3rd Austin Conference on Integrated Systems & Circuits 2008

An Invited Talk

Receivers Design:

CASE STUDIES

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http://amsc.tamu.edu, May 8th 2008

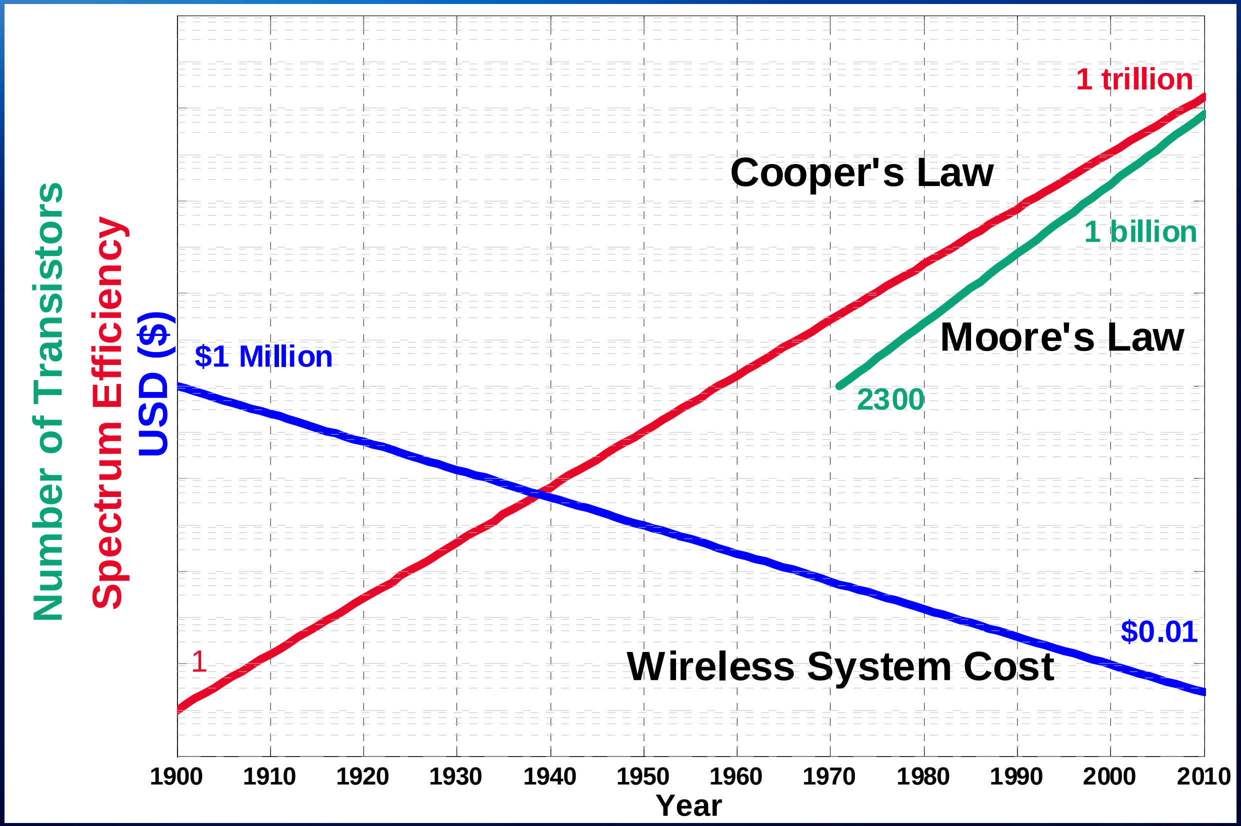
Purpose:

- Discussing Receiver Design Decisions
  - Architectures
  - Technology
- Future Trends
  - Applications
  - Technology
  - Standards

Outline

- Introduction: Wireless Revolution?
- Architecture Selection
- Case Studies:
  - Radios Designed in AMSC
- Recent Trends
- Emerging Technologies
- Conclusion

Wireless Revolution?



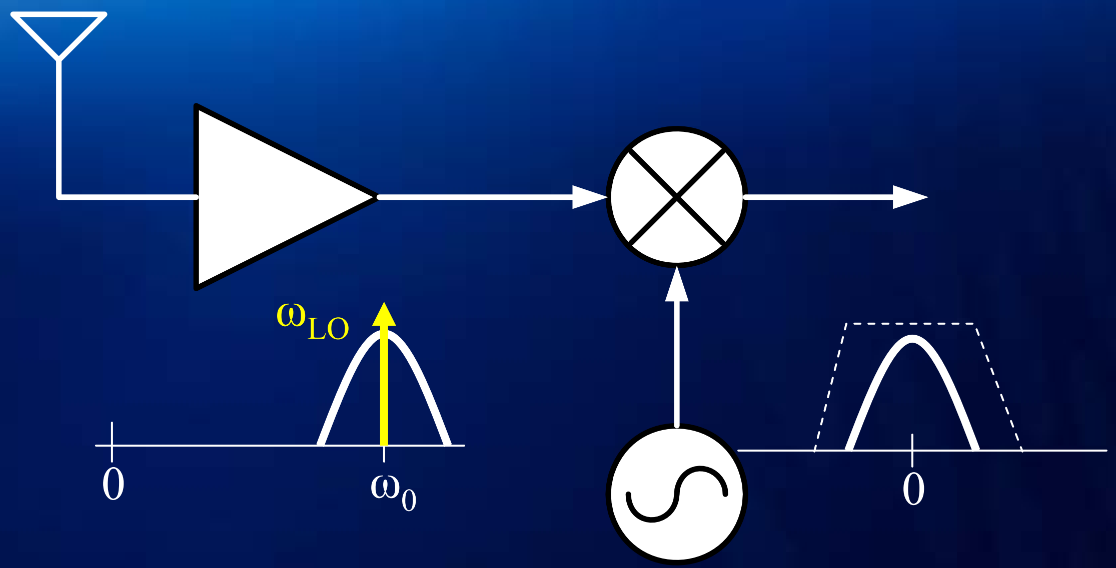
- *Moore's Law*: number of transistors double every 2 years
- Cooper's Law: Spectrum efficiency doubles every 2 ½ years
- Wireless systems cost per delivery halves almost every 5 years

Source: *Intel*; *Martin Cooper (ArrayComm)*

Wireless Standards

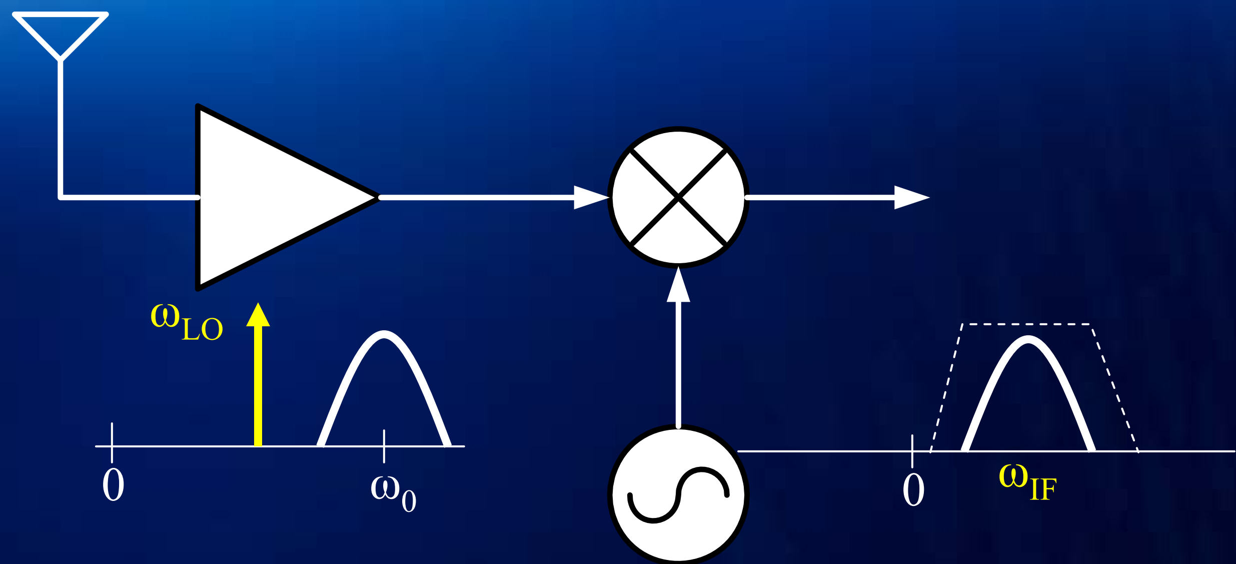
	Data Rate	Range	Cost
WiMax	15 Mb	5 km	$8
3G	14 Mb	10 km	$6
WiFi	54 Mb	50-100 m	$4
Bluetooth	700 kb	10m	$1
ZigBee	250 kb	30m	$4
UWB	~400Mb	5-10m	$5
RFID	1-200kb	0.01-10m	$0.04

Direct Conversion

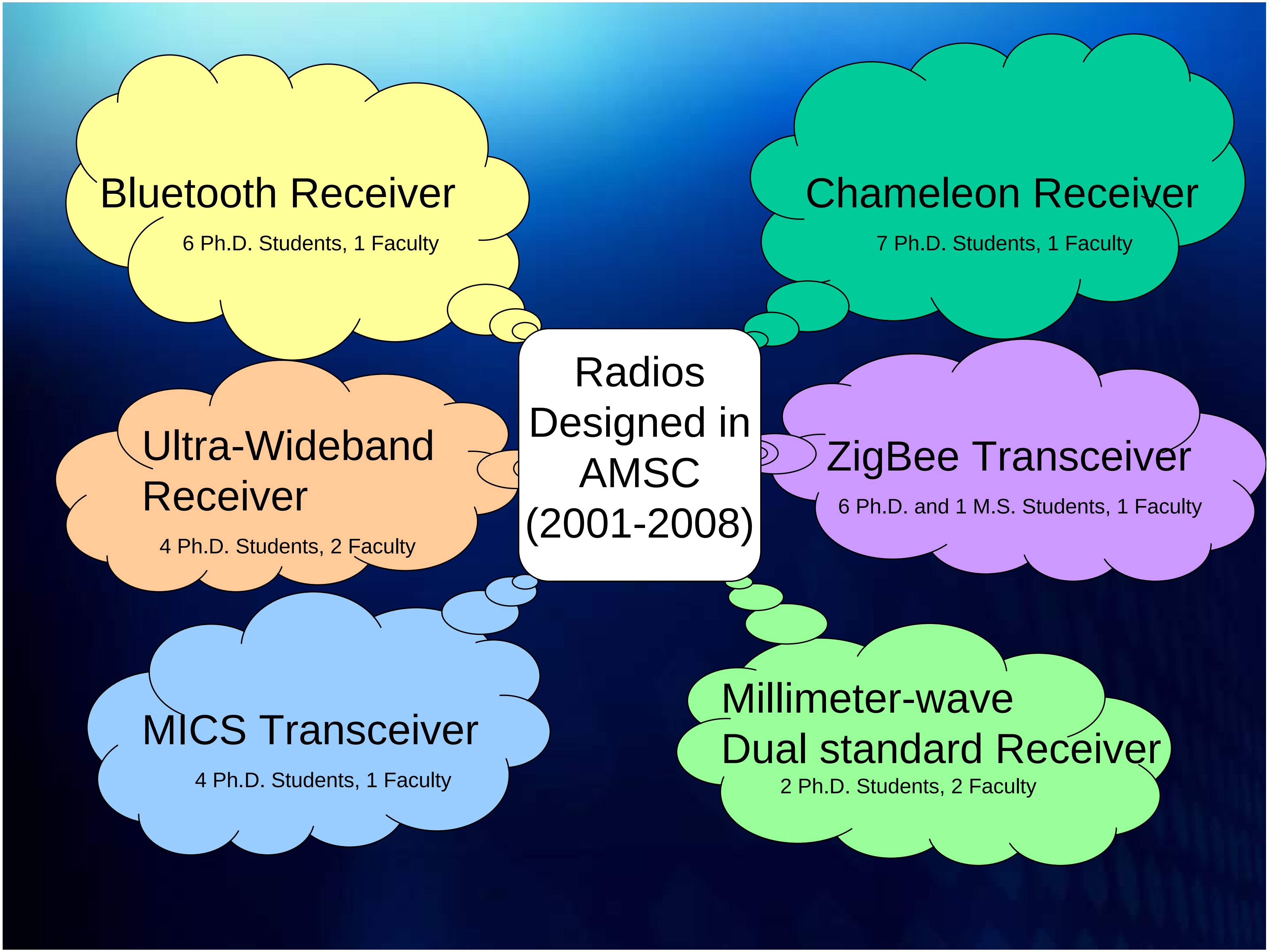


- High level integration.
- No image rejection required.
- Less components, possible low power consumption
- DC offset.
- Flicker Noise

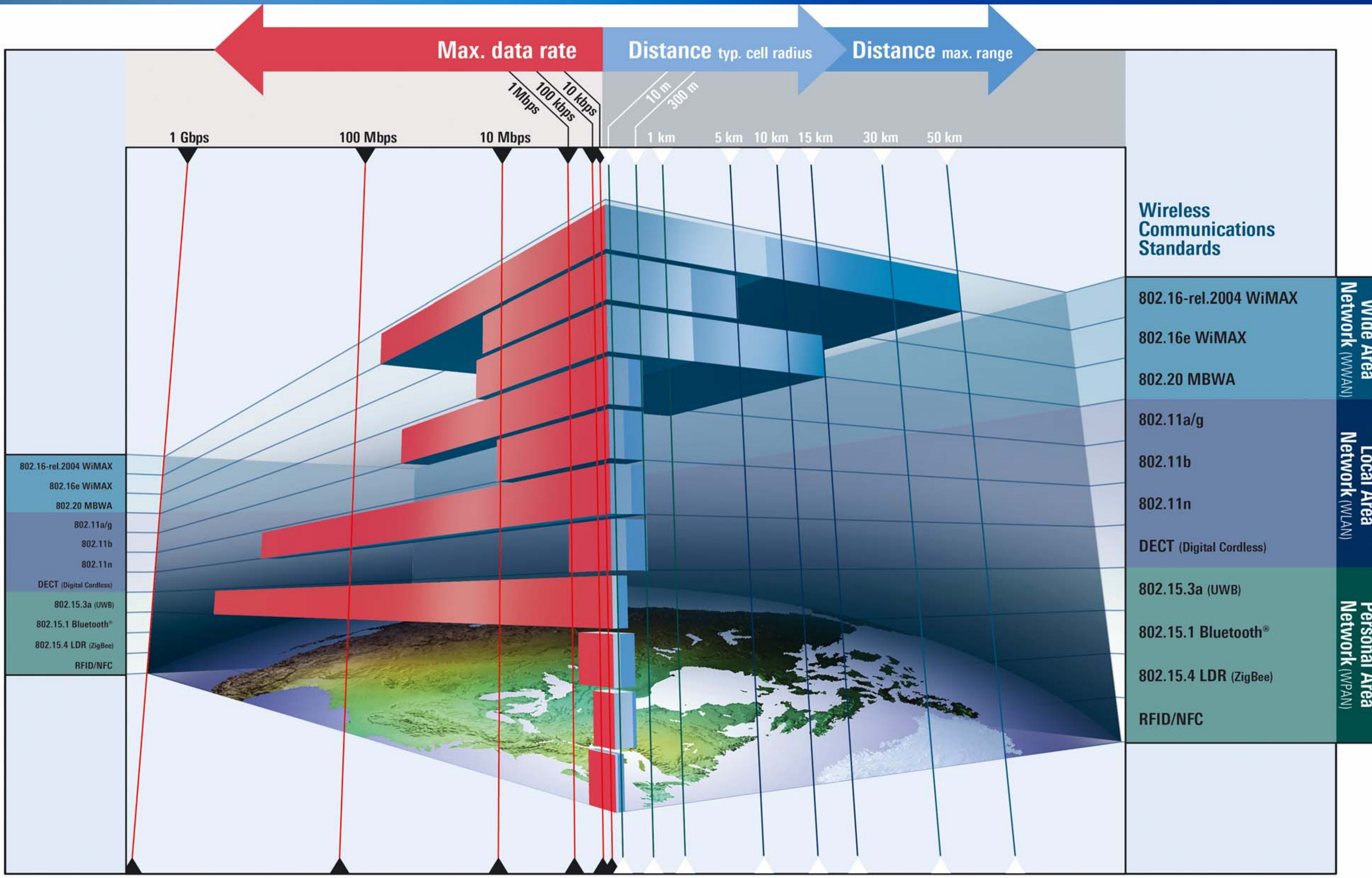
Low IF Receiver



- High level integration and possible low power design
- Flicker noise less significant in signal band
- DC offset can be easily removed
- Image rejection
- Folded-back interference


Radios Designed in AMSC (2001-2008)
Bluetooth Receiver
6 Ph.D. Students, 1 Faculty
Chameleon Receiver
7 Ph.D. Students, 1 Faculty
Ultra-Wideband Receiver
4 Ph.D. Students, 2 Faculty
ZigBee Transceiver
6 Ph.D. and 1 M.S. Students, 1 Faculty
MICS Transceiver
4 Ph.D. Students, 1 Faculty
Millimeter-wave Dual standard Receiver
2 Ph.D. Students, 2 Faculty

Data rate/Range



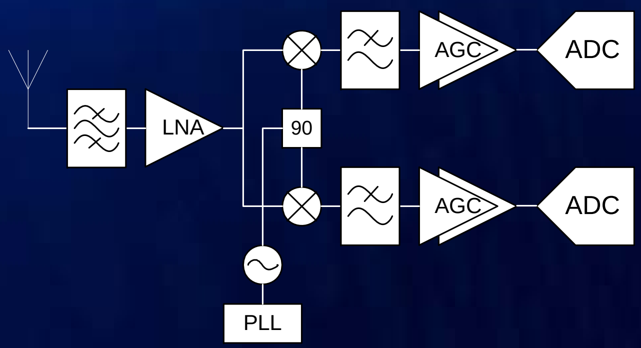
Bluetooth

Applications

Bluetooth Architectures

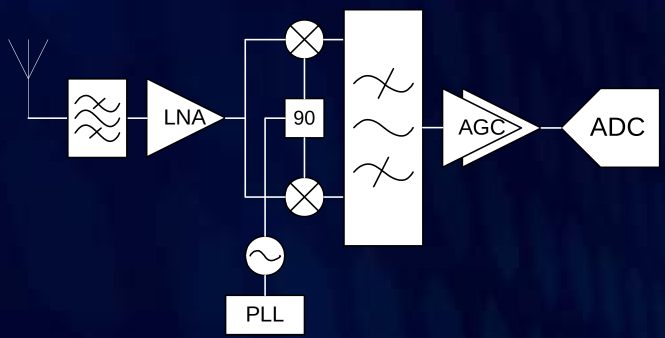
Direct-Conversion Receiver

- DC offset and flicker noise problem: 99% of signal power is within DC to 430kHz.
- A fast settling AGC may be required for GFSK demodulation.

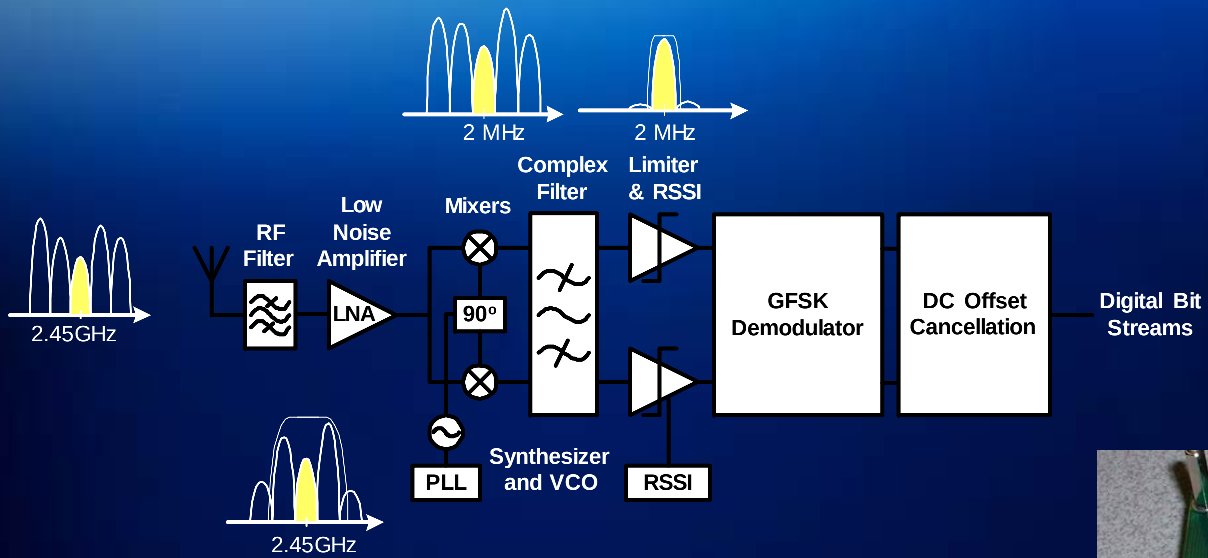


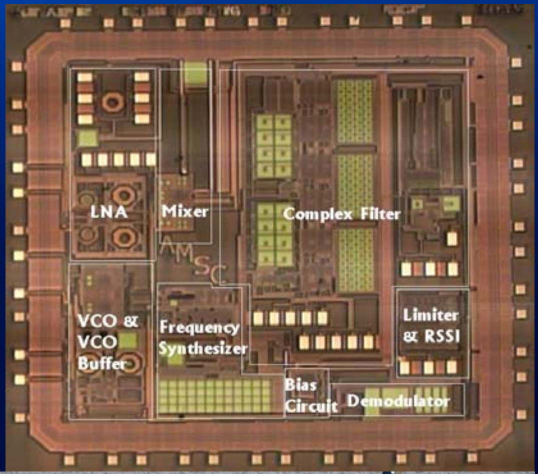
Low-IF Receiver

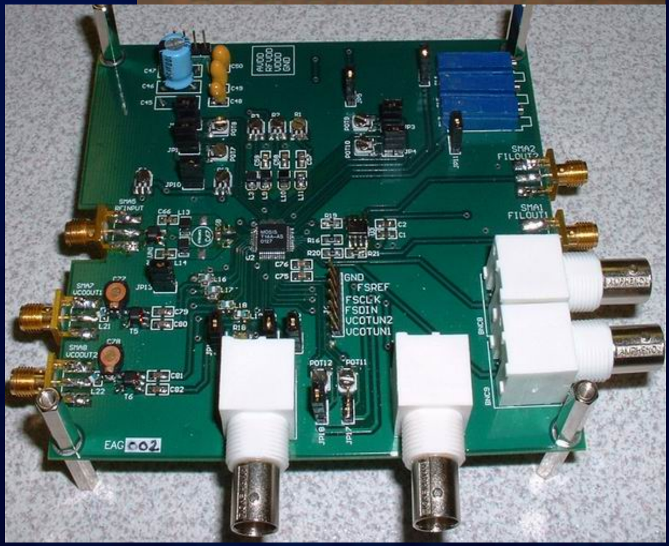
- Greatly alleviated DC offset and Flicker noise problem.
- Relaxed image rejection requirement (~33 dB).



AMSC Bluetooth*





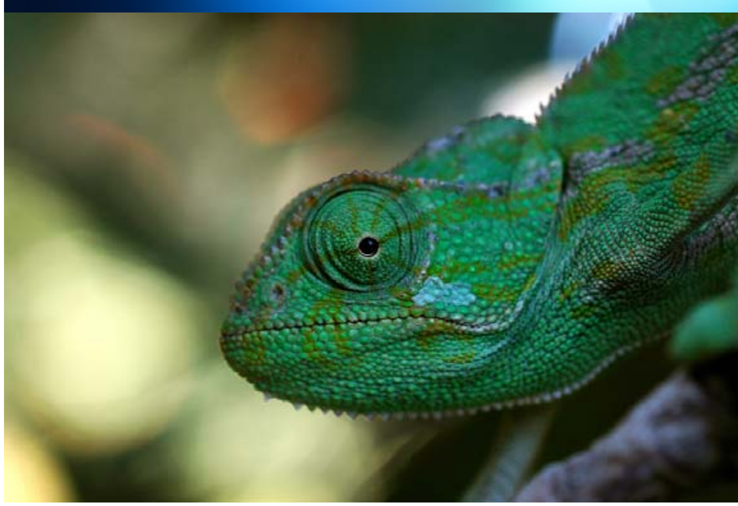


- ISM Band
- GFSK Signal
- Low-IF Quadrature
- Analog demodulator
  - No ADC, No AGC

* W. Sheng, B. Xia, A. Emira, C. Xin, A. Valero-López, S. Moon, E. Sánchez-Sinencio, "**A 3-V, 0.35um CMOS Bluetooth Receiver IC**" *IEEE Journal of Solid-State Circuits*, Vol. 38, No. 1, Jan. 2003

Chameleon (Bluetooth/WiFi)

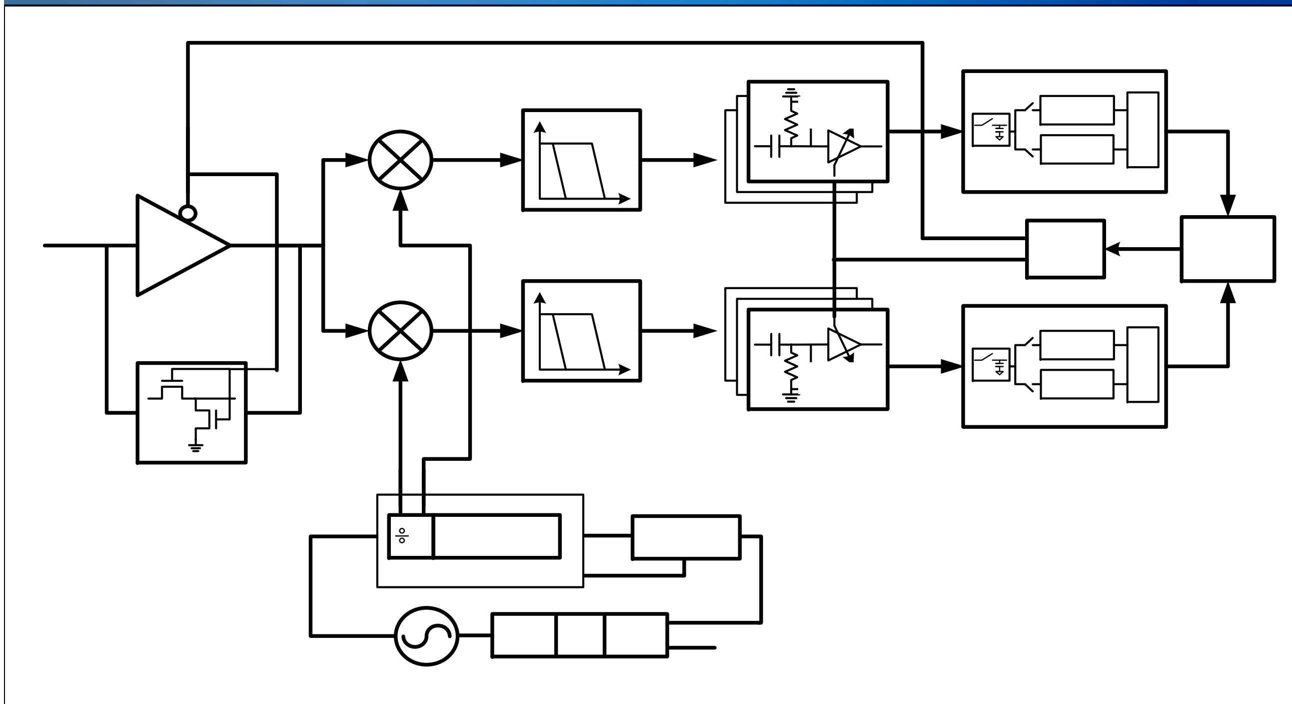
Applications

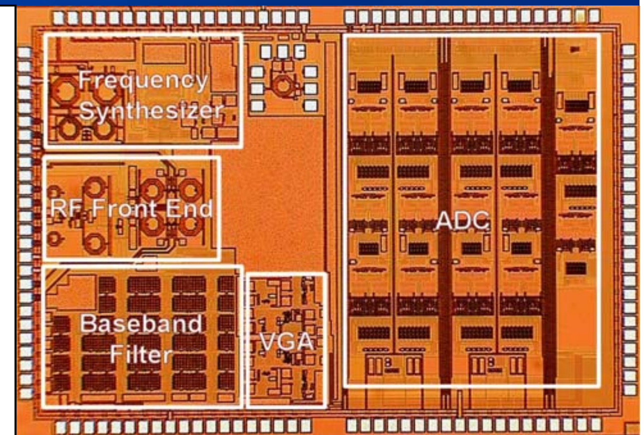


Standard comparison

	Bluetooth	Wi-Fi
RF Frequency	2.4GHz	2.4GHz
Sensitivity	-70dBm	-80dBm
Maximum Signal	-20dBm	-4dBm
Modulation	GFSK	CCK
Data rate	1Mb/s	1, 2, 5.5, 11Mb/s
Channel Bandwidth	1MHz	22MHz

Chameleon* (Wifi /Bluetooth)





- Direct conversion allows for maximum block sharing
- Shared RF front-end and programmable baseband components
- Programmable channel selection filter with constant linearity
- AC coupled VGA with constant output offset
- On-chip time-interleaved pipeline ADC

* A. A. Emira, A. Valedes-Garcia, B. Xia, A. N. Mohieldin, A. Y. Valero-López, S. T. Moon, C. Xin, E. Sánchez-Sinencio, "**Chameleon: A Dual-Mode 802.11b/Bluetooth Receiver System Design**" *IEEE Journal of Solid-State Circuits*, Vol. 53, No. 5, May 2006

Wi-F

BT

Ultra Wideband

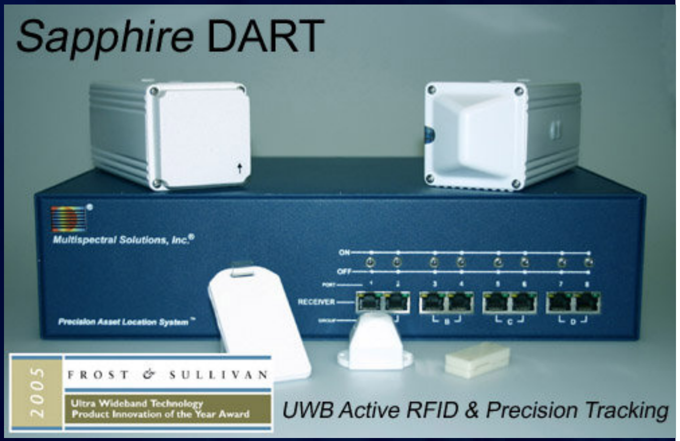
Communication

Ultra-Wideband Communication

- UWB Applications
  - Certified wireless USB
    - **Hub and dongle adapter kits**
  - Embedded laptop solutions
  - Real Time Location System
- Late take-off in 2007
  - 40,000 units shipped in 2007
  - 400,000,000[1] predicted by 2013
  - Tremendous potential in handsets
  - Possibility of integration w/ Bluetooth

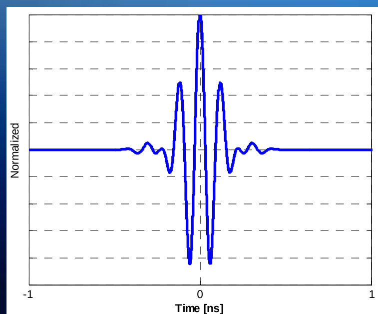
[1] ABI Research prediction

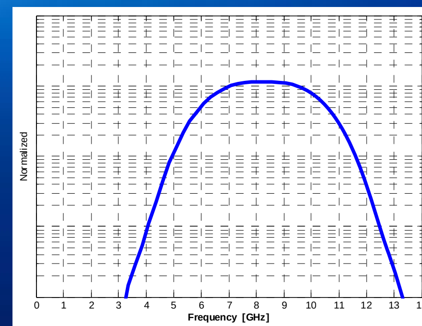
Wireless USB (Courtesy of Belkin)



RTLS System (Courtesy of MultiSpectral Solutions)

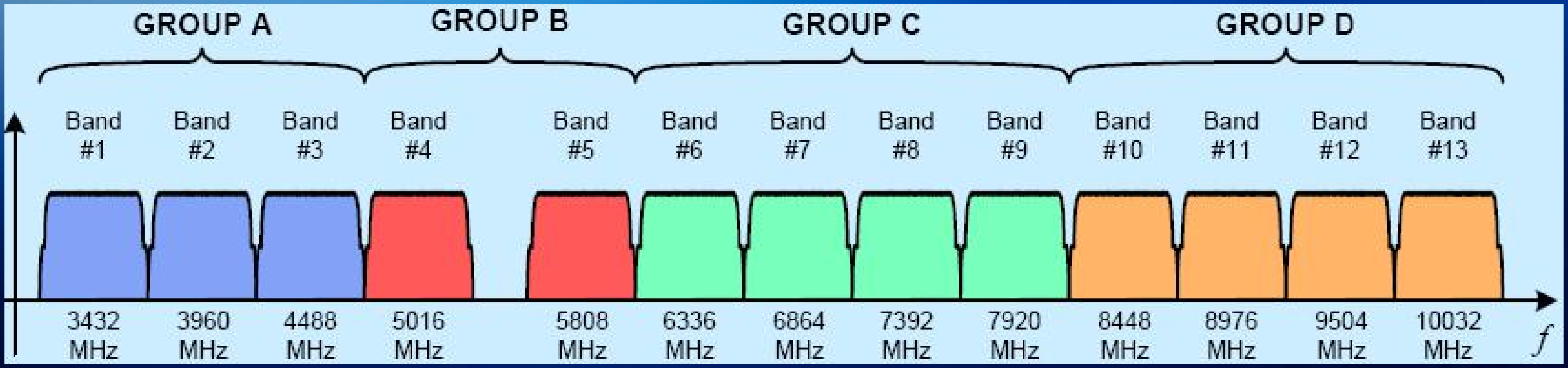
Pulse-based UWB





- Short burst of electromagnetic energy
  - Efficient battery use
  - Multi-path fading immunity
  - Secure
  - High Crest factor (PAR)
  - Not immune to ISI
- Applications
  - Radar/Imaging (1-100M Pulse/S)
  - Precision Asset localization
  - RFID
  - Communication (1-2G Pulse/S)

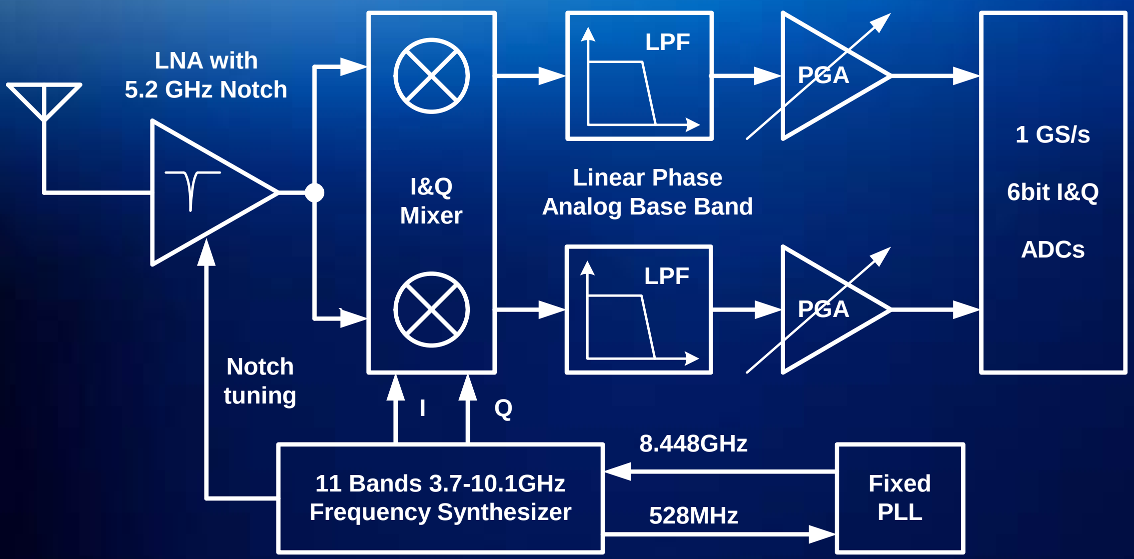
MB-OFDM UWB

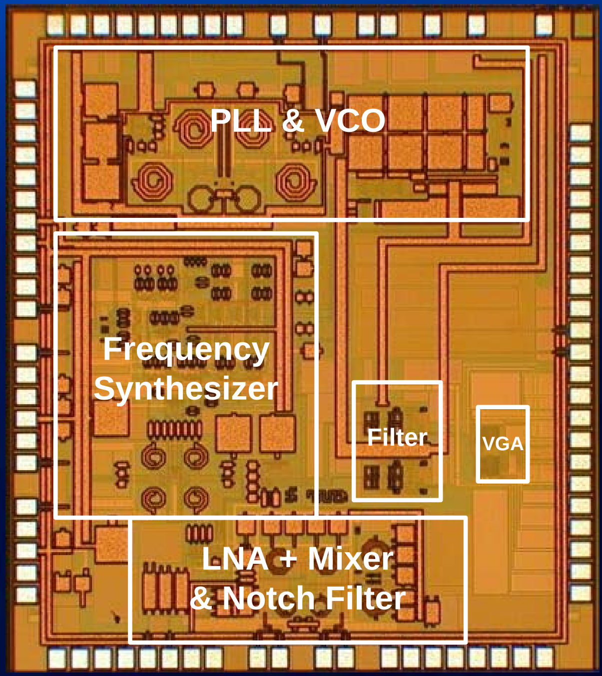


- 7500 MHz divided into 14 bands of 528 MHz
- Only first Band Group is mandatory
- All-band receiver is challenging
  - Range of frequencies to be generated spans several gigahertz
  - Switch time between different bands within band group should be less than 9.5ns

* C. Mishra, A. Valedes-Garcia, F. Bahmani, Anuj Batra, E. Sánchez-Sinencio, J. Silva-Martinez,"**Frequency Planning and Synthesizer Architectures for Multiband OFDM UWB Radios**" *IEEE Transactions on Microwave Theory and Techniques*, Vol. 53, No. 12, December 2005

AMSC UWB*





- Direct Conversion Receiver
- Full implementation from LNA to ADC
- Includes on-chip rejection of interference in the 5.2GHz U-NII band (WLAN)
- On-Chip Synthesizer generates the 11 required carriers

* A. Valedes-Garcia, C. Mishra, F. Bahmani, J. Silva-Martinez, E. Sánchez-Sinencio, "**An 11-Band 3-10 GHz Receiver in SiGe BiCMOS for Multiband OFDM UWB Communications**" *IEEE Journal of Solid-State Circuits*, Vol. 42, No. 2, April 2007

Highlight of Experimental Results

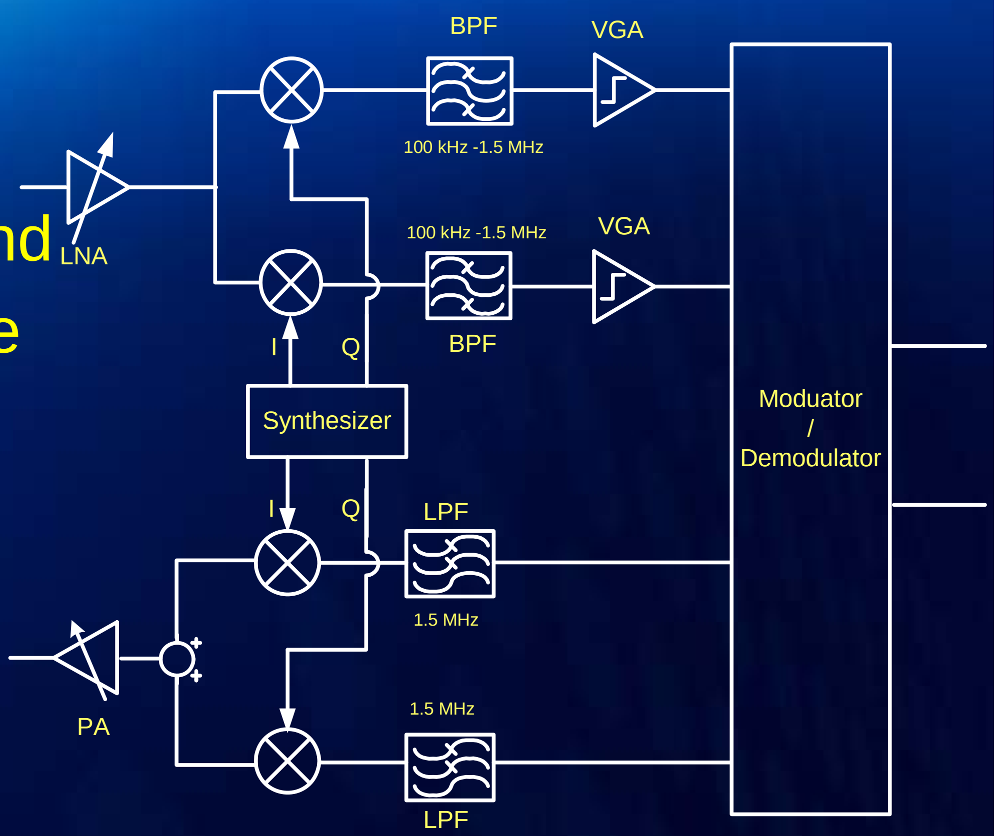
- First 3-10GHz MB-OFDM UWB receiver.
- Features first 3-10GHz 11 band fast switching frequency synthesizer.
- First UWB receiver beyond 5GHz demonstrated in package

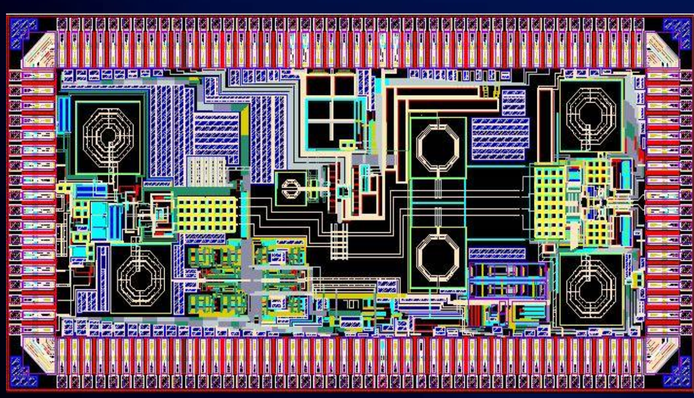
Maximum conversion gain	78-67 dB
Noise figure across bands	5-10 dB
IIP3 for band group 1 (worst case)	-9 dBm
Baseband group delay variation	<0.6 nS
Active area	5.6 mm^2 including pads
Current consumption	114 mA
Supply voltage	2.5 V
Package	QFN
Technology	IBM 6HP 0.25um SiGe

ZigBee Applications

AMSC ZigBee Transceiver*

- Very low-power standard
- Direct Conversion / ISM Band
- OQPSK Signal w/ sine-wave shaping
- Analog Mo/Dem
  - Coherent
  - Non-Coherent





- Integer-N Synthesizer
- Switching-Type PA
  - Constant-envelope signal

* ***Under fabrication***; Team Members: Faisal Hussien, Hesam A. Aslanzadah, Sang Wook Park, Didem Turker, Rangakrishnan Srinivasan, Felix Fernandez, Mohamed Mobarak, Gang Bu, Edgar Sánchez-Sinencio

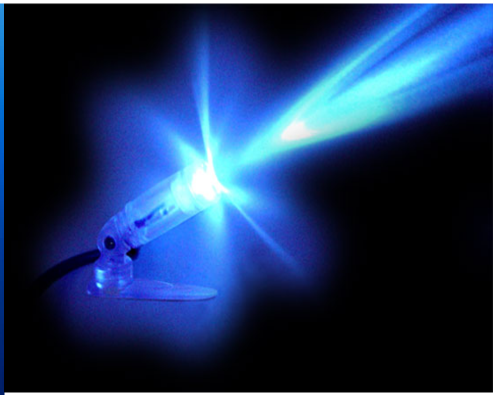
Recent Trends

in **Wireless Technologies**

Recent Trends

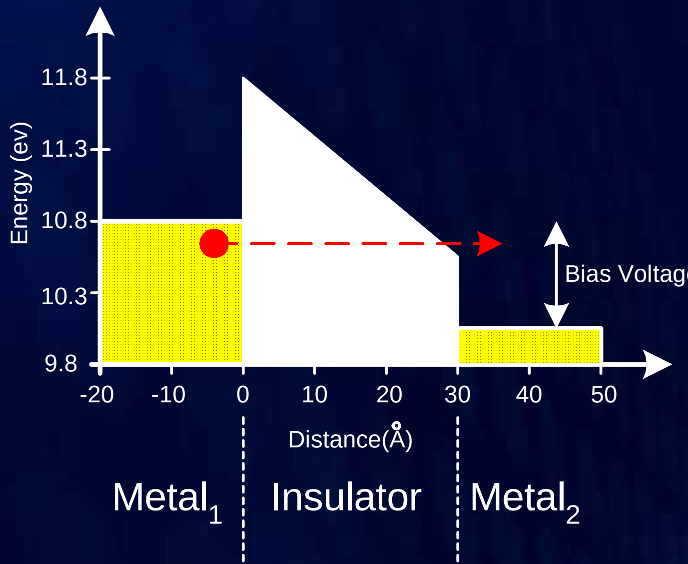
- Multi-Standard Transceivers
  - Multifunctional, Multi-band, Concurrent radios
- Adaptive Radios
  - Software-Defined Radio
- Baseband blocks
  - Reconfigurable
  - Programmable
  - Power-Adjustable
- High Integration
  - Antenna integration at millimeter-wave frequencies
- Wearable devices
  - Ultra low-power reliable RF/Analog
- MIMO
  - IEEE 802.11n, WiMax, …

Emerging Technologies



- Concept: Quantum tunneling
- Low-Cost MIM technology
- *Phiar Inc.* models f_T of 1.8 THz for MIIMIM transistors to be produced in 2008
- "Amorphous and compatible with a wide range of substrate materials"
  - Single chip CMOS 60-GHz transceiver possible w/ digital CMOS and integrated antenna + front-end in MIM

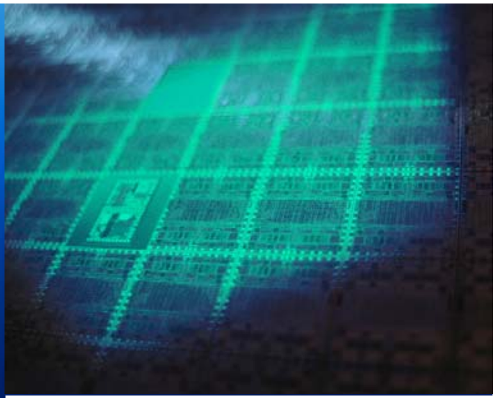
Phiar CORPORATION



Electron Tunneling used in a Diode
(Source: Phiar.com)

Emerging Technologies

- Concept: Green Wireless
- No Battery, No wire
- Building/Home/Industrial Automation
- Radio Module
  - Energy Scavenging: 50uW
  - Range: 300m (free field) / 30m(Building)
  - 868MHz (license free) / 315MHz (less crowded)
  - Data rate: 125kbps
- How?
  - Avoid over-crowded ISM band (2.4GHz)
  - ASK / 1% duty cycle
  - Multiple short telegrams (1ms) w/ checksum

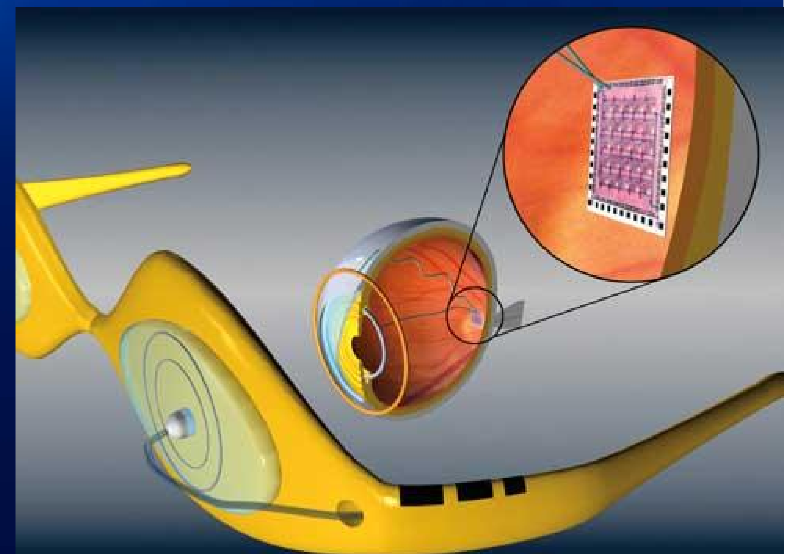


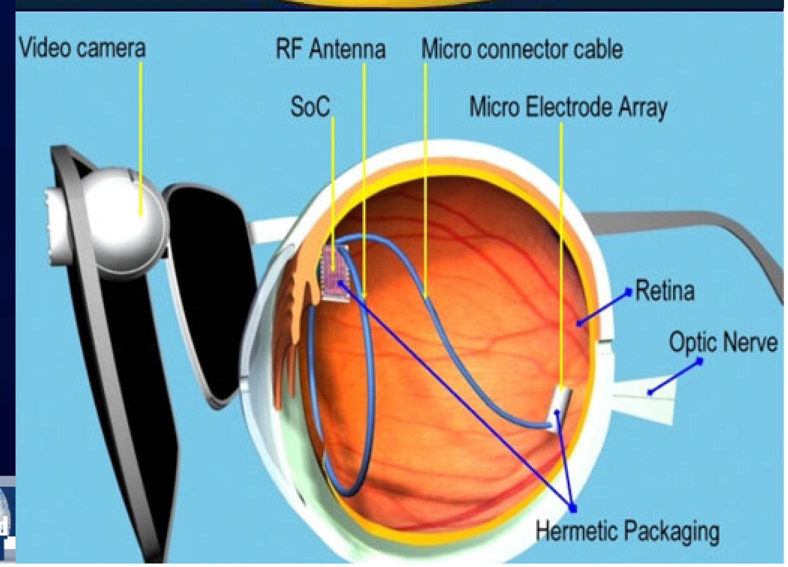
Green. Smart. Wireless. enocean®

***Torre Espacio Building,** Madrid, is automated using self-powered wireless network of 4200 switches, 13500 addressable luminaries and 4500 blinds*

Emerging Technologies

- Concept: *Artificial Vision*
- Using
  - Video camera
  - Image processor + transmitter
  - Self-powered wireless receiver
    - Energy Scavenging
    - Receiving Processed Video Data
    - Ultra-low power
    - MICS unlicensed frequency (400 MHz)
- Second Sight
  - (Argus II) 16 Electrode Device
- Intelligent Medical Implants AG
  - 50 Electrode Device





Pictures Courtesy of ***Second Sight*** and ***Intelligent Medical Implants***

Intelligent Medical Implants

Second Sight

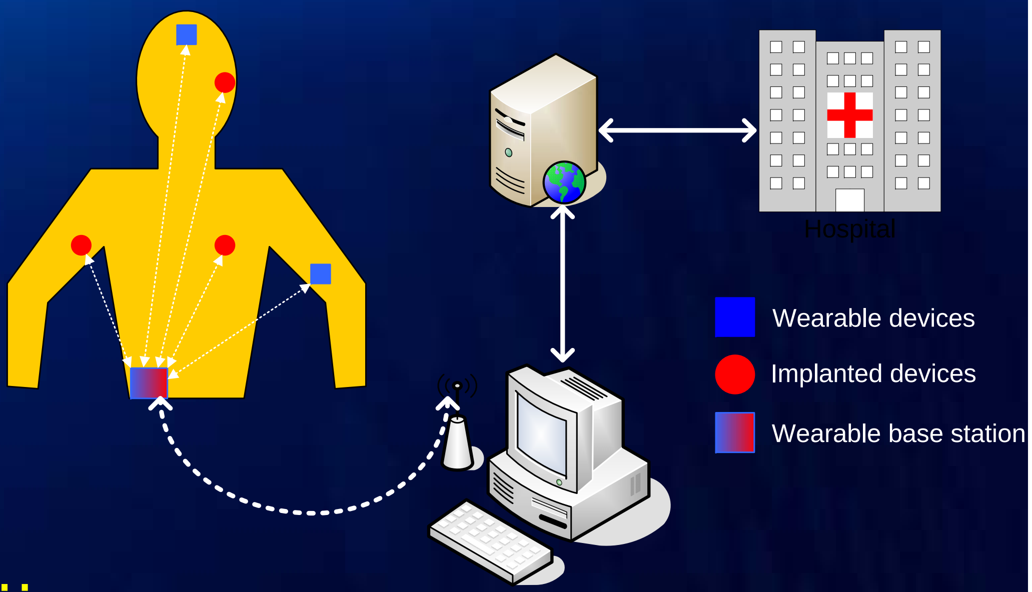
Emerging Technologies

- Wireless HD (High Definition)
- Three contenders:
  - UWB (MBOA)
  - IEEE 802.11n
  - 60 GHz license-free waveband

	Available Spectrum [GHz]	Channel BW [MHz]	P_{max} [dBm]	Data rate [Mbps] Typ./Max.
UWB	1.5 (1 BG)	520	-4	200/480
IEEE 802.11n	0.67	40	22	74/248
60 GHz	7	2500	39	4000/25000

Medical Implant Communications Service*

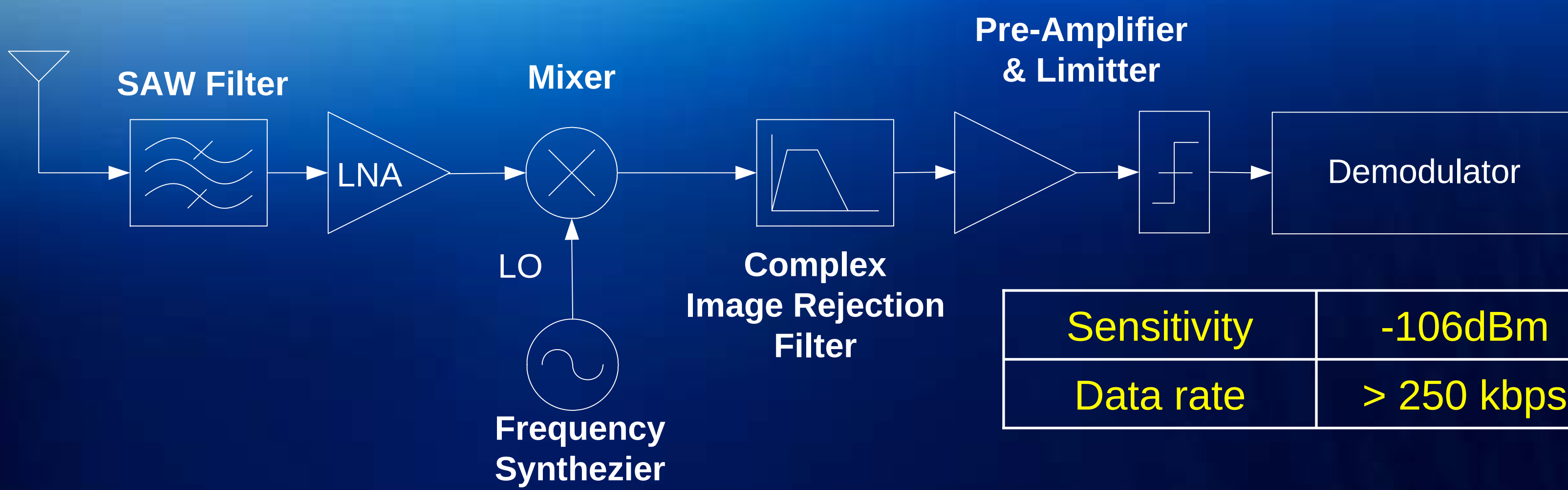
- Concept: Wearable Communication device
- $40B Market by 2011
- Implantable Medical Devices (IMD)
  - Heart diseases
  - Neurological disorders, …
- 402-405MHz band



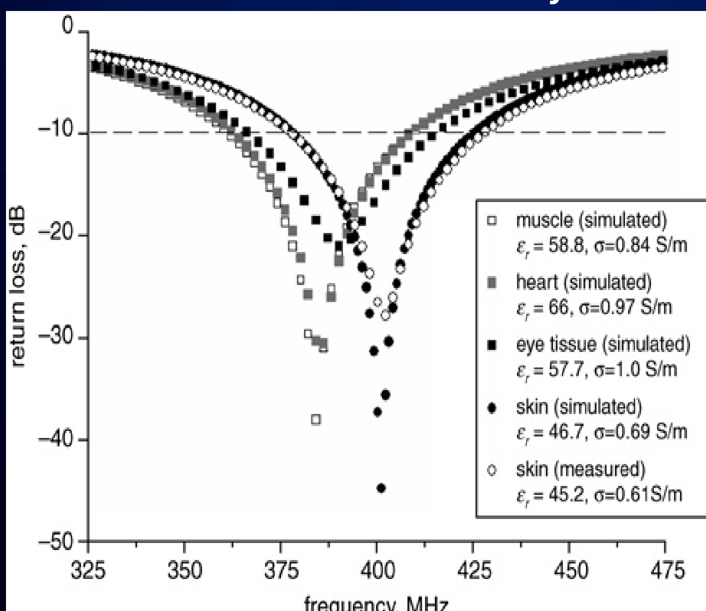
Possible scenario where patient conditions can be addressed remotely in real time using both implanted and wearable devices

* *Under Tape-out;* **Team: Félix O. Fernández-Rodríguez, Mohamed S. Mobarak, Mohammed M. Abdul-Latif, Jincheng Li, Kwisung Yoo, Edgar Sánchez-Sinencio**

Architecture:



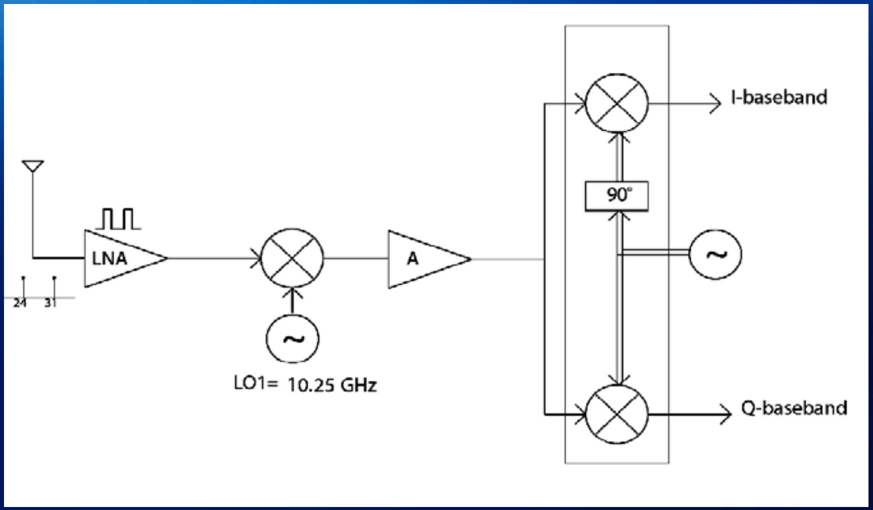
Sensitivity	-106dBm
Data rate	> 250 kbps



Measured and simulated return loss for stacked implantable planar inverted-F antenna implanted into different biological tissue

- Why 402-405 MHz?
  - Good radio propagation characteristic within human body (less return loss)
  - Suitable to meet MICS requirements (e.g. size, power, antenna performance and relaxed receiver design)

AMSC MM-wave Receiver*



- Project Goals
  - Design/Implementation of a dual band receiver for the ISM(24GHz) and LDMS(31GHz) bands
  - The receiver should comply with IEEE802.16 standard
- MM-wave Dual Band receiver
  - The RF front-end is reused
  - Sub-harmonic mixing to reduce LO frequency
  - Band selection is preformed at IF

* *Under Design; Team:* **Mohamed El-Nozahi, Ahmed Amer, Kamran Entesari and Edgar Sanchez-Sinencio**

Conclusion

- Wireless applications in all areas of our lives
  - Medical, Environmental, Communication, House Automation, Security, …
- Different architectures for varying applications

Cartoons courtesy of ***The Economist (by Bell Mellor)***

Thank You

Q&A