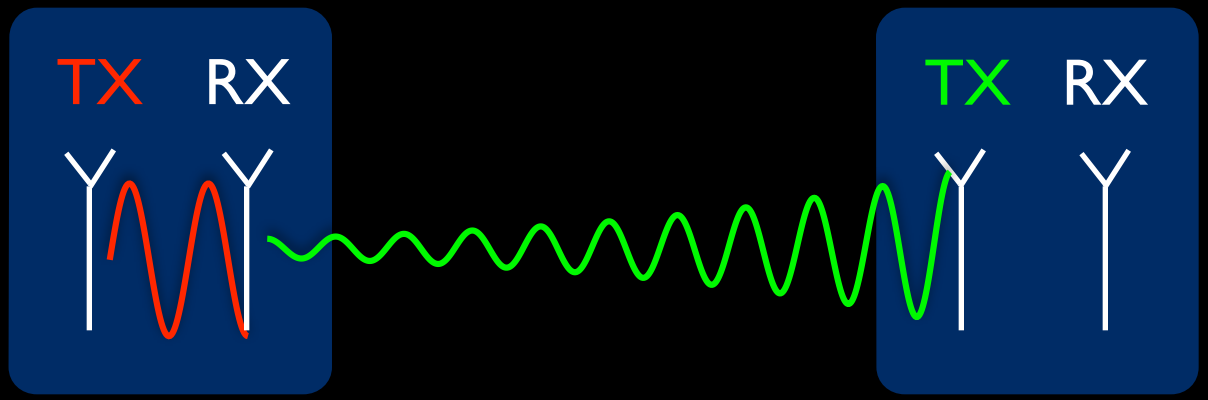
"It is generally not possible for radios to receive and transmit on the same frequency band because of the interference that results."

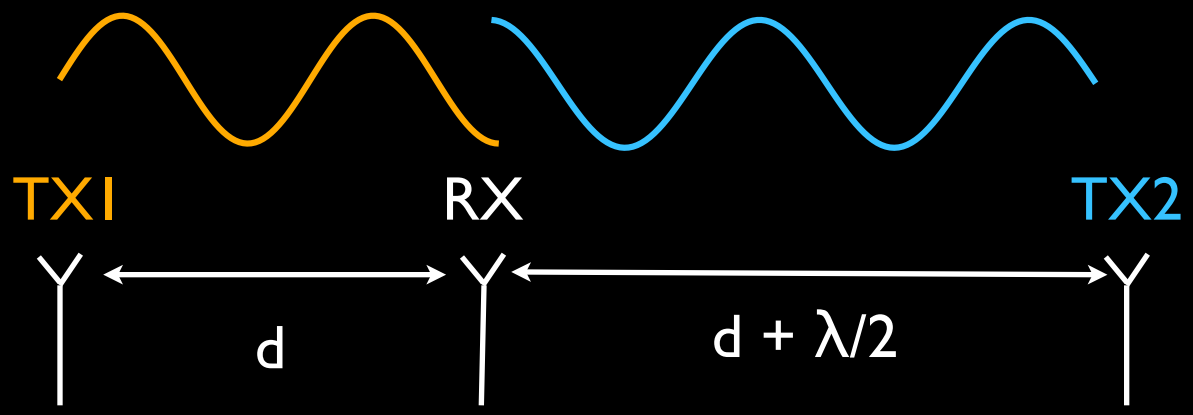
- Andrea Goldsmith, "Wireless Communications," Cambridge Press, 2005.

Why Half Duplex?

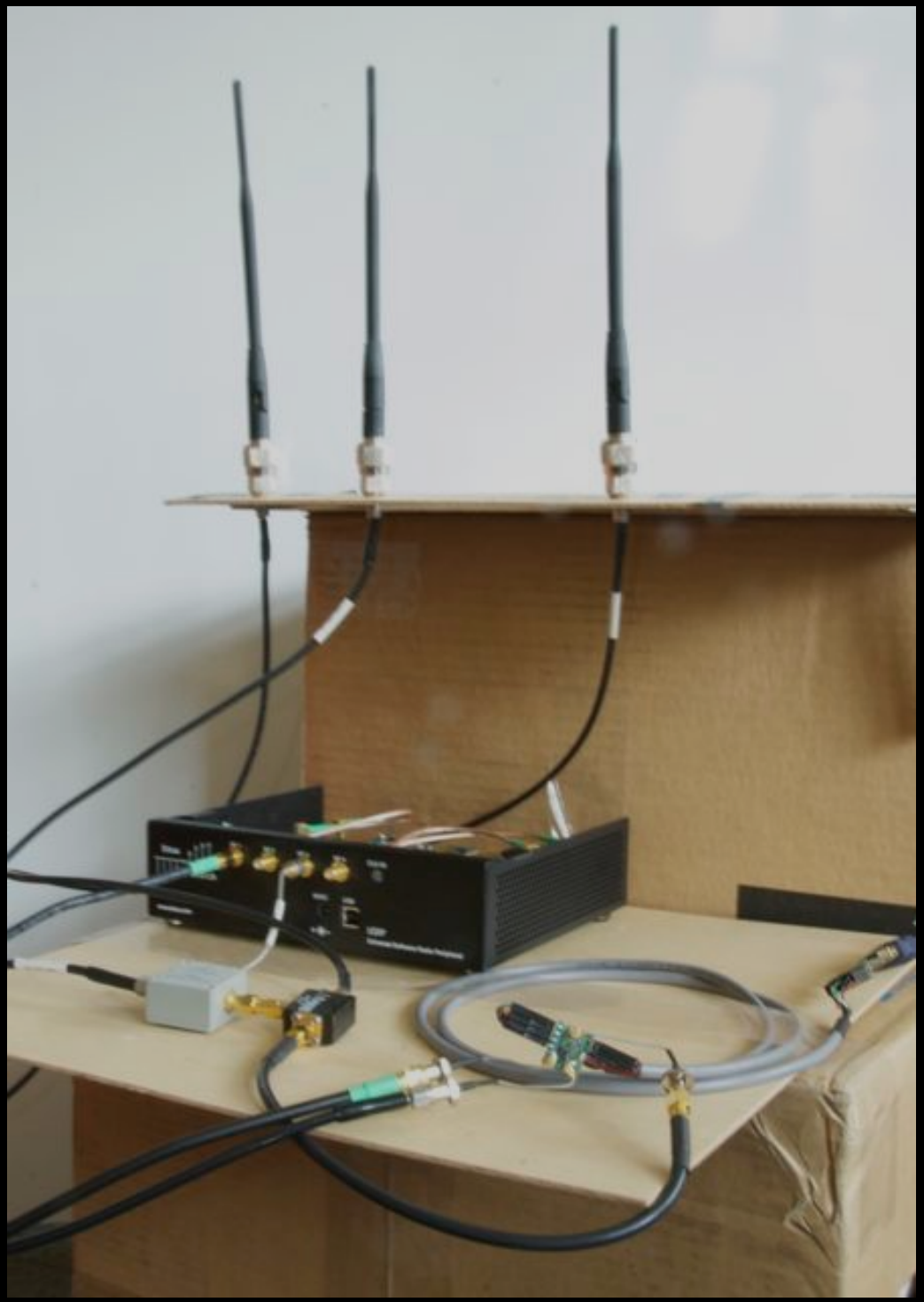


- Self-interference is millions to billions (60-90dB) stronger than received signal
- If only we could "subtract" our transmission...

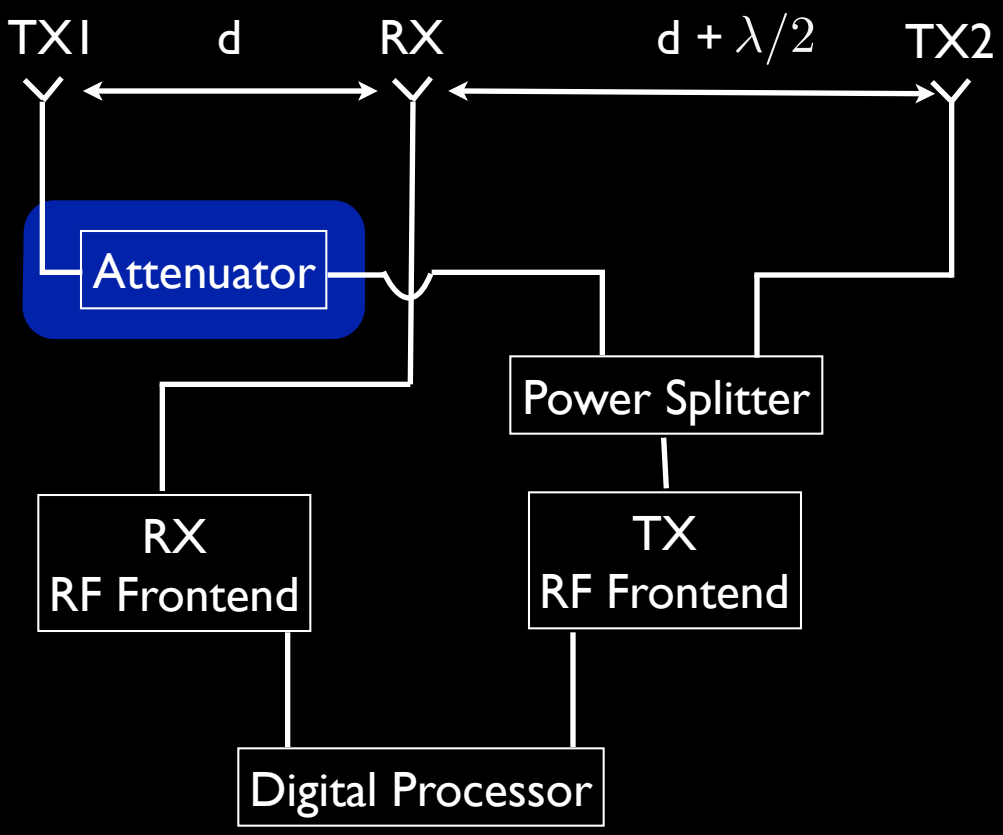
Innovation: Antenna Cancellation



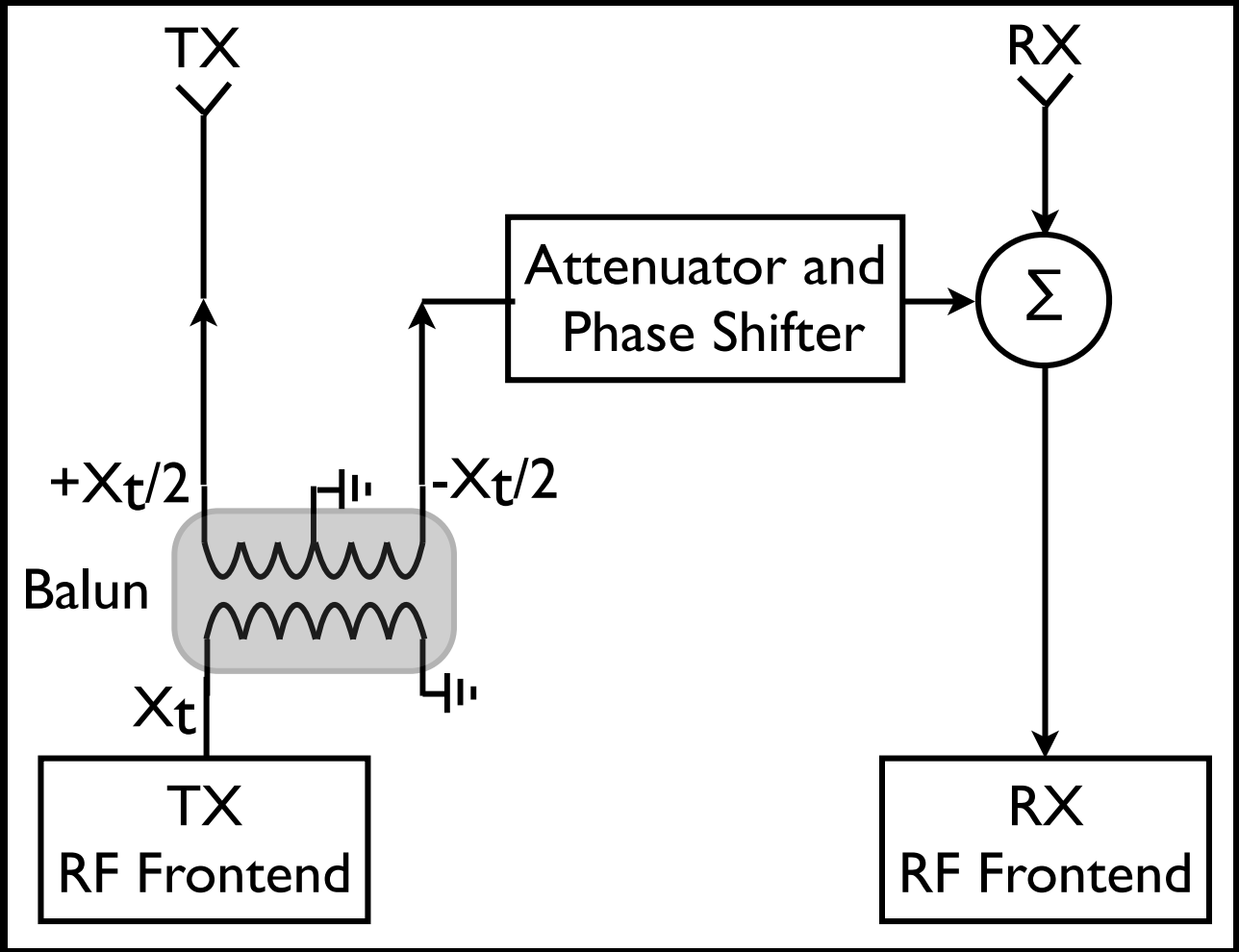
Antenna cancellation



Antenna Cancellation: Block Diagram

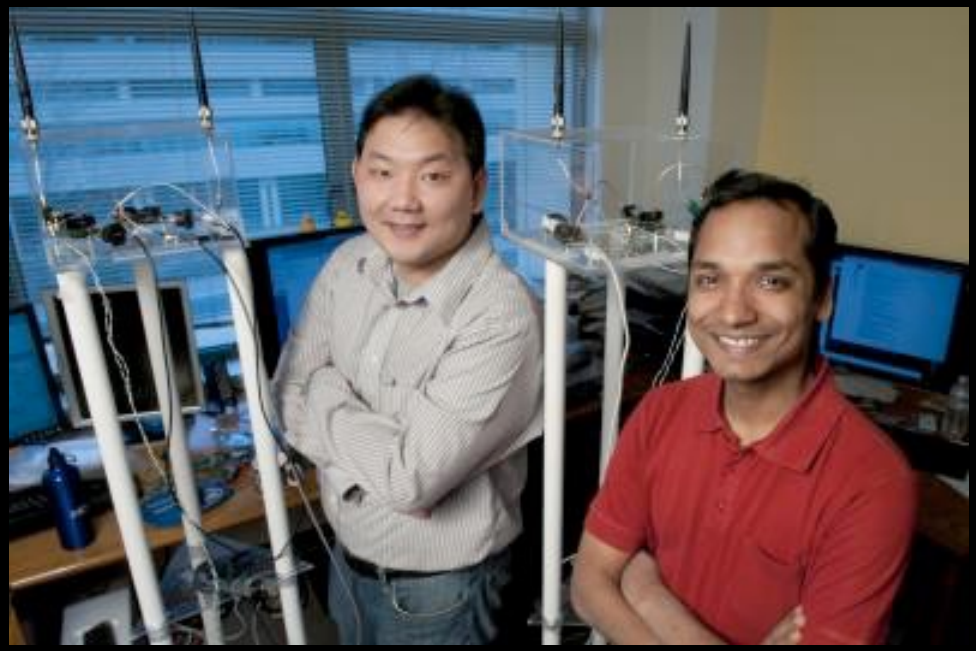


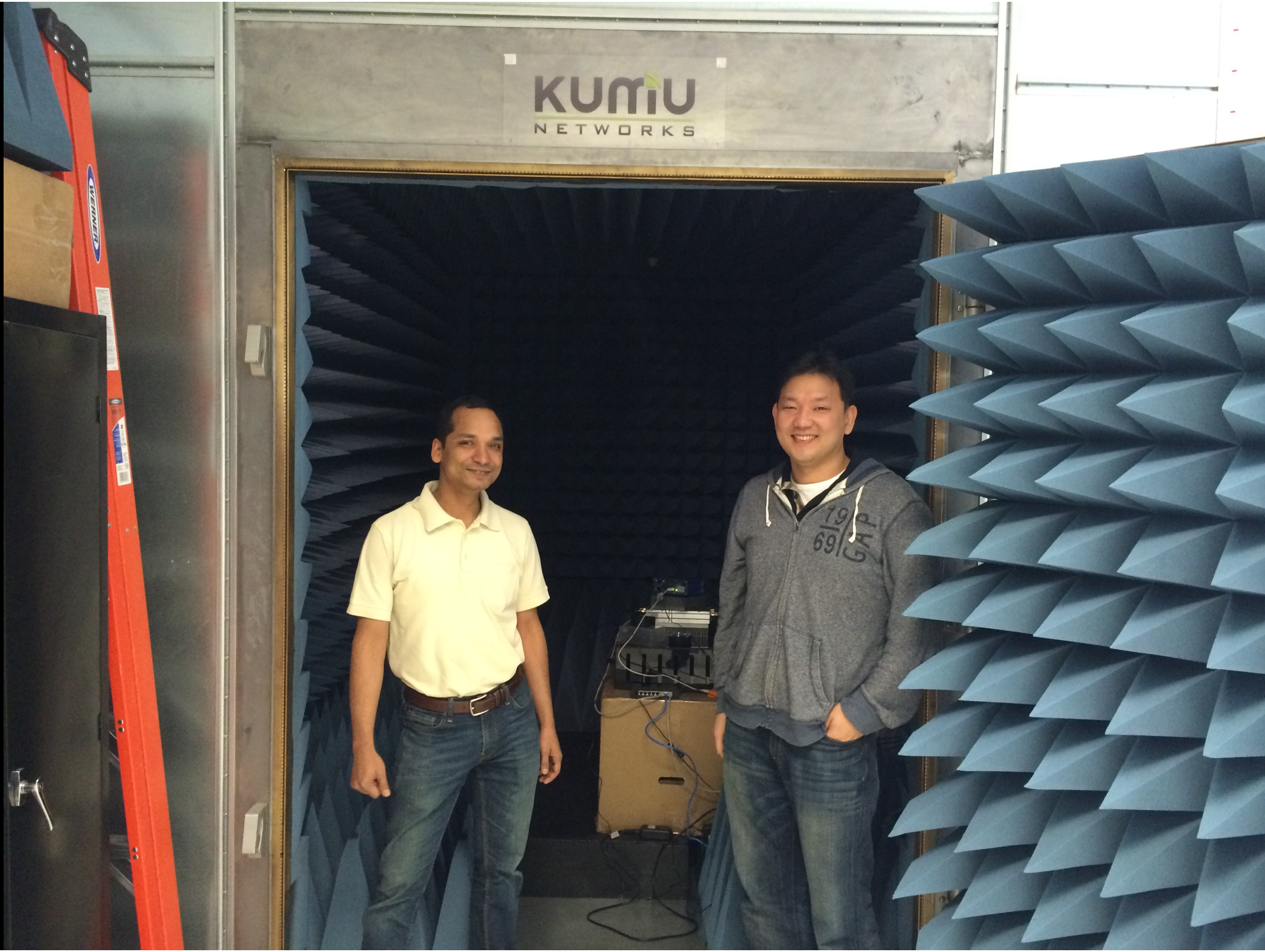
2 Antennas!


TX
RX
Attenuator and
Phase Shifter
Σ
+Xt/2
-Xt/2
Balun
Xt
TX
RF Frontend
RX
RF Frontend

Secret Weapon

- Mixture of hardware and software
- Didn't know much about either when they started — fearless!




KUMU
NETWORKS
WERNER
GAP
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Linux and Beyond

Modes

Privileged modes

Exception modes

User	System	Supervisor	Abort	Undefined	Interrupt	Fast interrupt
R0	R0	R0	R0	R0	R0	R0
R1	R1	R1	R1	R1	R1	R1
R2	R2	R2	R2	R2	R2	R2
R3	R3	R3	R3	R3	R3	R3
R4	R4	R4	R4	R4	R4	R4
R5	R5	R5	R5	R5	R5	R5
R6	R6	R6	R6	R6	R6	R6
R7	R7	R7	R7	R7	R7	R7
R8	R8	R8	R8	R8	R8	R8_fiq
R9	R9	R9	R9	R9	R9	R9_fiq
R10	R10	R10	R10	R10	R10	R10_fiq
R11	R11	R11	R11	R11	R11	R11_fiq
R12	R12	R12	R12	R12	R12	R12_fiq
R13	R13	R13_svc	R13_abt	R13_und	R13_irq	R13_fiq
R14	R14	R14_svc	R14_abt	R14_und	R14_irq	R14_fiq
PC	PC	PC	PC	PC	PC	PC
CPSR	CPSR	CPSR	CPSR	CPSR	CPSR	CPSR
		SPSR_svc	SPSR_abt	SPSR_und	SPSR_irq	SPSR_fiq

indicates that the normal register used by User or System mode has been replaced by an alternative register specific to the exception mode

Modes

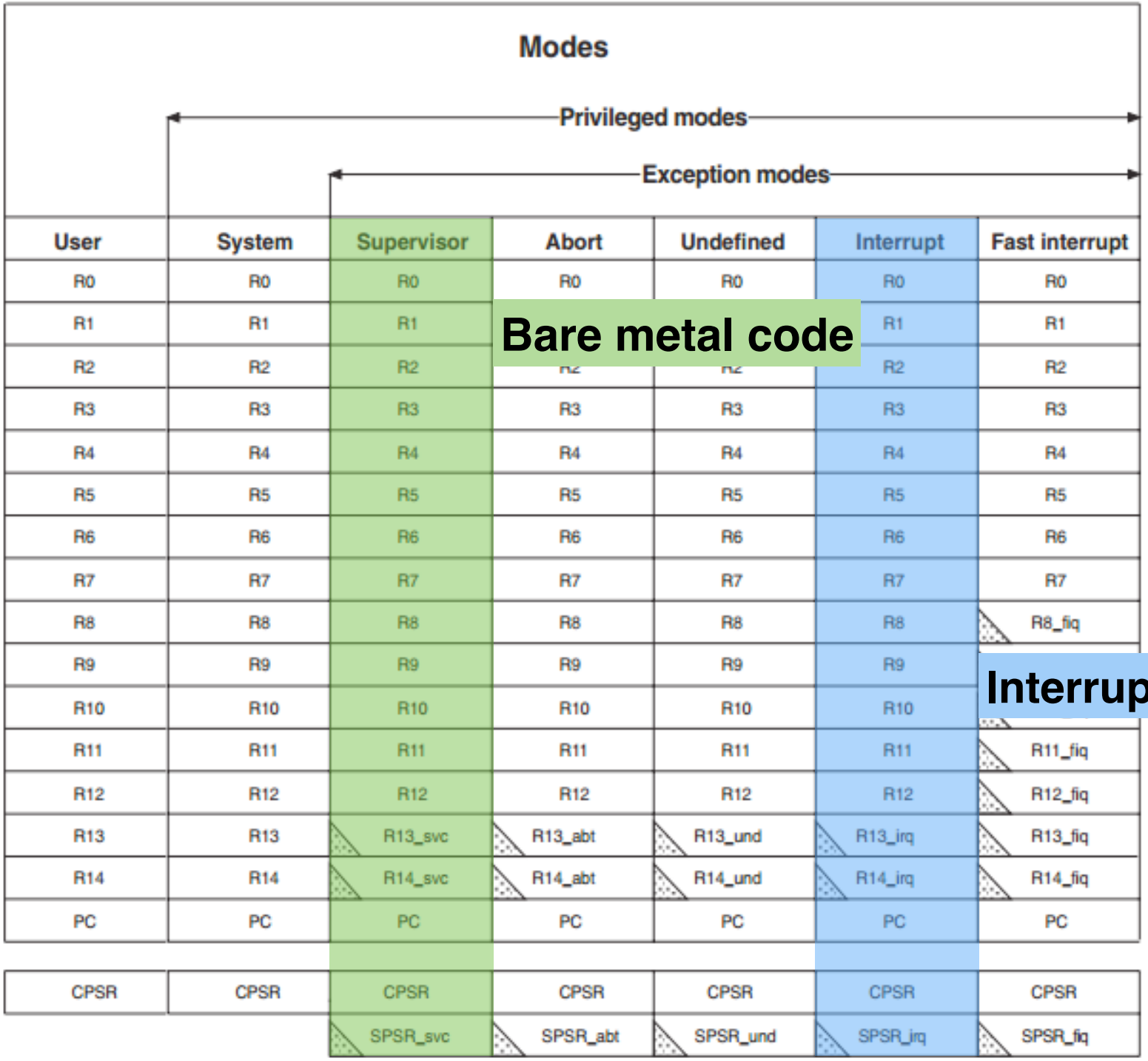
Privileged modes

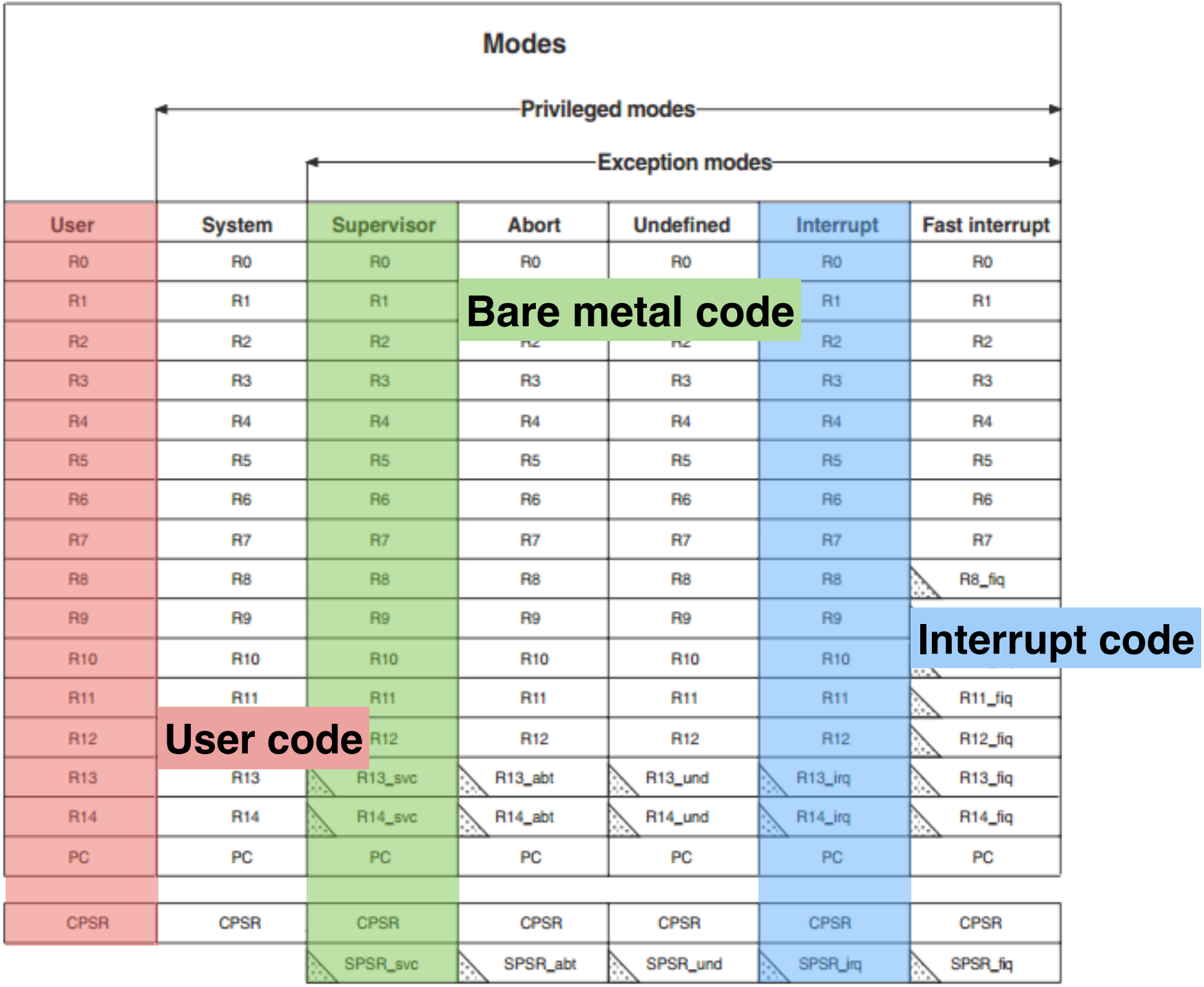
Exception modes

User	System	Supervisor	Abort	Undefined	Interrupt	Fast interrupt
R0	R0	R0	R0	R0	R0	R0
R1	R1	R1			R1	R1
R2	R2	R2			R2	R2
R3	R3	R3	R3	R3	R3	R3
R4	R4	R4	R4	R4	R4	R4
R5	R5	R5	R5	R5	R5	R5
R6	R6	R6	R6	R6	R6	R6
R7	R7	R7	R7	R7	R7	R7
R8	R8	R8	R8	R8	R8	R8_fiq
R9	R9	R9	R9	R9	R9	R9_fiq
R10	R10	R10	R10	R10	R10	R10_fiq
R11	R11	R11	R11	R11	R11	R11_fiq
R12	R12	R12	R12	R12	R12	R12_fiq
R13	R13	R13_svc	R13_abt	R13_und	R13_irq	R13_fiq
R14	R14	R14_svc	R14_abt	R14_und	R14_irq	R14_fiq
PC	PC	PC	PC	PC	PC	PC
CPSR	CPSR	CPSR	CPSR	CPSR	CPSR	CPSR
		SPSR_svc	SPSR_abt	SPSR_und	SPSR_irq	SPSR_fiq

Bare metal code

indicates that the normal register used by User or System mode has been replaced by an alternative register specific to the exception mode


Modes
Privileged modes
Exception modes
User
System
Supervisor
Abort
Undefined
Interrupt
Fast interrupt
R0
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
R13
R14
PC
CPSR
SPSR_svc
SPSR_abt
SPSR_und
SPSR_irq
SPSR_fiq
R8_fiq
R9_fiq
R10_fiq
R11_fiq
R12_fiq
R13_svc
R13_abt
R13_und
R13_irq
R13_fiq
R14_svc
R14_abt
R14_und
R14_irq
R14_fiq
Bare metal code
Interrupt code
indicates that the normal register used by User or System mode has been replaced by an alternative register specific to the exception mode


Modes
Privileged modes
Exception modes
User
System
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Abort
Undefined
Interrupt
Fast interrupt
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R2
R3
R4
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R8
R9
R10
R11
R12
R13
R14
PC
CPSR
R8_fiq
R9_fiq
R10_fiq
R11_fiq
R12_fiq
R13_svc
R13_abt
R13_und
R13_irq
R13_fiq
R14_svc
R14_abt
R14_und
R14_irq
R14_fiq
SPSR_svc
SPSR_abt
SPSR_und
SPSR_irq
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Bare metal code
Interrupt code
User code
indicates that the normal register used by User or System mode has been replaced by an alternative register specific to the exception mode

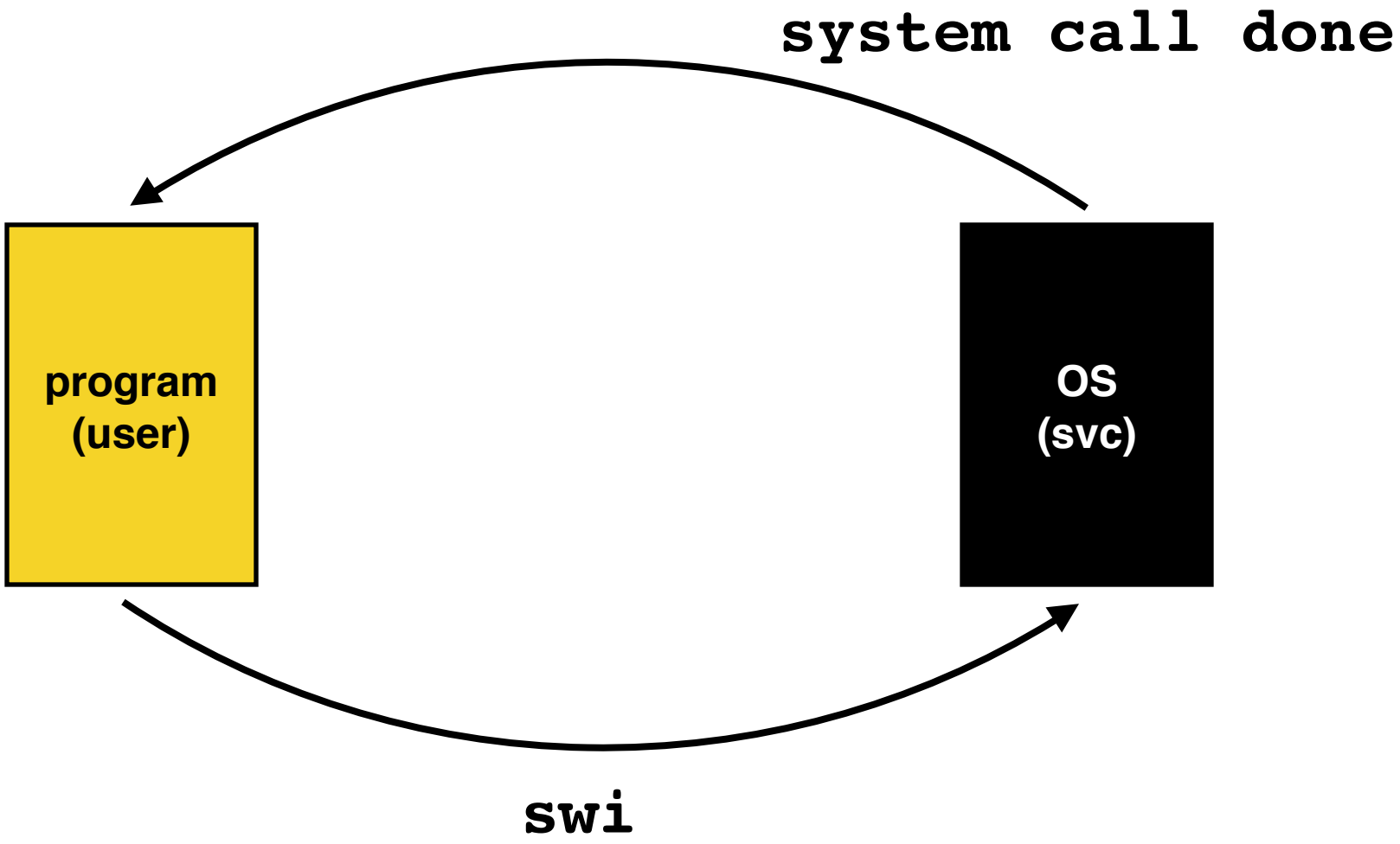
User mode

User mode can’t do a lot of things…

1. Modify CPSR
2. Access configuration registers
3. Access IO registers/memory

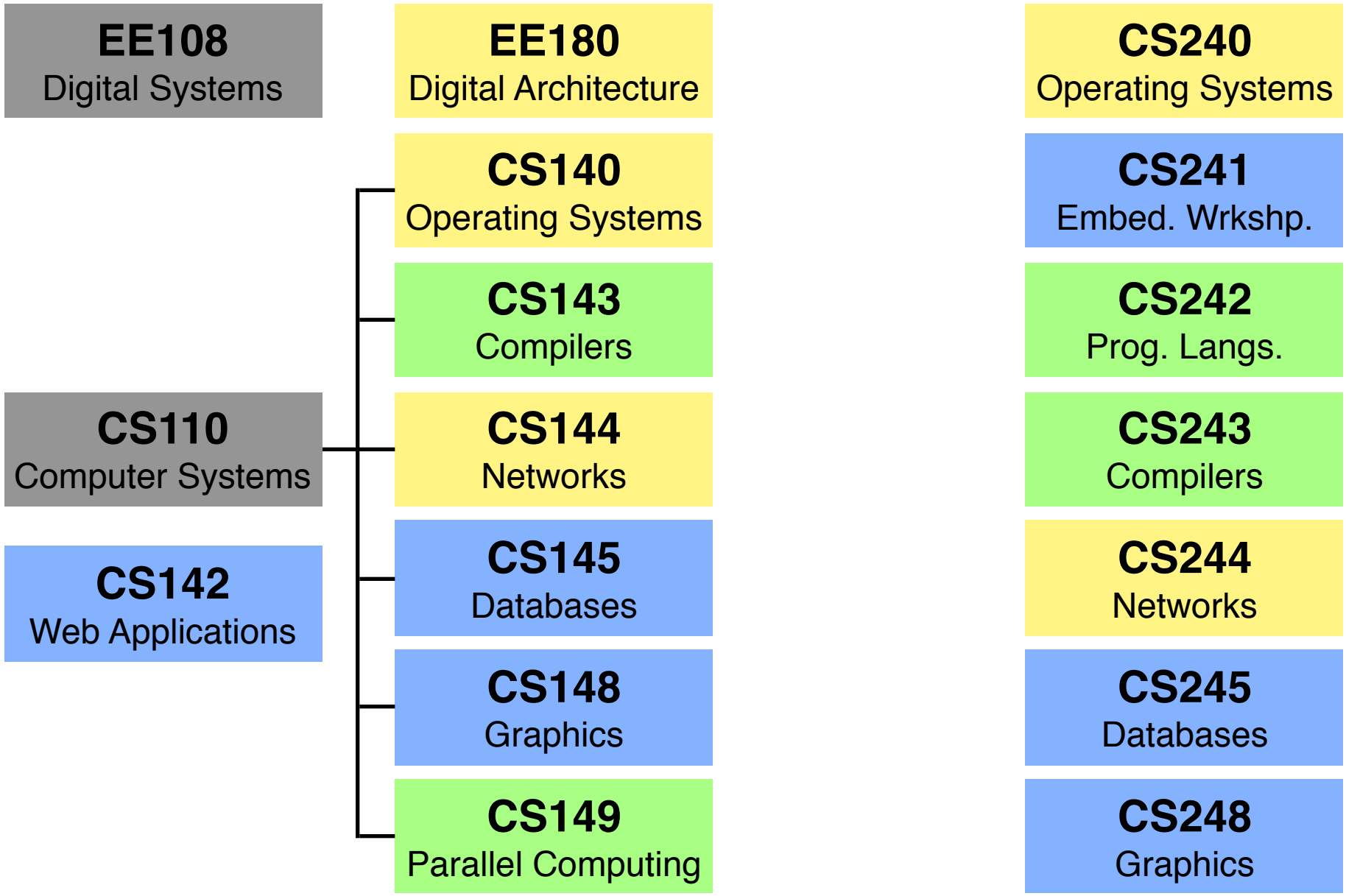
Hardware throws an exception if it tries

Operating System



Running Linux

Next Steps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CS110
Computer Systems
CS142
Web Applications
EE180
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Operating Systems
CS143
Compilers
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Networks
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Databases
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Graphics
CS149
Parallel Computing
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Operating Systems
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Embed. Wrkshp.
CS242
Prog. Langs.
CS243
Compilers
CS244
Networks
CS245
Databases
CS248
Graphics