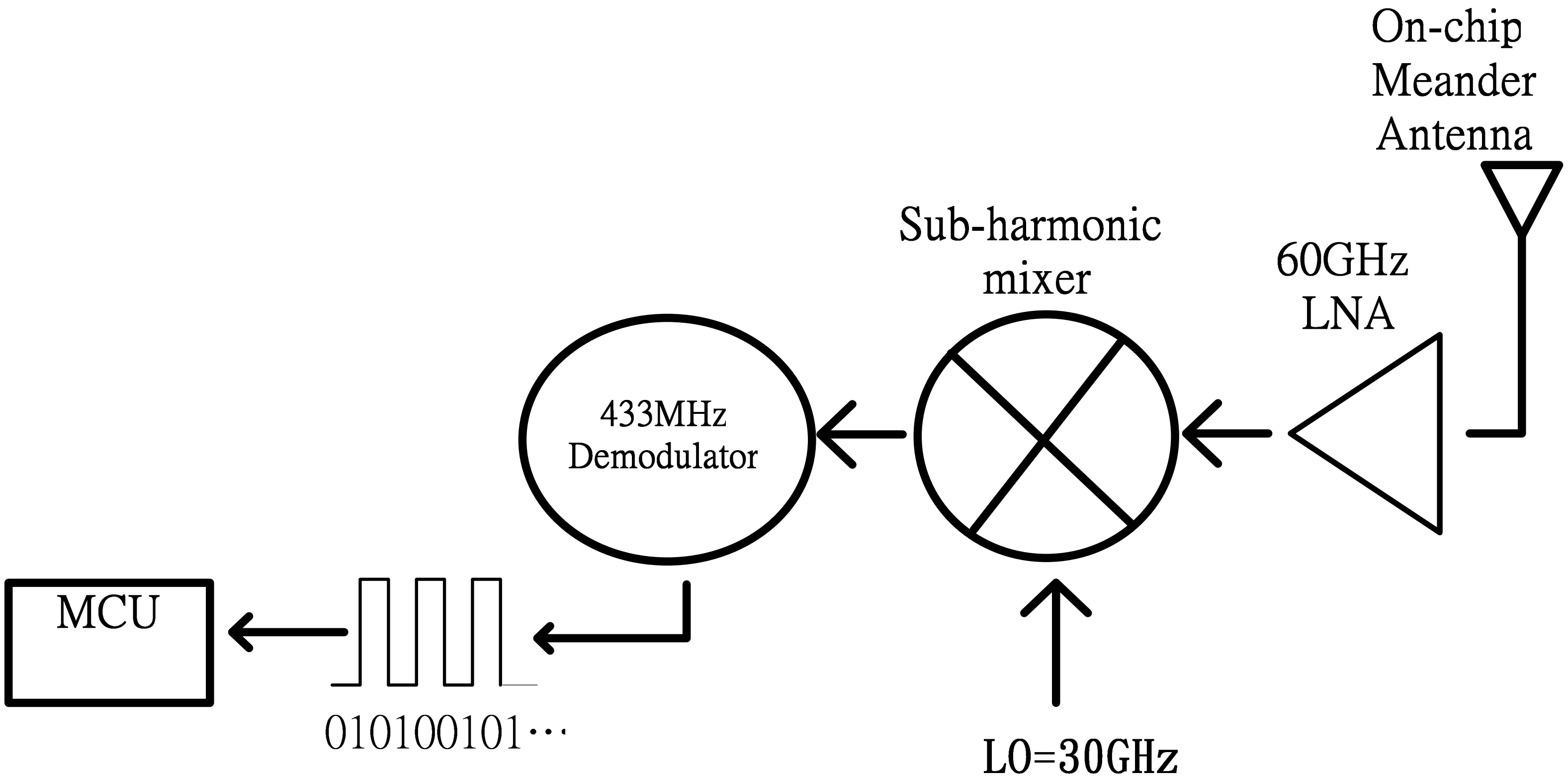


SOC solution: academic like

ASK Transmitter



SOC solution:ASK Receiver



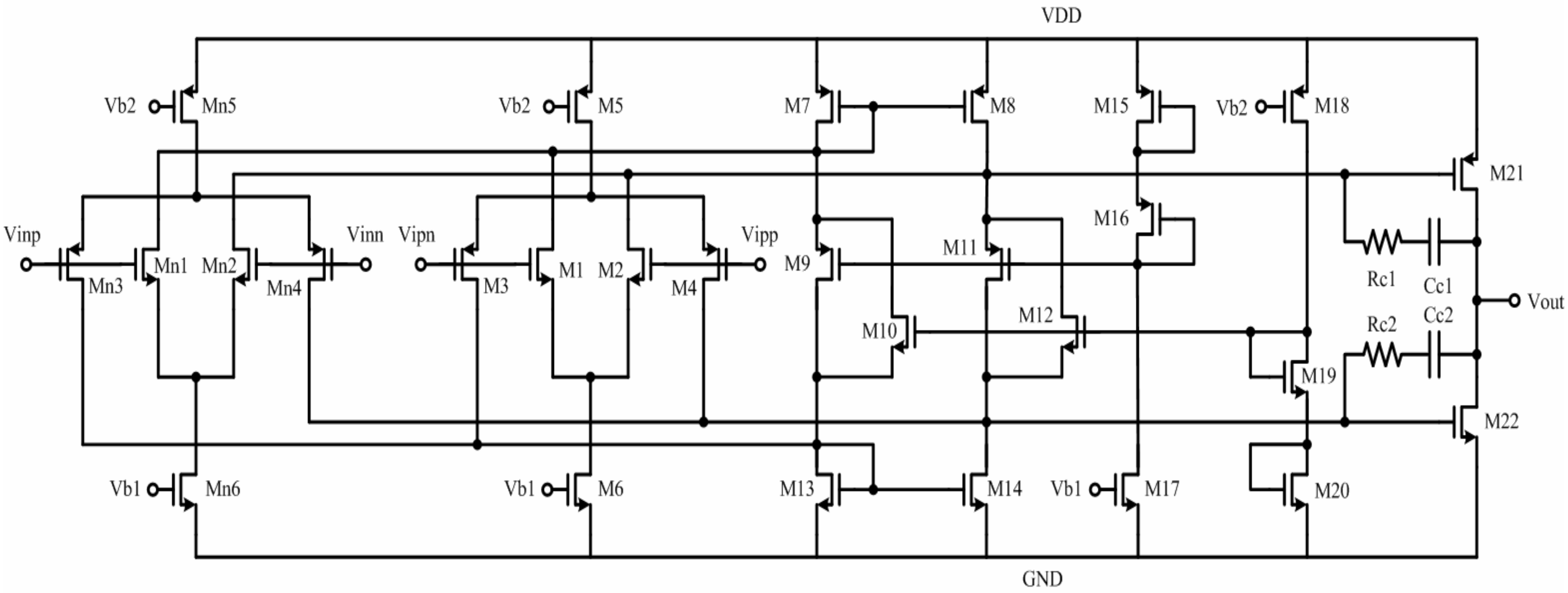
Demodulated signal

- Demodulated signal (Data rate: 100 kbps)

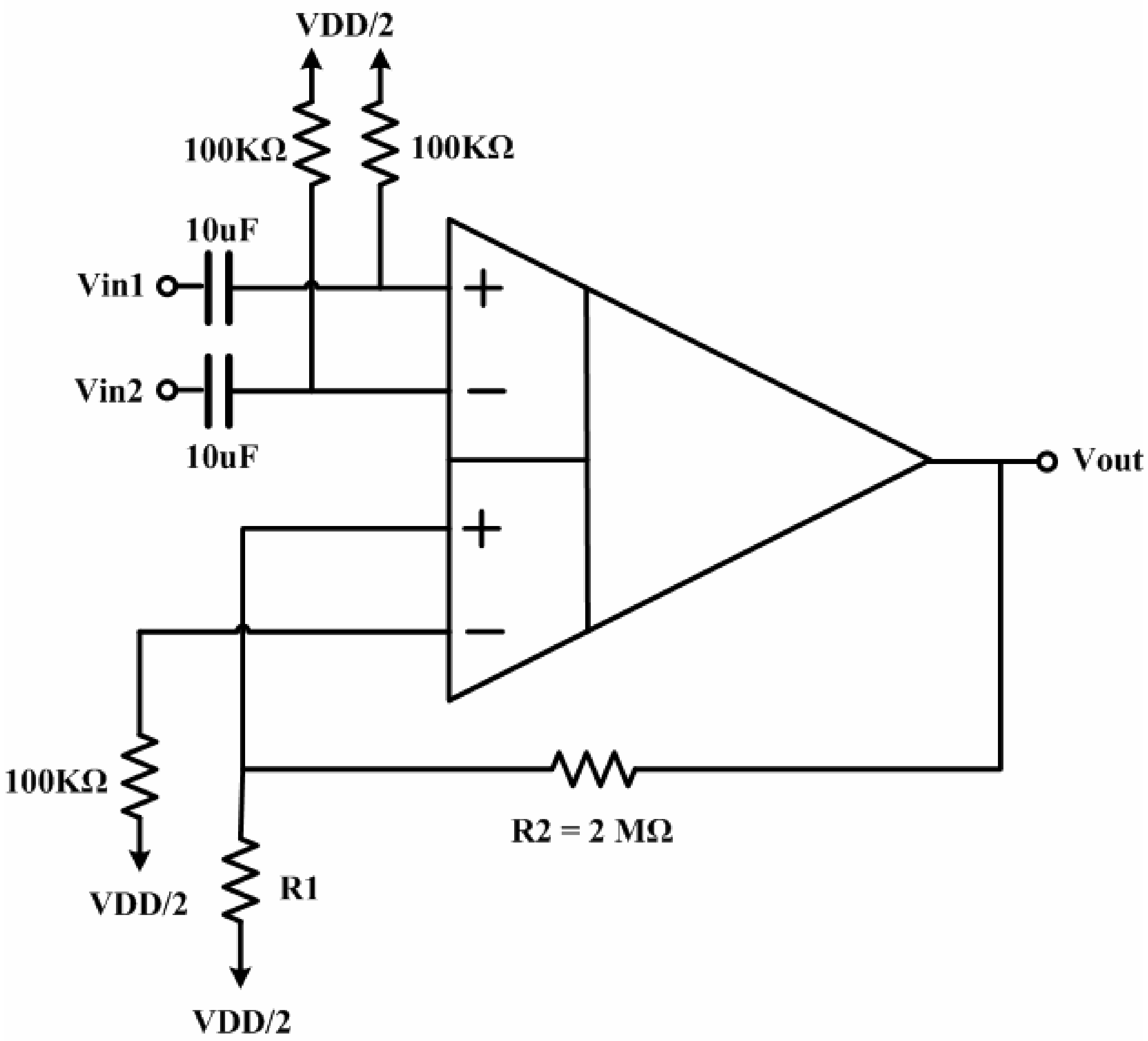
Performance summary

	Simulation	Measurement
Supply voltage	1 V	0.85 V
DC current	3 mA	1.62 mA
Sensitivity (433MHz)	- 65 dBm	-40 dBm
Max. bit rate	3 Mbps	1.5 Mpbs
Power consumption	3 mW	1.38mW

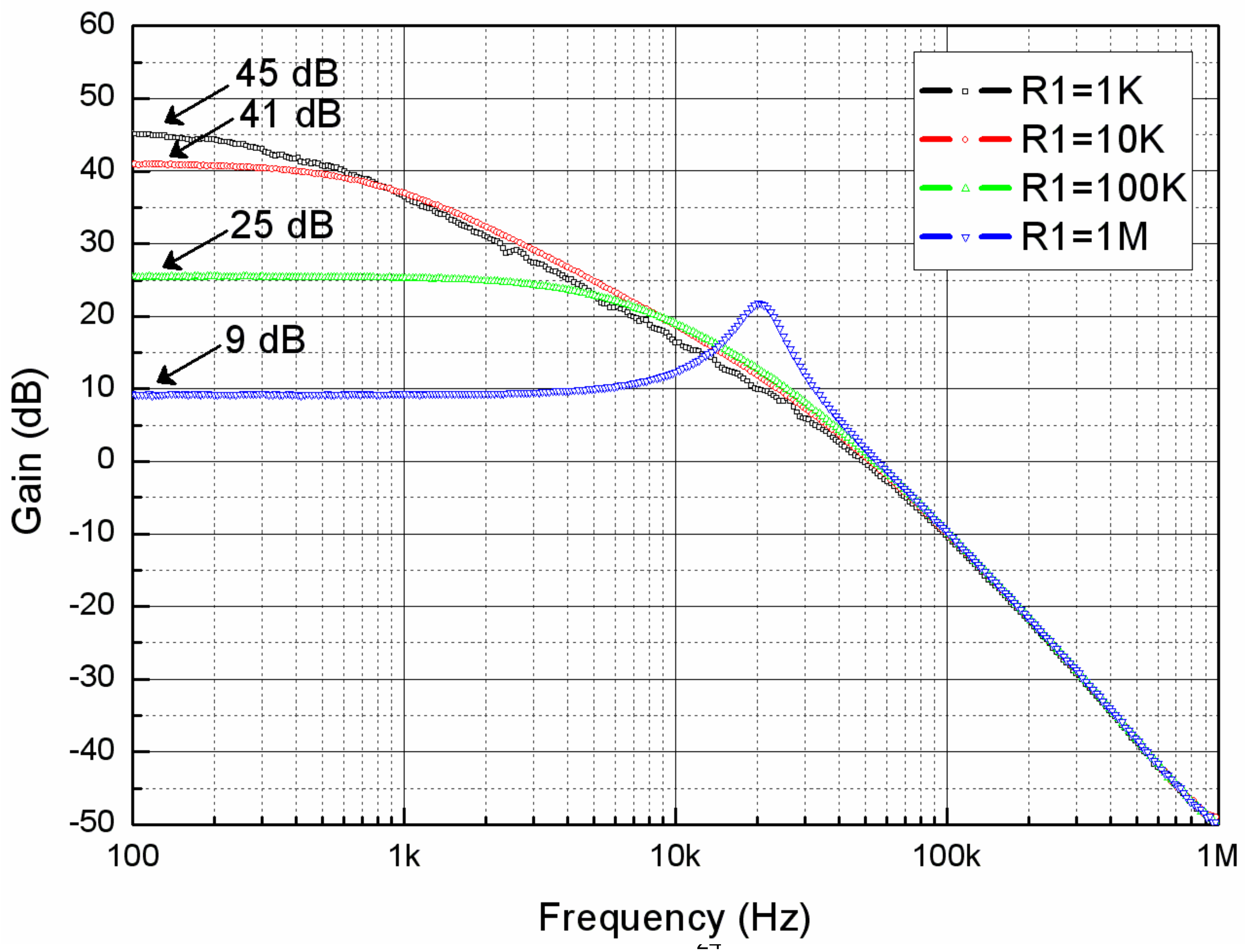
Schematic of Rail-to-Rail Pre-Amp



TSMC13 DDA Closed-loop Gain Measurement Setup



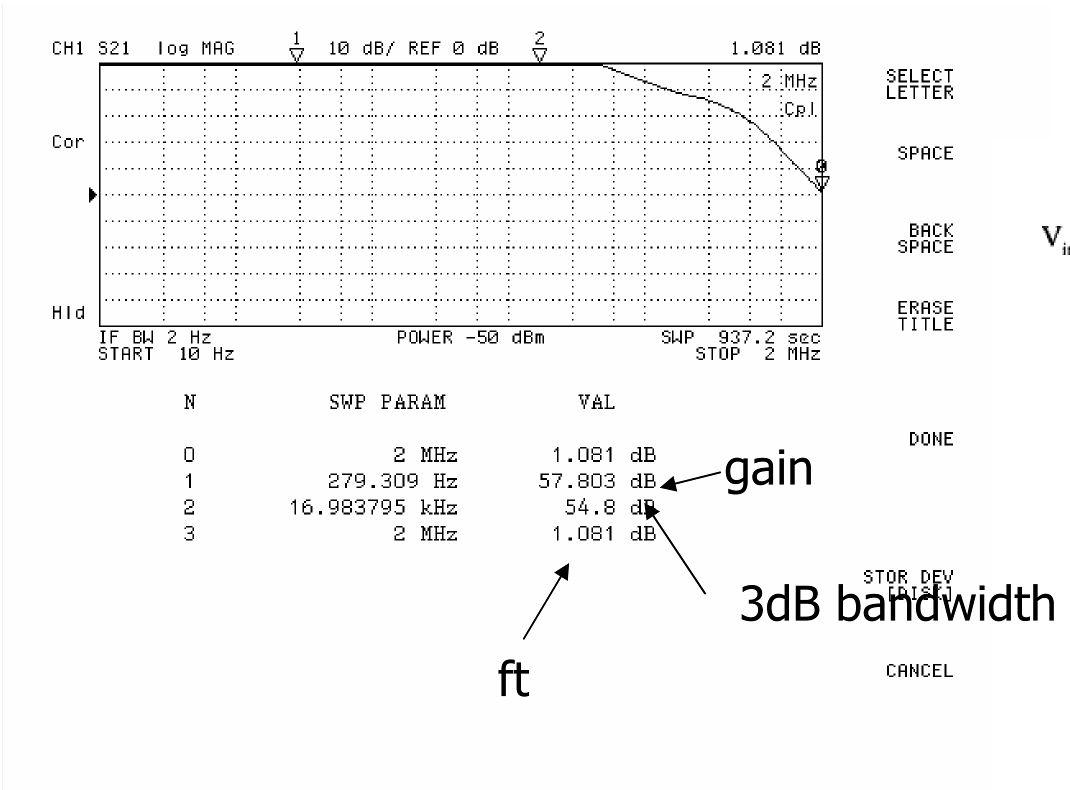
Measured TSMC13 Pre-Amp Closed-loop Gain

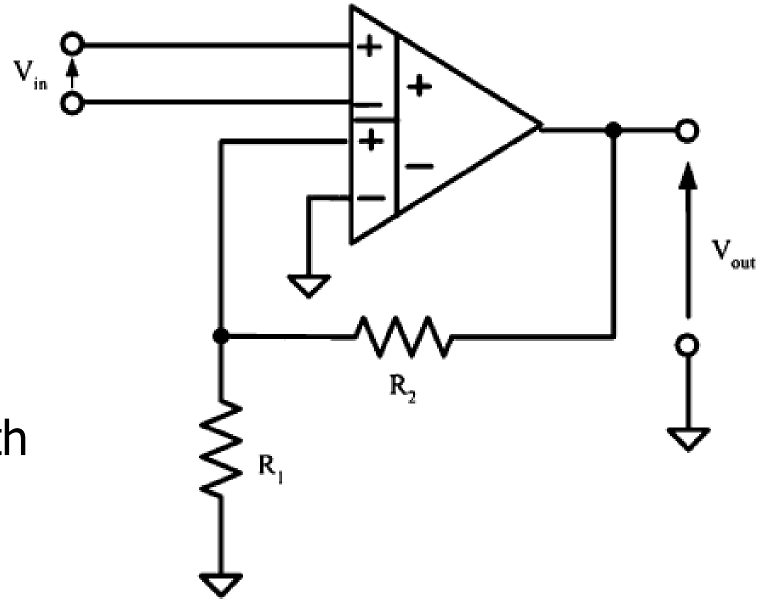


Agilent 4395-measure AC response

- Gian=60dB

- R1=1k
- R2=1M

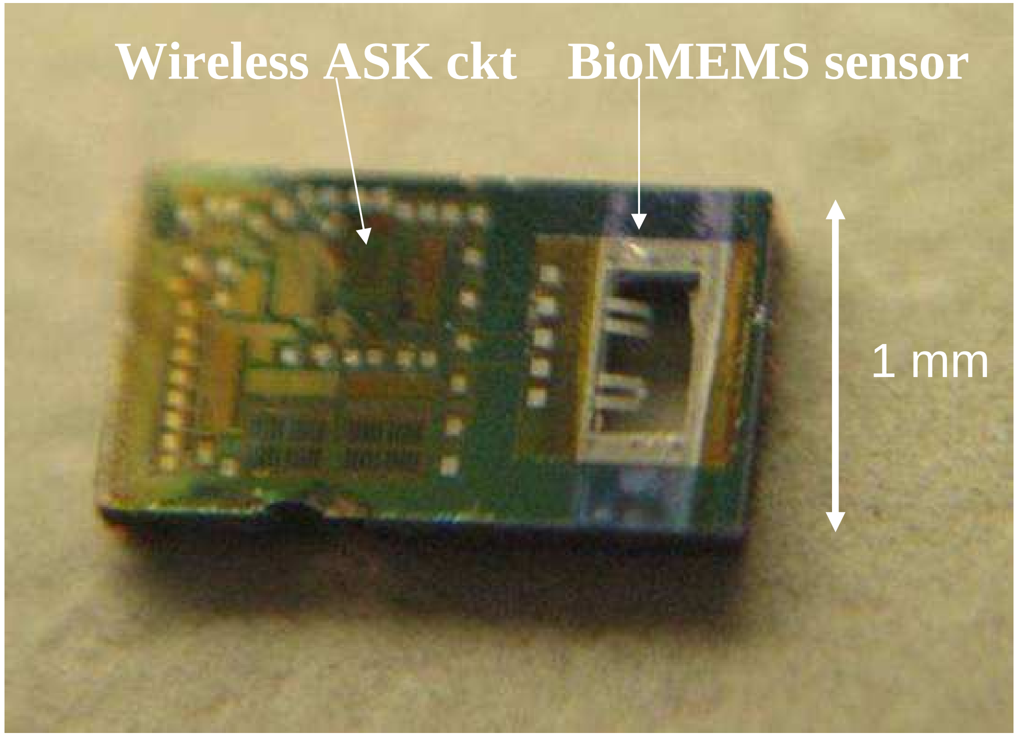




Summary

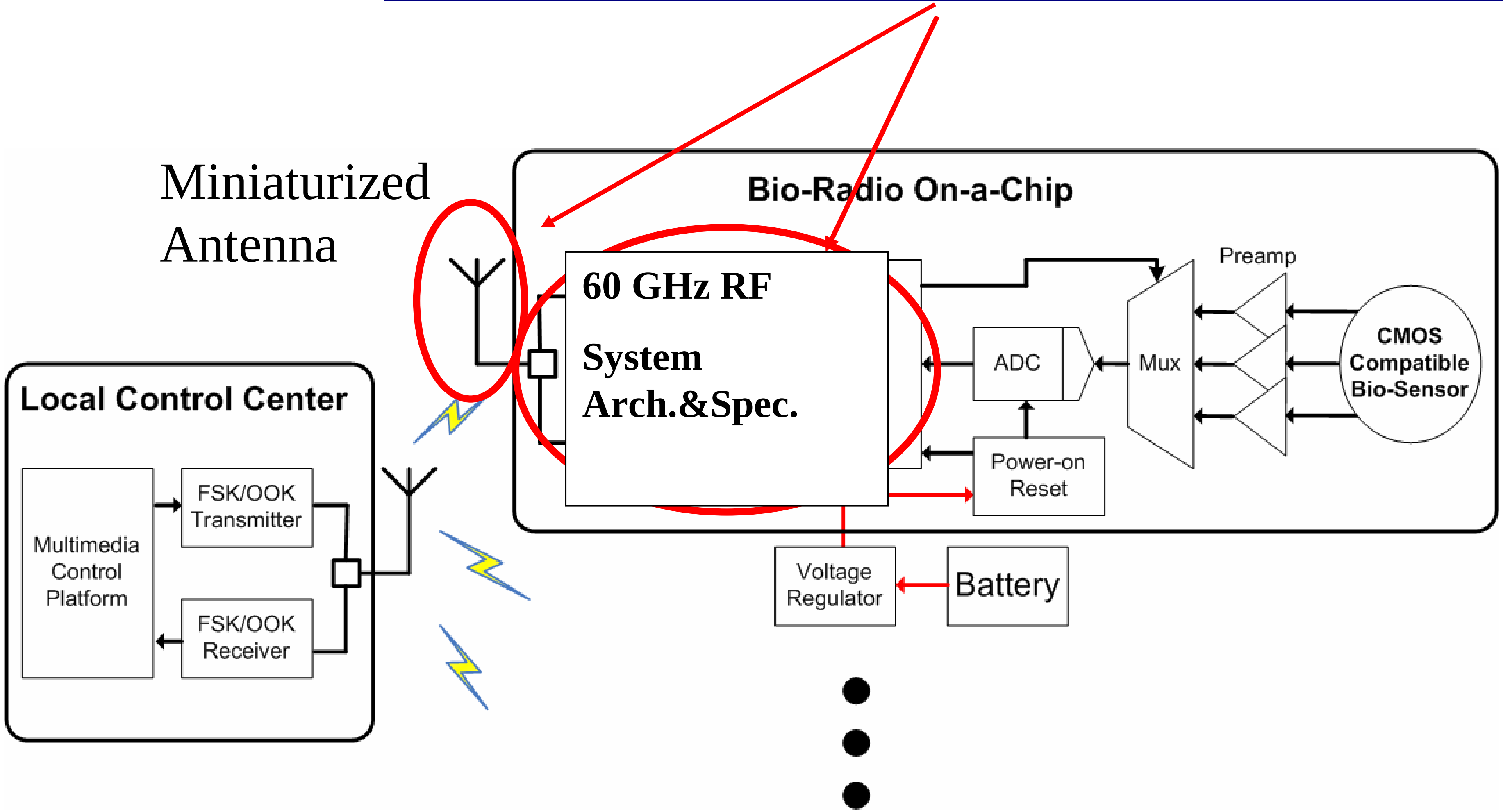
Specifications	Simulation	Measurement
Power supply	1.2 V	1.2 V
Input-referred offset voltage	N/A	Min. 480 uV
Unity gain frequency	147 KHz	50 KHz
DC current	1.7 uA	2 uA
Power consumption	2 uW	2.4 uW
Die area	0.3 mm^2	
Technology	Standard 0.13 um CMOS 1P9M	

BMW SOC Sensor



BMW: Bio-Medical Wireless

What We Need from CRC



Discussions (Non-SOC)

- 60 GHz RF: LNA + mixer + VCO (+PLL)
- LNA and Mixer: NF? IIP3? + other specs
- VCO: phase Noise? +other specs

Discussions (SOC)

- System voltage?
- System Architecture?
- System NF (sensitivity)? System Linearity
- I-Q or non IQ?
- Analog base-band ?(channel filter?)
- modulation scheme? (ASK, FSK, QPSK)
- Dynamic range? (How many bits of AD?)
- Etc..

附件四

60 GHz Wireless Sensor Networks for Environmental Applications

Ibrahim Haroun
Communications Research Centre Canada CRC
ibrahim.haroun@crc.ca

October 18 , 2006
Ottawa, Canada

Presentation Outline

- Motivation behind the research interest in the 60 GHz band
- Design Challenges of 60 GHz System-On-Chip in CMOS Process
- Overview of Short-Range 60 GHz Wireless Sensor Networks
- Link Budget Analysis for 60 GHz Wireless Sensor Systems
- 60 GHz RF Transceivers for Wireless Systems
  - FDD RF Transceiver
  - TDD RF Transceiver
- Proposed 60 GHz RF Transceiver in CMOS process
  - 2.4/60 GHz RF Transceiver for ZigBee and 802.11b/g.
  - 5.25/60 GHz Transceiver for 802.11a.
- Status of our 60 GHz Research Activities.
- Conclusion

Reasons for the Research Interest in 60 GHz Band

- Availability of 7 GHz in the unlicensed 60 GHz band (57-64 GHz).
- Advances in CMOS technology which support millimeter-wave system-on-chip.
- Highly secure operation because of the short-range transmission.
- It allows frequency reuse without harmful co-channel interference.
- It supports high data rate (Gb/s) applications.
- Antenna elements at 60 GHz are small enough to allow on-chip system integration.
- It allows small size devices which contribute to the miniaturization of wireless sensor nodes.

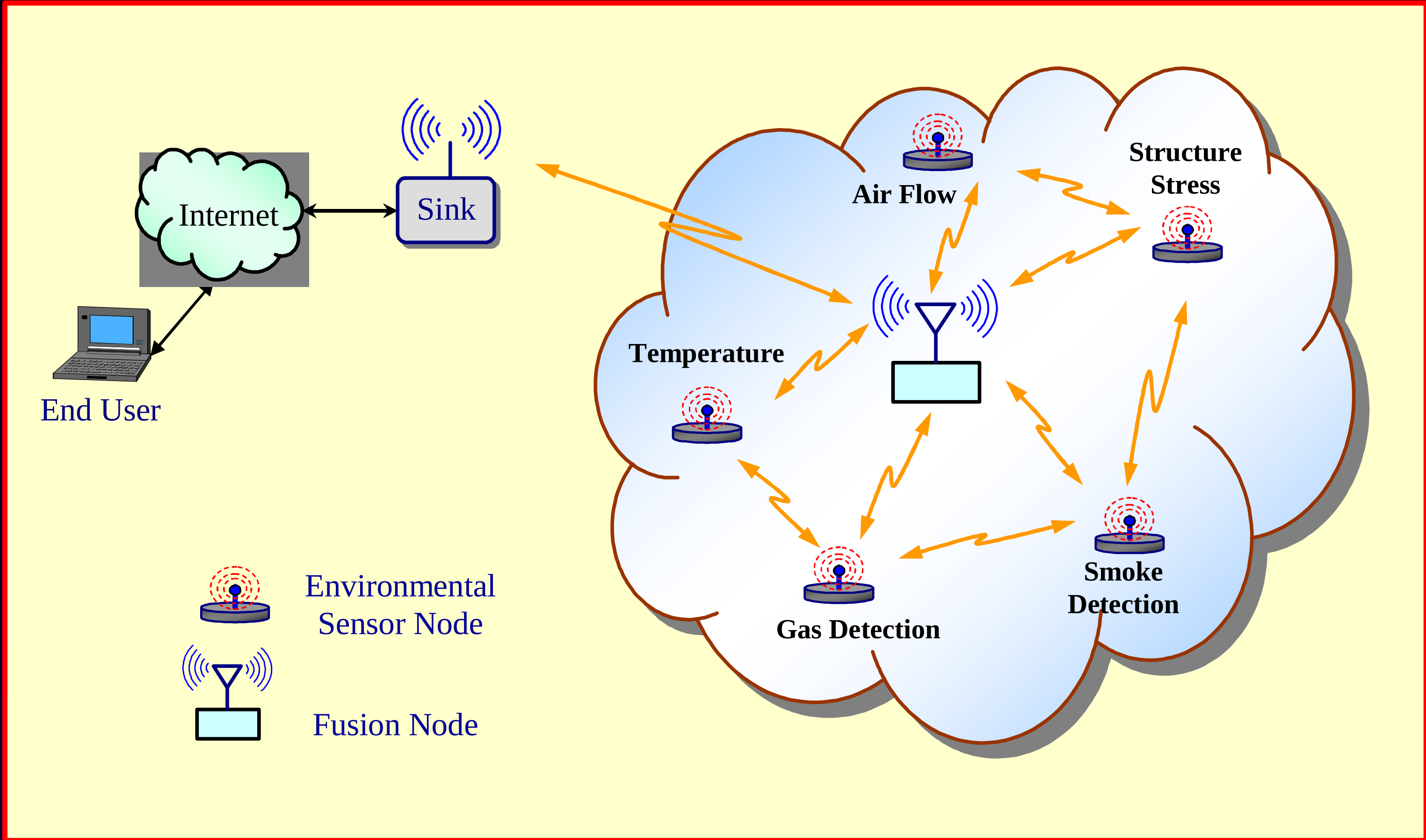
Possible Applications of the 60 GHz Band in an Indoor Environment

- Short-Range High-Data Rate Communication Systems (Wireless USB)
- Wireless Local Area Networks (WLANs)
- Short-Range Wireless Sensor Networks
- RF Over Fiber Communication Systems

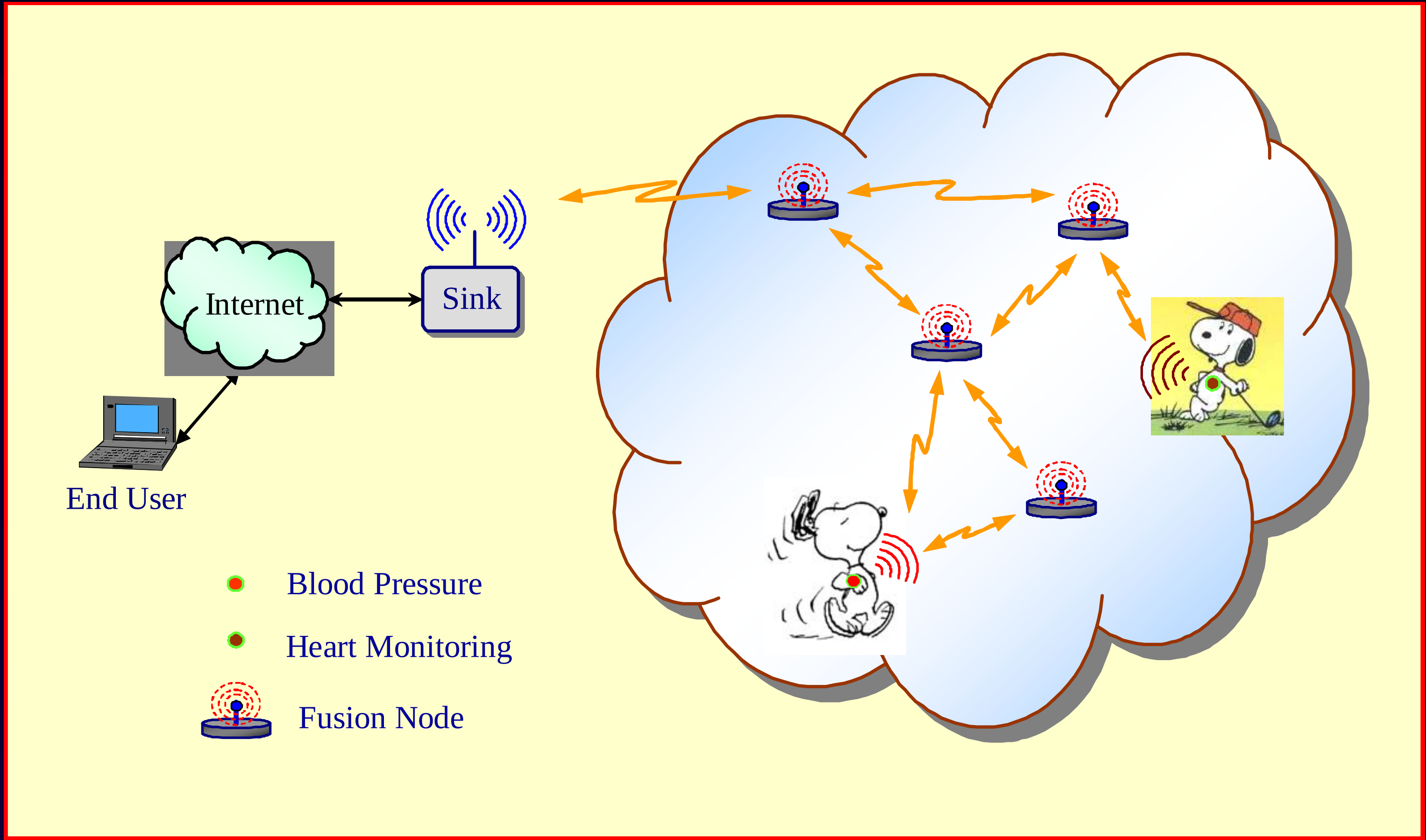
Design Challenges of 60 GHz System-On-Chip in CMOS Process

- Silicon substrate is lossy which makes the realization of high-Q passive elements difficult task.
- The design of the on-silicon oscillators for RF transceivers become challenging if an OFDM access is to be implemented.
- The design of on-chip T/R switches with sufficient isolation could be a design challenge at the 60 GHz band.
- The characterization of the radiation pattern of on-silicon integrated antennas at 60 GHz is very critical and could be a challenging task.
- The capacitors, inductors, and devices models which are provided by RF simulation tools are not validated at 60 GHz.

Overview of Short-Range 60 Wireless Sensor Networks for Environmental Applications



Short-Range 60 Wireless Sensor Network for Biomedical Applications



60 GHz Node-to-Node Link Budget Analysis for an Indoor Environment (n=2.5)

Link Parameters	Specifications
Operating Frequency	60 GHz
Modulation	QPSK
Required BER	1.0E-05
Data Rate	3 Mb/s
Receiver's Noise Figure	8.5 dB
Estimated Receiver Sensitivity	-88.23 dBm
Receiver's Antenna Gain	2 dBi
Node-to-Node Distance	10 meters
Transmitter's Antenna Gain	2 dBi
Estimated Transmit Power	-2.23dBm

10 Meters Node-to-Node Link Budget of 3 Mb/s System

60 GHz Node-to-Node Link Budget Analysis for an Indoor Environment (n=2.5)

Link Parameters	Specifications
Operating Frequency	60 GHz
Modulation	QPSK
Required BER	1.0E-05
Data Rate	5 Mb/s
Receiver's Noise Figure	8.5 dB
Estimated Receiver Sensitivity	-86.01dBm
Receiver's Antenna Gain	2 dBi
Node-to-Node Distance	10 meters
Transmitter's Antenna Gain	2 dBi
Estimated Transmit Power	-0.01 dBm

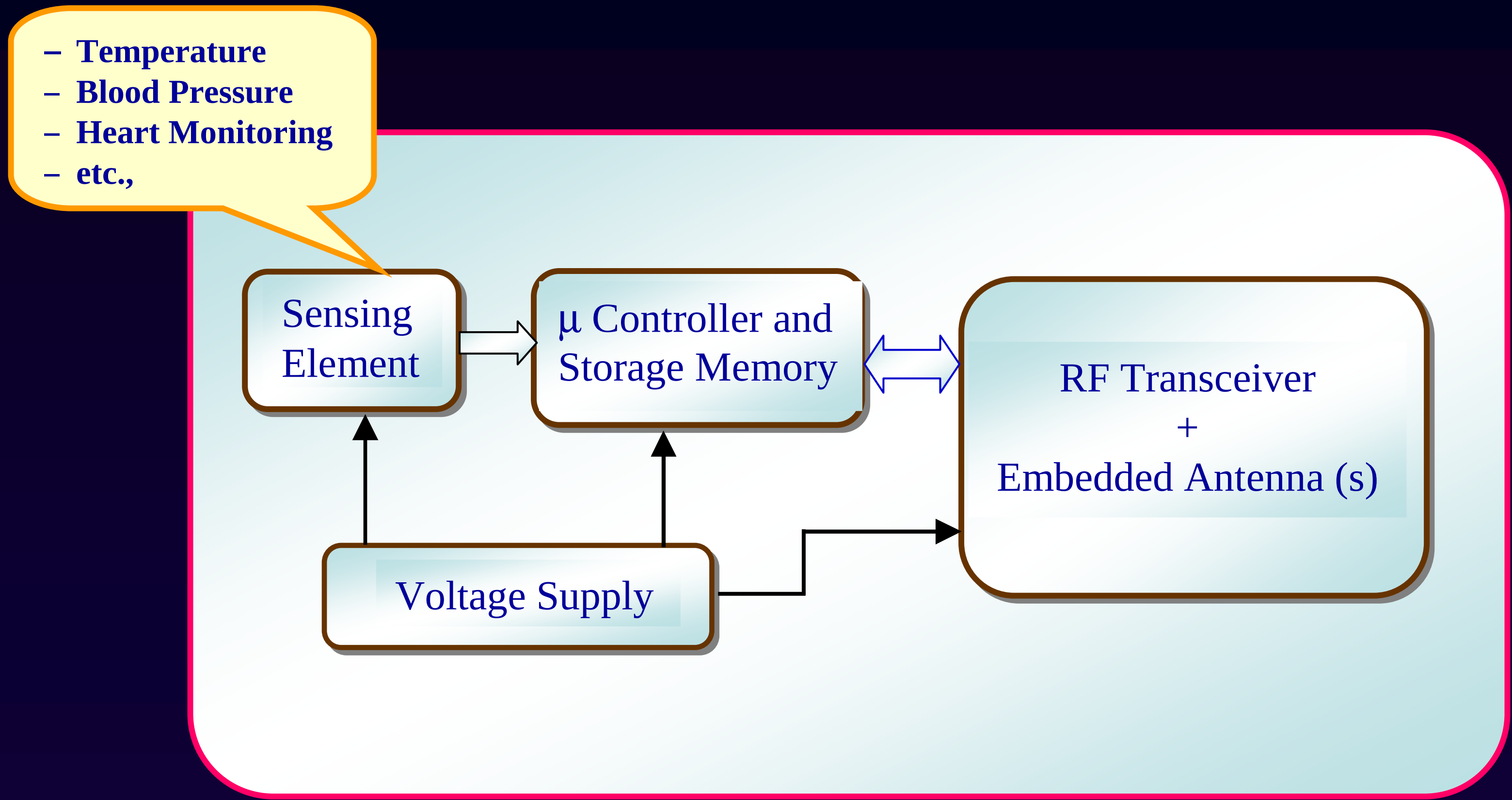
10 Meters Node-to-Node Link Budget of 5 Mb/s System

60 GHz Node-to-Node Link Budget Analysis for an Indoor Environment (n=2.5)

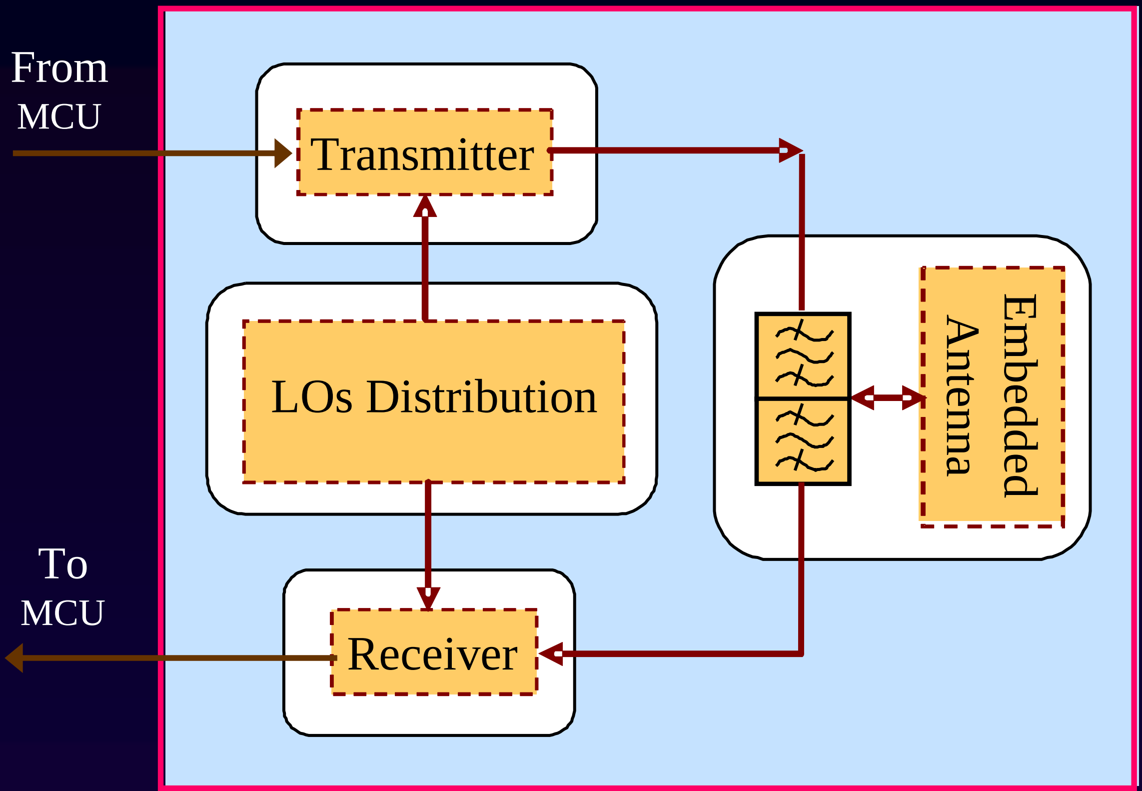
Link Parameters	Specifications
Operating Frequency	60 GHz
Modulation	QPSK
Required BER	1.0E-05
Data Rate	8 Mb/s
Receiver’s Noise Figure	8.5 dB
Estimated Receiver Sensitivity	-83.97dBm
Receiver’s Antenna Gain	2 dBi
Node-to-Node Distance	10 meters
Transmitter's Antenna Gain	2 dBi
Estimated Transmit Power	2.03 dBm

10 Meters Node-to-Node Link Budget of 8 Mb/s System

60 GHz Wireless Sensor Node Architecture

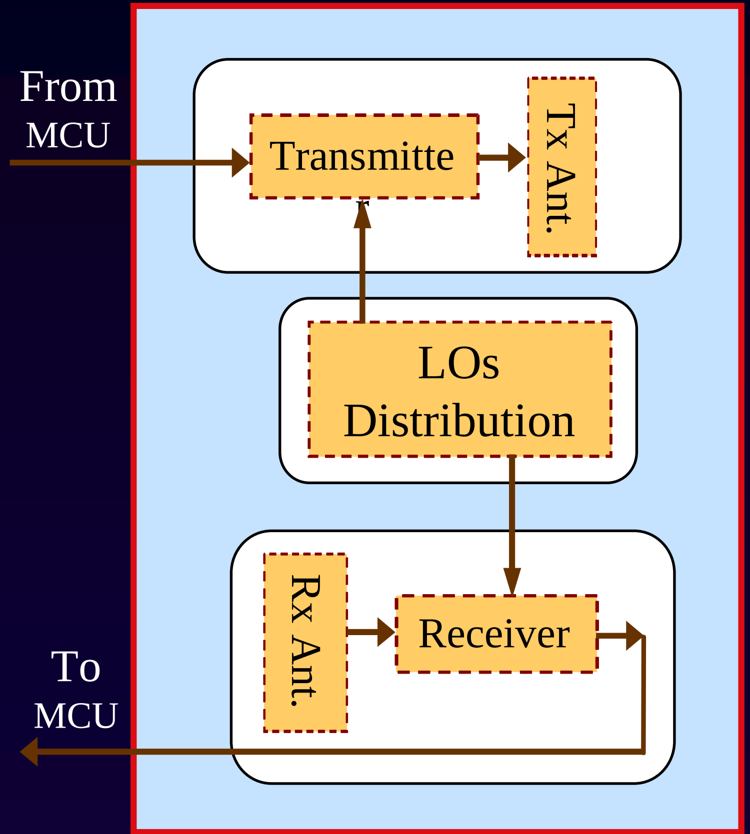


60 GHz FDD RF Transceiver Architecture for Wireless Communication Systems



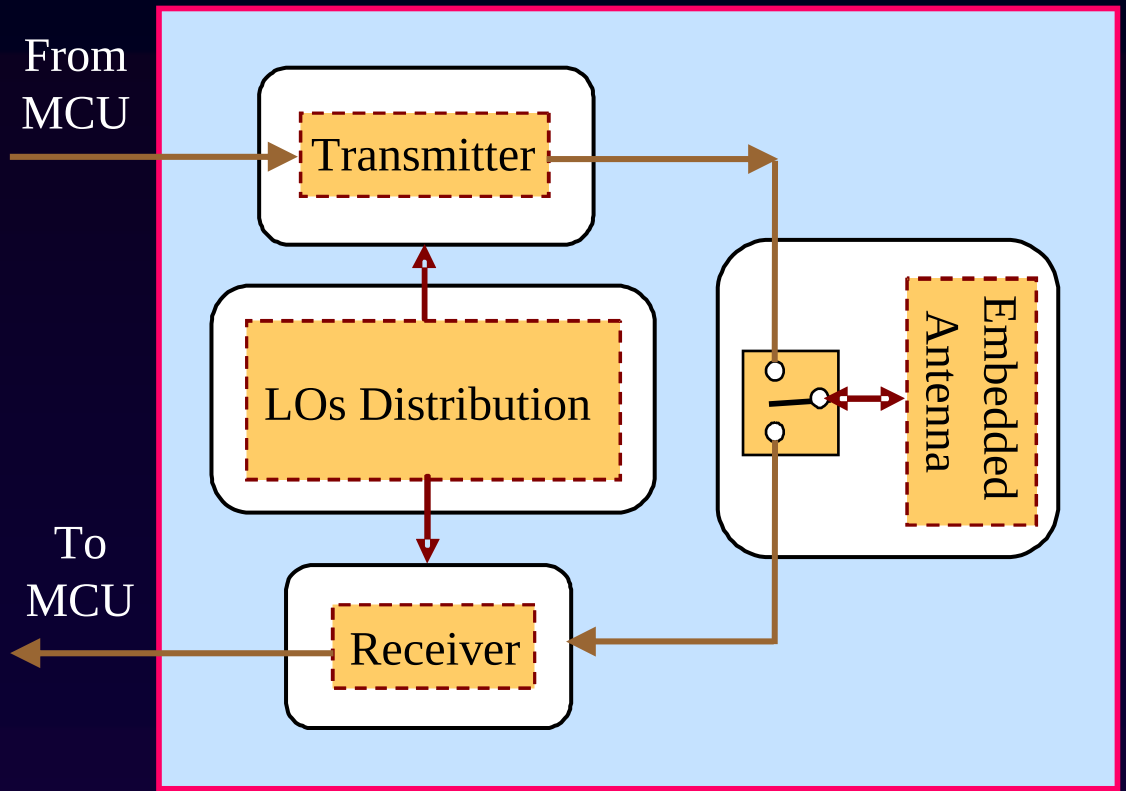
FDD Transceiver with One Antenna

60 GHz FDD RF Transceiver Architecture for Wireless Communication Systems



FDD Transceiver with Two Antennas

60 GHz TDD RF Transceiver Architecture for Wireless Communication Systems

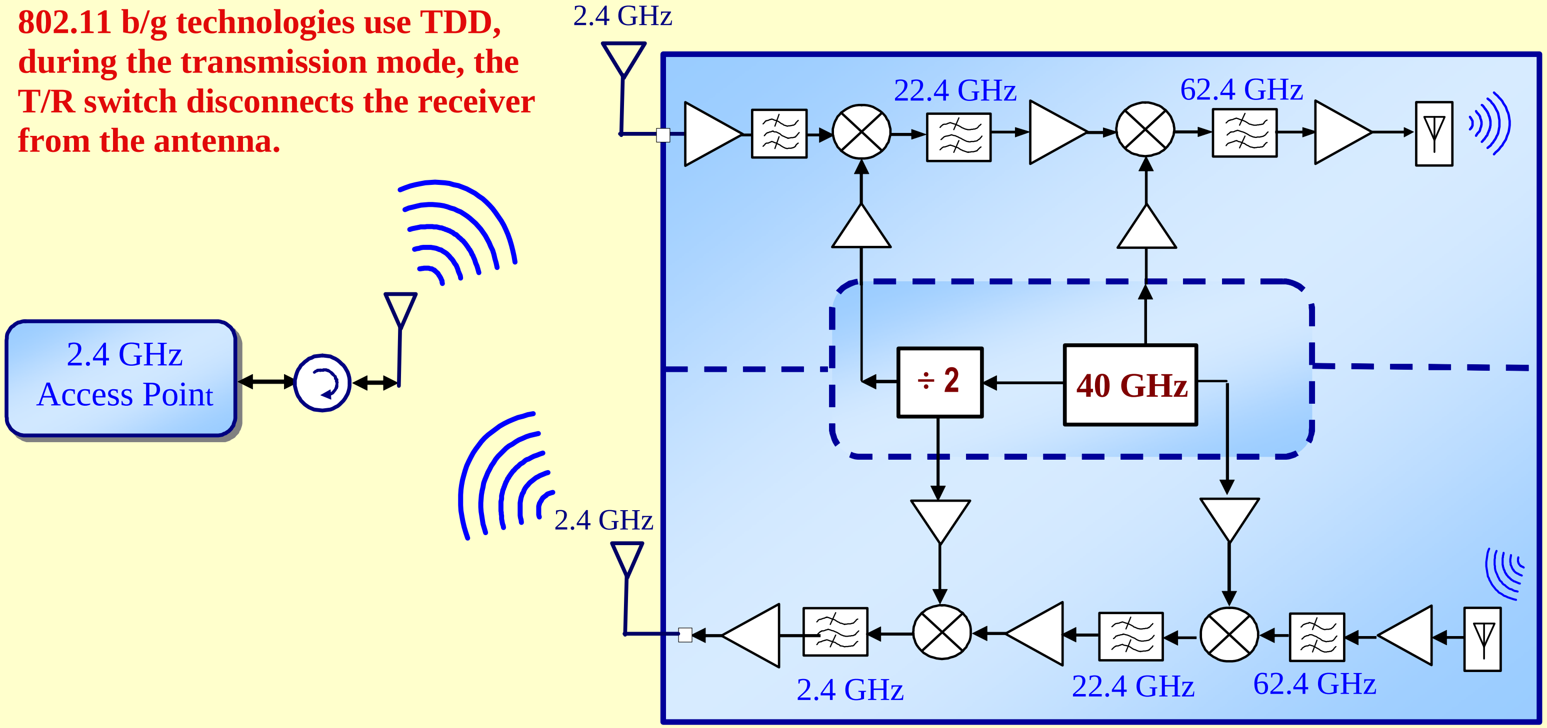


TDD Transceiver with One Antenna

Proposed 2.4/60 GHz On-Chip RF Transceiver for Wireless Sensor Networks

Note:

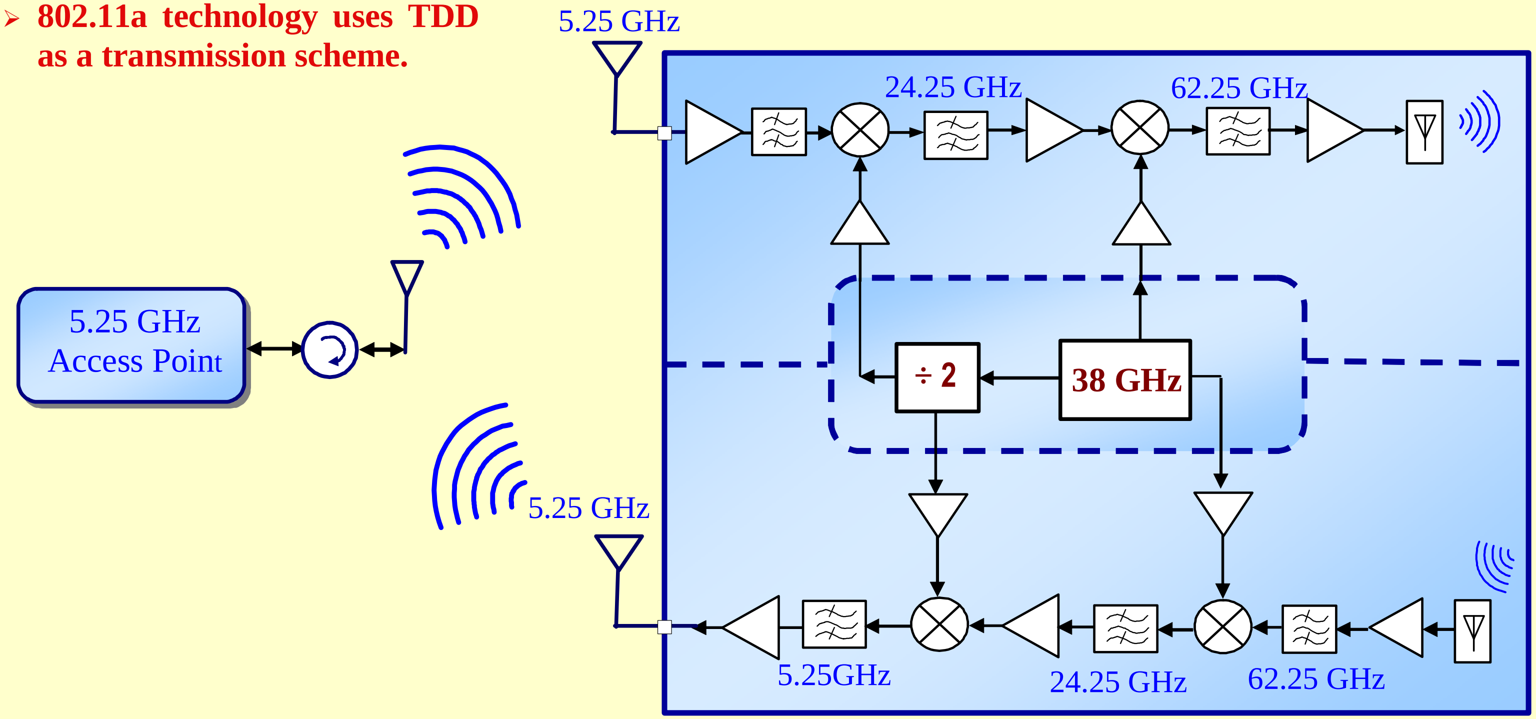
- **802.11 b/g technologies use TDD, during the transmission mode, the T/R switch disconnects the receiver from the antenna.**



Proposed 5.25/60 GHz On-Chip RF Transceiver for Wireless Sensor Networks

Note:

- **802.11a technology uses TDD as a transmission scheme.**



Status of our 60 GHz Research Activities

- Node-to-Node link budget analysis for a 60 GHz link was investigated.
- Supporting students with the study of on-silicon 60 GHz transmission-line elements for matching and interconnect of millimeter-wave circuits.
- Supporting students with the design and simulation of a 60 GHz LNA.

Conclusion

- The availability of 7 GHz in the 60 GHz unlicensed band and the advances in CMOS technology, make the 60 GHz band a potential candidate for short-range high-data rate wireless systems and wireless sensor networks.
- 60 GHz band enables complete system integration including antennas, in addition, it allows small size nodes for wireless sensor networks.
- A 60 GHz CMOS RF transceiver is proposed for wireless sensor applications.

Thank You !

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