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Reshaping Wireless

Tunable Antennas for Increasing SNR in 5G Handsets

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September 26, 2019

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Higher *Channel Capacity*

Results - for Users

- Faster downloads, less buffering
- Better image/video quality
- Longer battery life
- Larger geographical coverage

Results - for Carriers

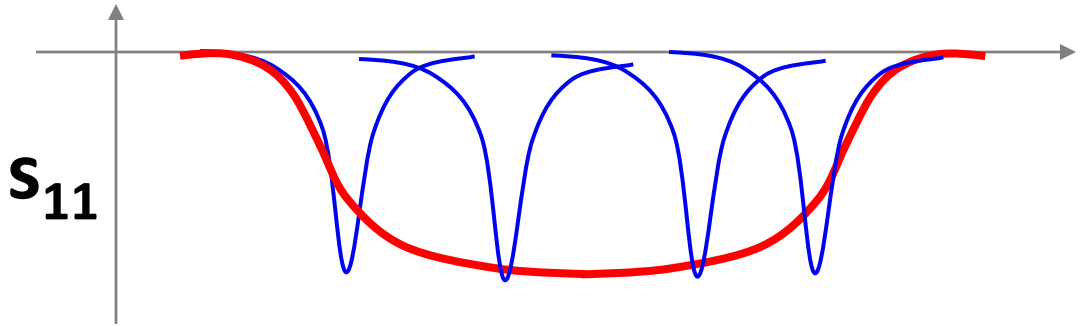
- More efficient use of licensed spectrum
- Lower tower density
- Higher subscriber satisfaction

Increase Efficiency via Frequency Tuning

Conservation of Energy dictates…

B x η ~ Constant

B: *Instantaneous Bandwidth*
η : *Radiation Efficiency*



So…

1. *Make the antenna narrow-band and*
2. *Cover the same band via tuning!*

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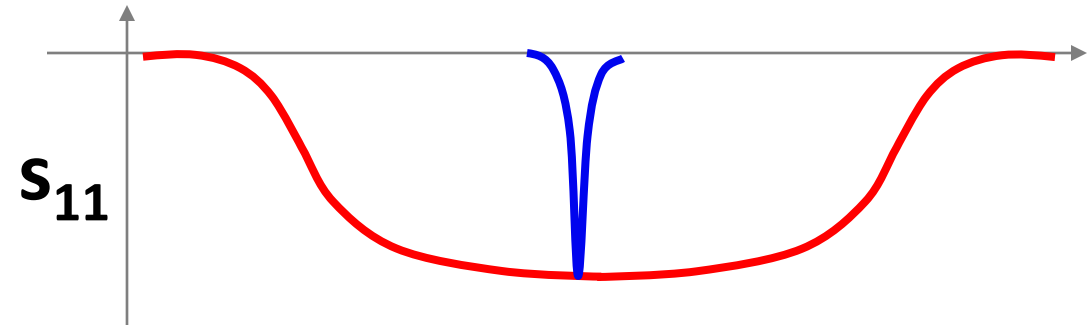
Tune at Channel (MHz) or Sub-Carrier (KHz) level

$$\eta \sim 1/B$$



- *GHz vs MHz (or KHz)*
  => Potentially 1000x improvement in η (or SNR)
- *$Log_2(100) = 4.6$*
- *Equivalent to 4x4 MIMO*

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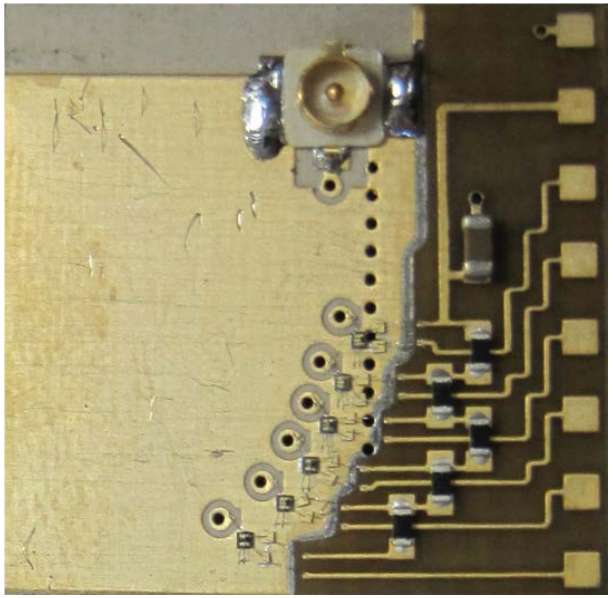
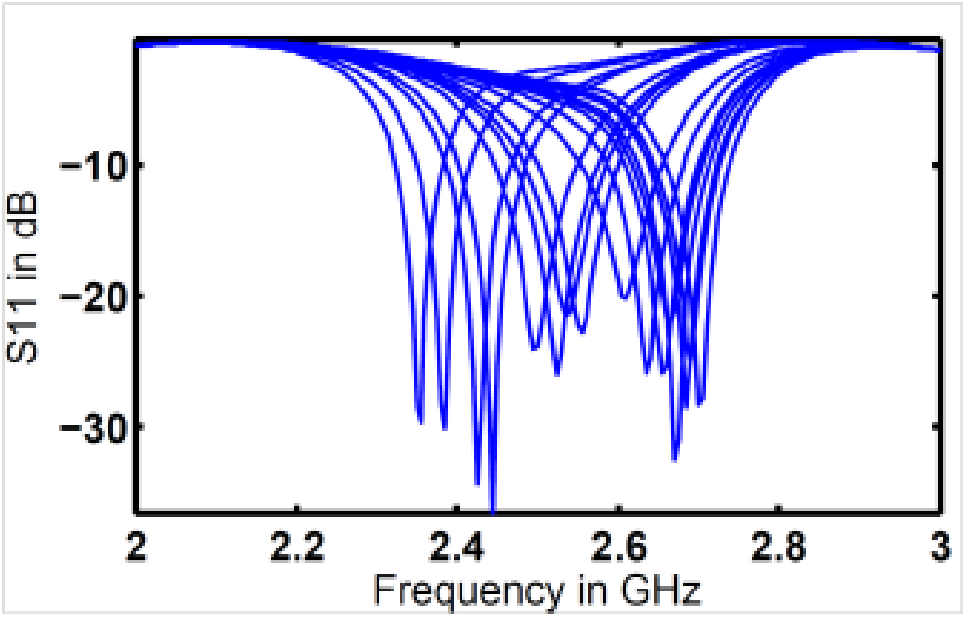
Tunable 4G/LTE Handset Antenna (2.1-2.9GHz)



(16mm x 16mm x 5mm)



US Patent No. 9,941,593, April 10, 2018

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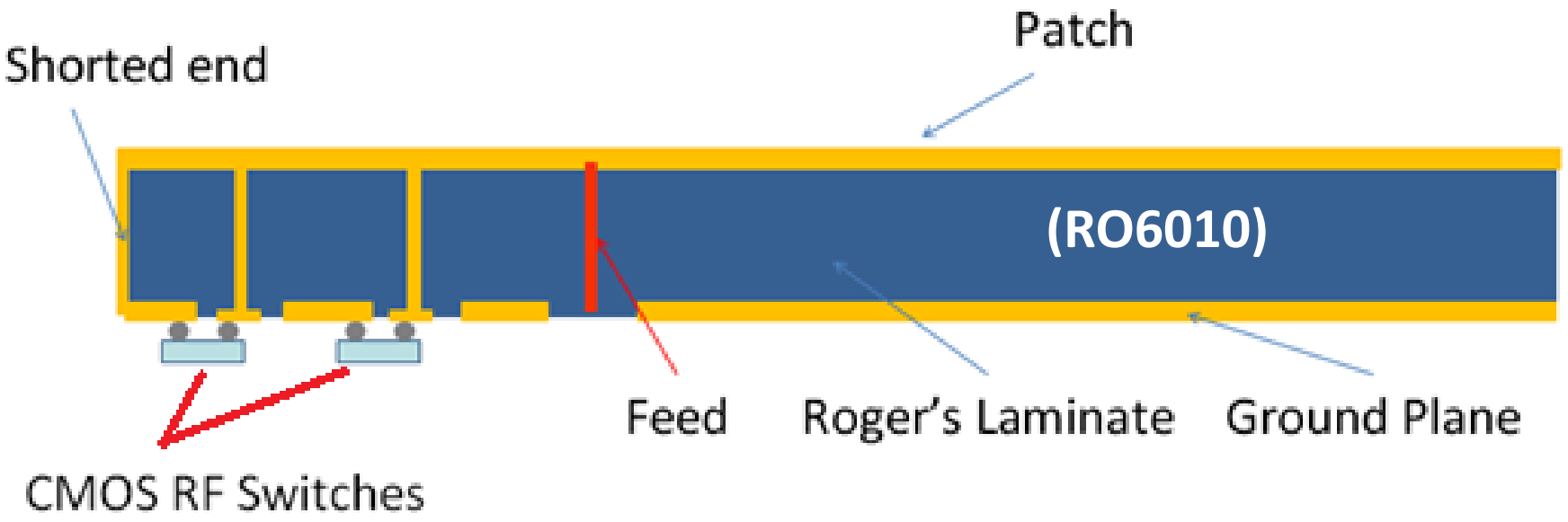
Design



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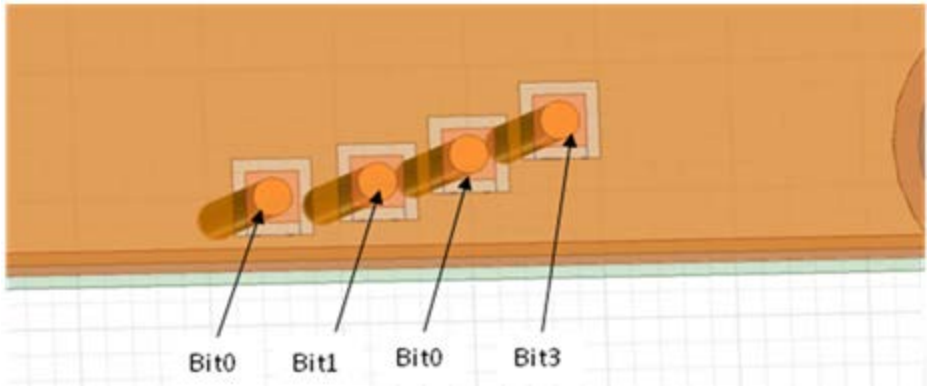
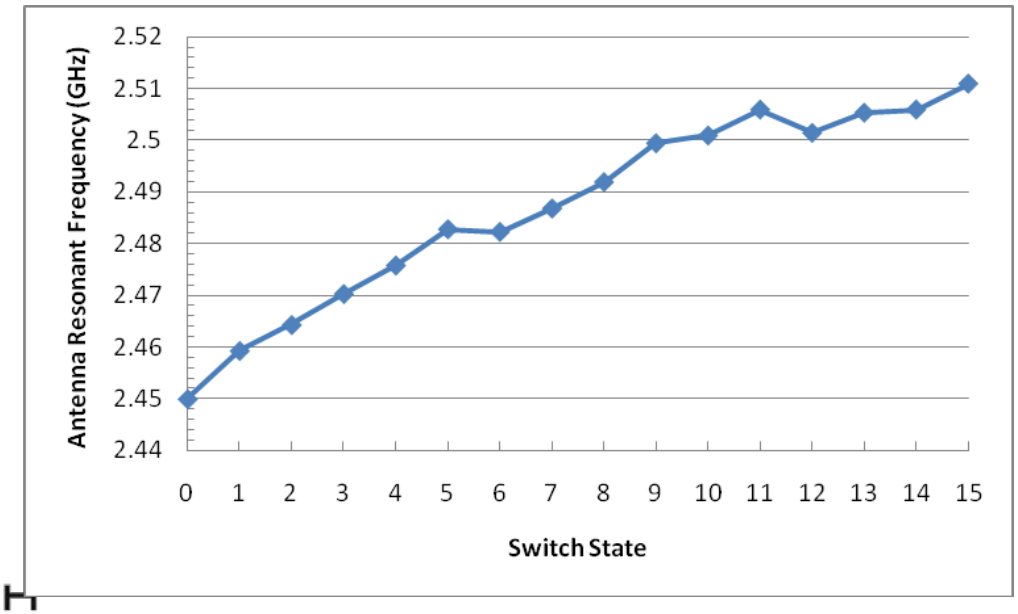
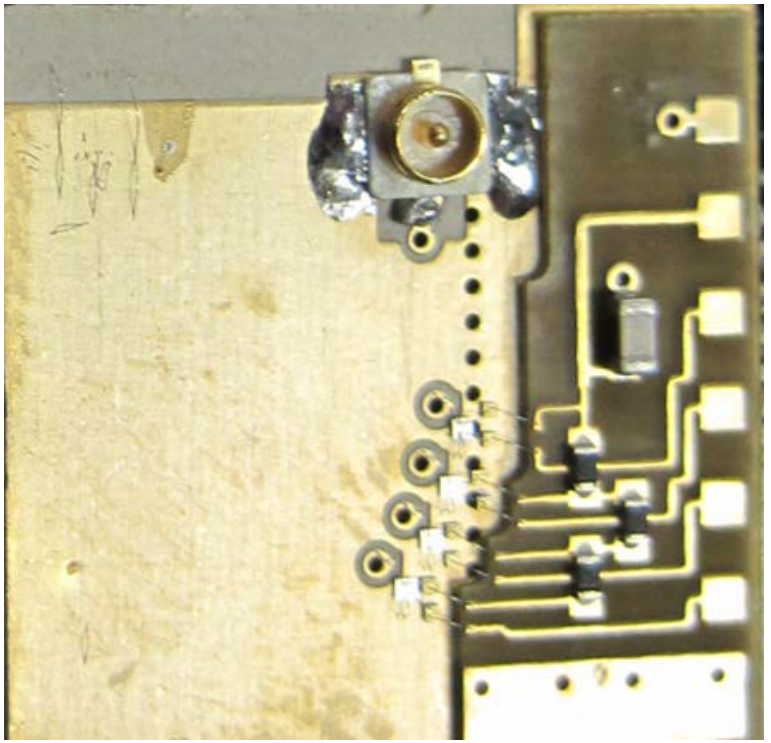
Frequency Tuning



(LSB)



Manufacturing



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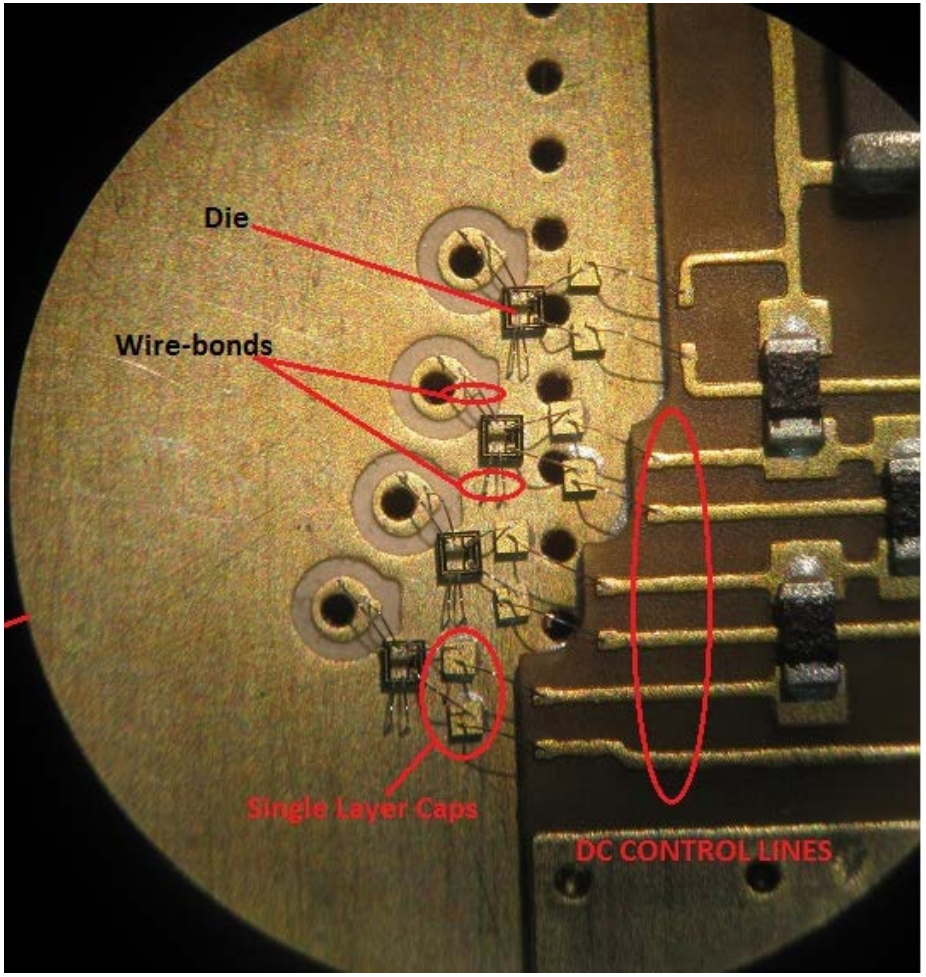
Manufacturing



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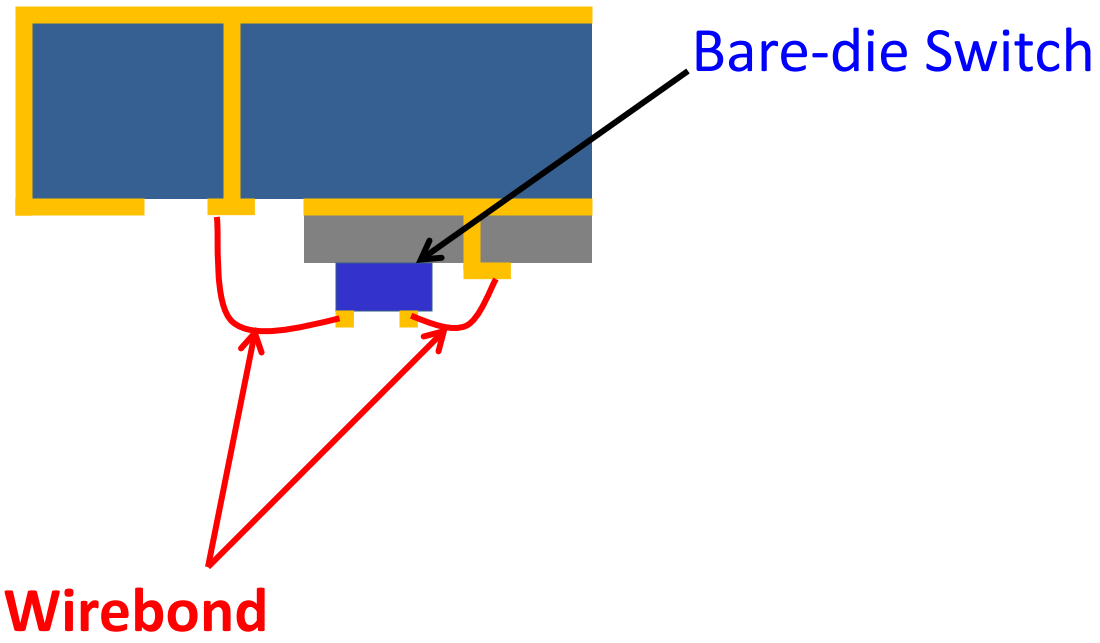
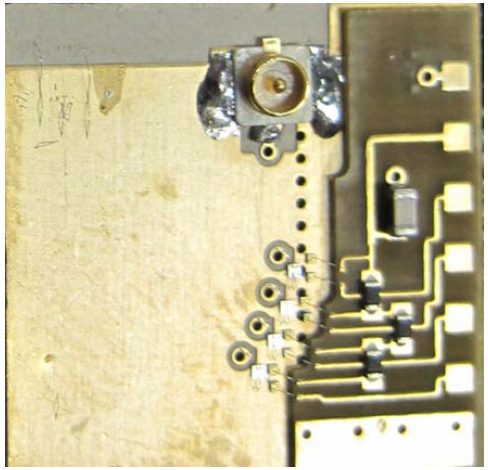
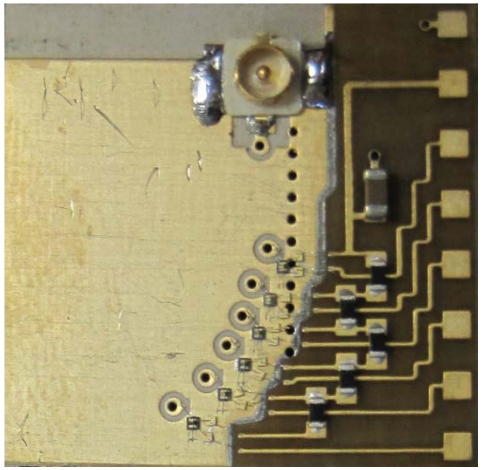
Manufacturing



4-bit and 6-bit versions



•2.3 - 2.7 GHz
•(16%)



•2.2 - 2.9 GHz
•(27%)

Finished Assembly:
16mm x 16mm x 5mm

Patch Antenna:
10mm x 7mm x 4mm

GP:
13mm x 10mm

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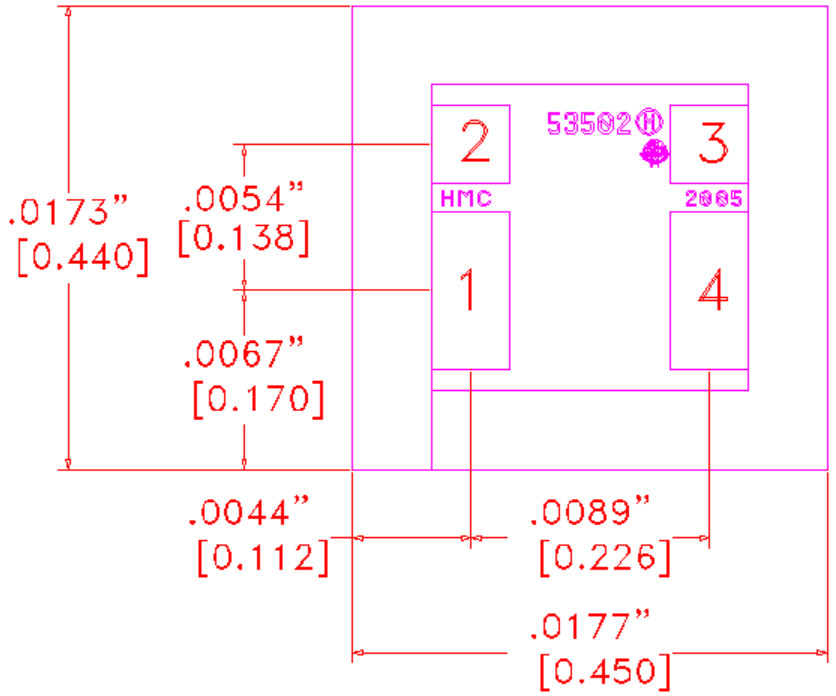
RF Switch

- **HMC550,** Analog Devices
- Bare Die 53502, SPST Reflective, Floating Ground
- Ron=5.9 Ω, Coff=0.09pF
- 0.44mm x 0.45mm



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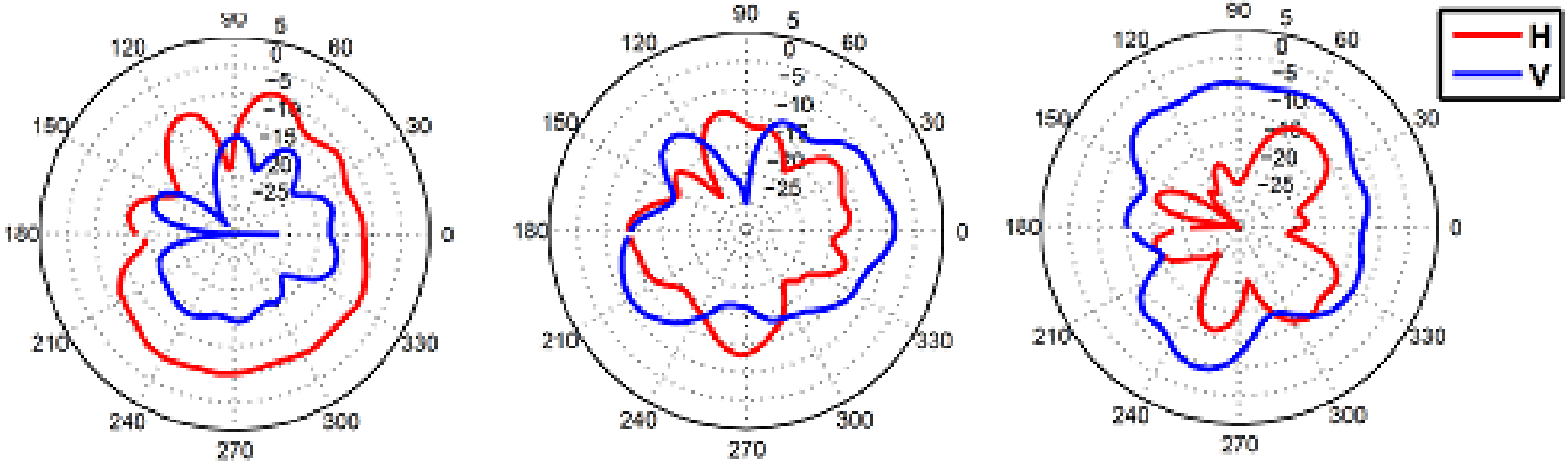
Gain

- Average Peak gain = **-4.7 dBi**
- High R_{on} resistance (**5.9 Ω**) is to blame.



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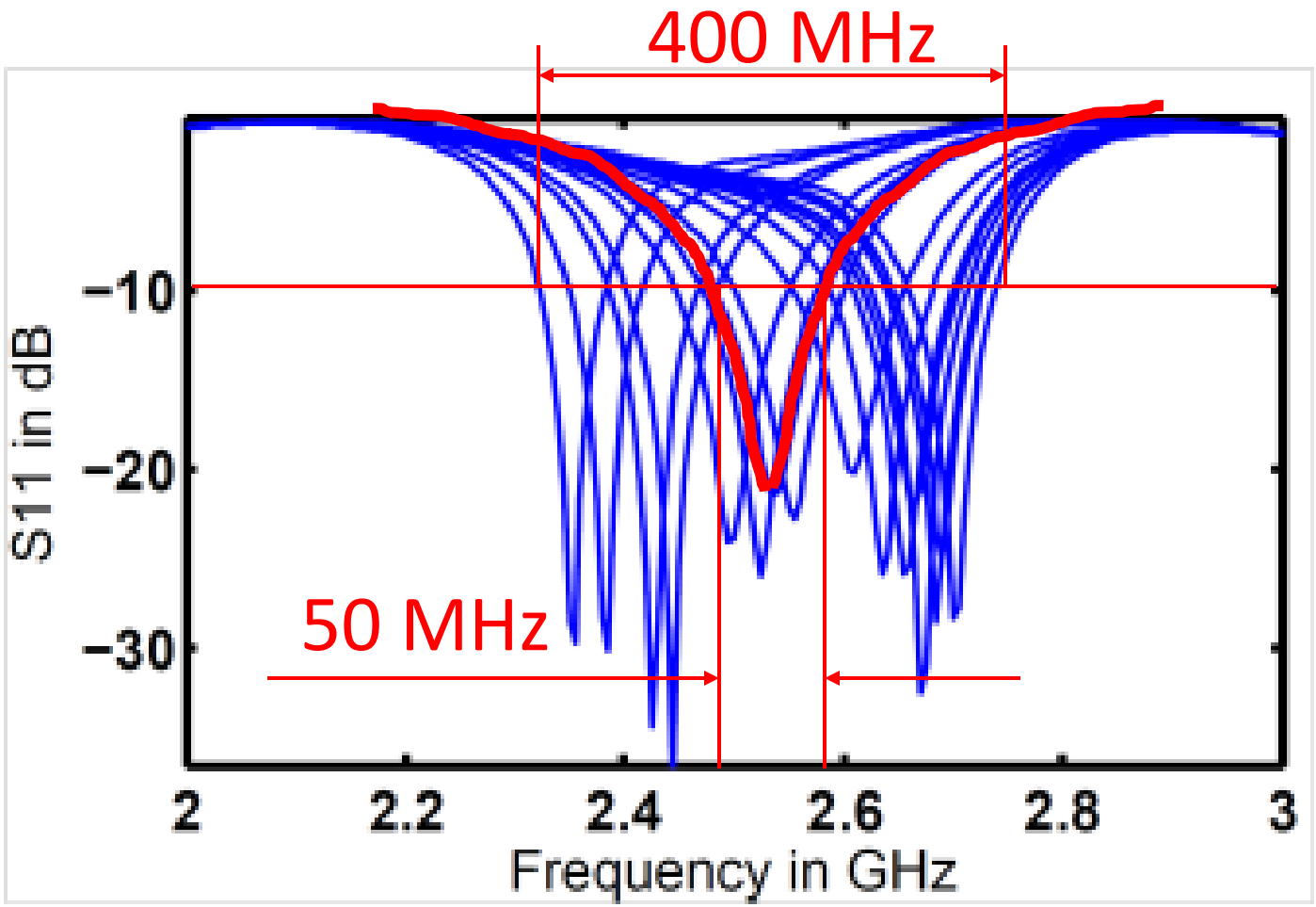
Drop in *B*



50/400 = 1/8 reduction

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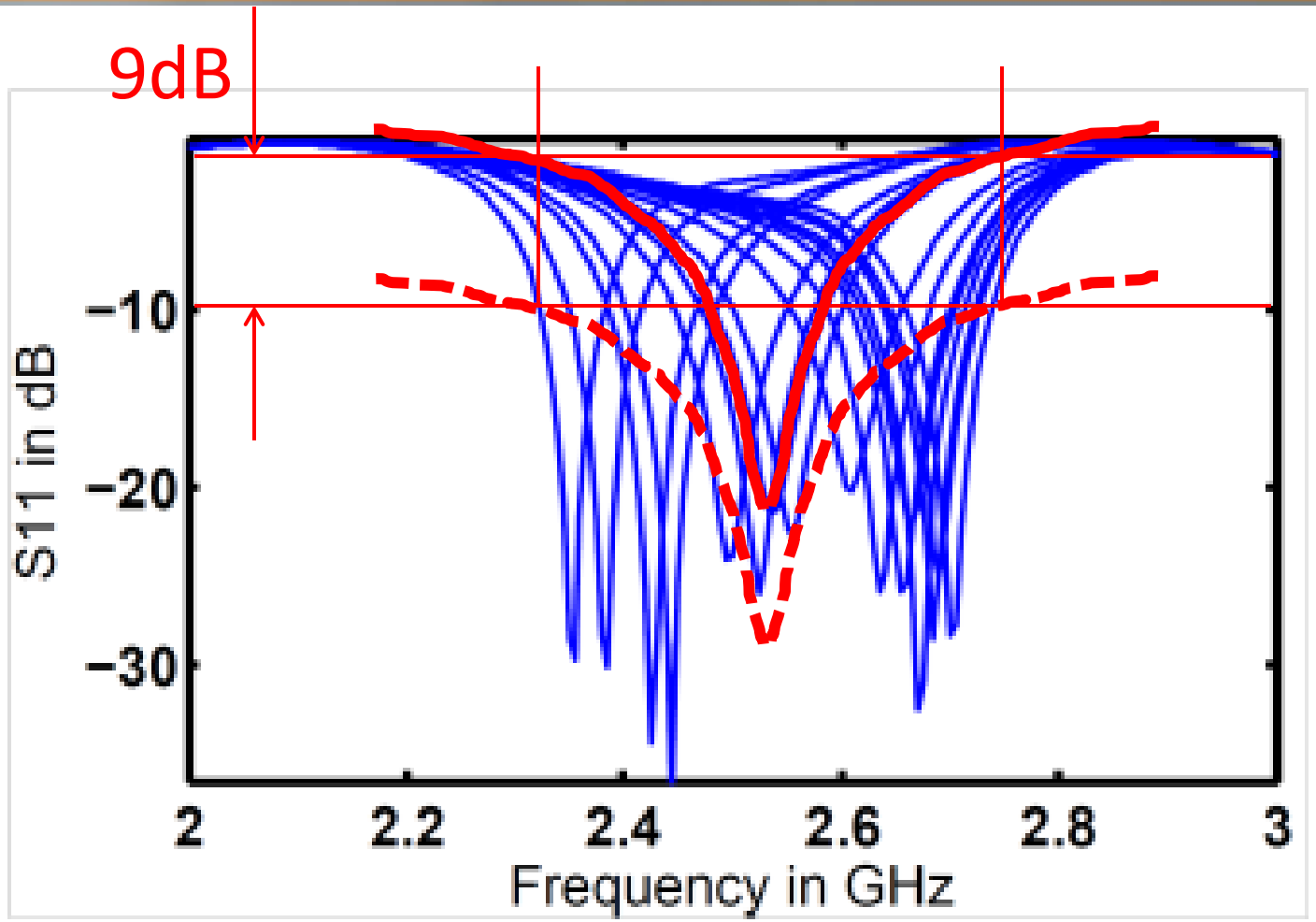
Increase in η



$10^{(9/10)}$ = 7.9 x increase

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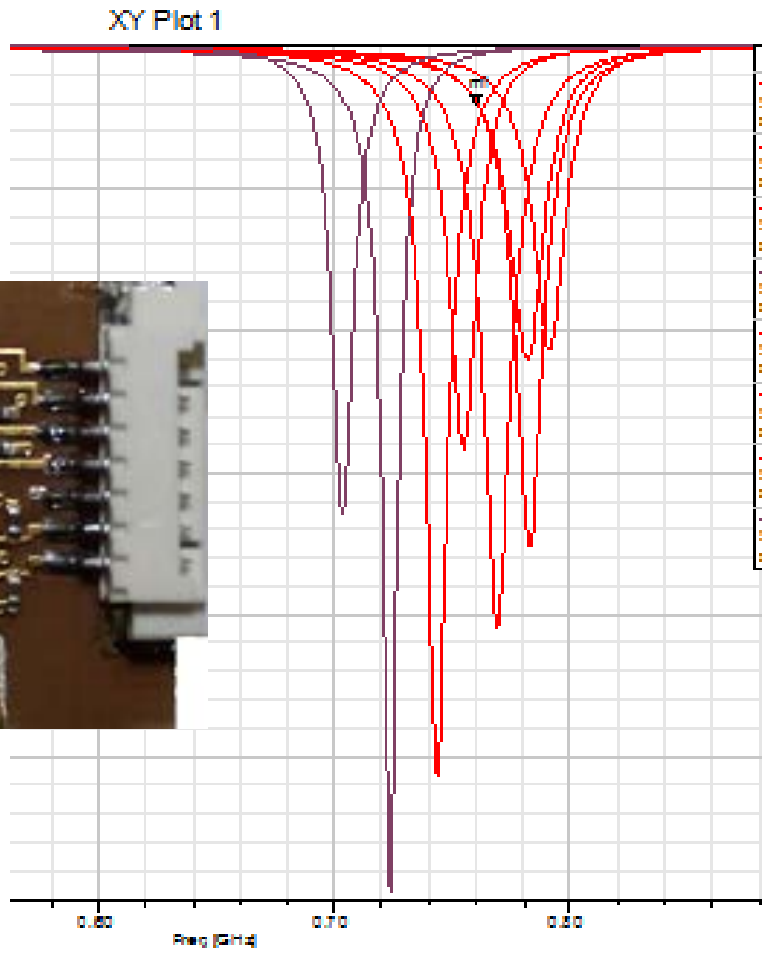
LTE/4G Low-band (700-800 MHz)

- Three switches (Eight sub-bands)

40mm x 18mm x 3mm



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Thank you!

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Backup Slides

Enabling Technology: SPST Switches

- Solid State (GaAs or others)
  - HMC550: R_{on} x C_{off} = 531 fSec
  - Current State of Art: 240 fSec
  - 60fSec – Desired (4x Improvement)
  - Non-linearity
- MEMS
  - Yield
  - Cost
  - Speed (μs)
  - Hot-switching

•DESIRED SPECS

Switch Type	Bare Die, SPST, Reflective, Floating Ground
Size (mm)	0.4 x 0.4
Pad Configuration	2 DC bottom/RF opposite side (preferred)
Frequency (GHz)	0.6 – 3.0
Ron ()	2.0
Coff (Pf)	.03
RF Power (watts)	1.0
Non-Linearity (IP3)	50 dBm

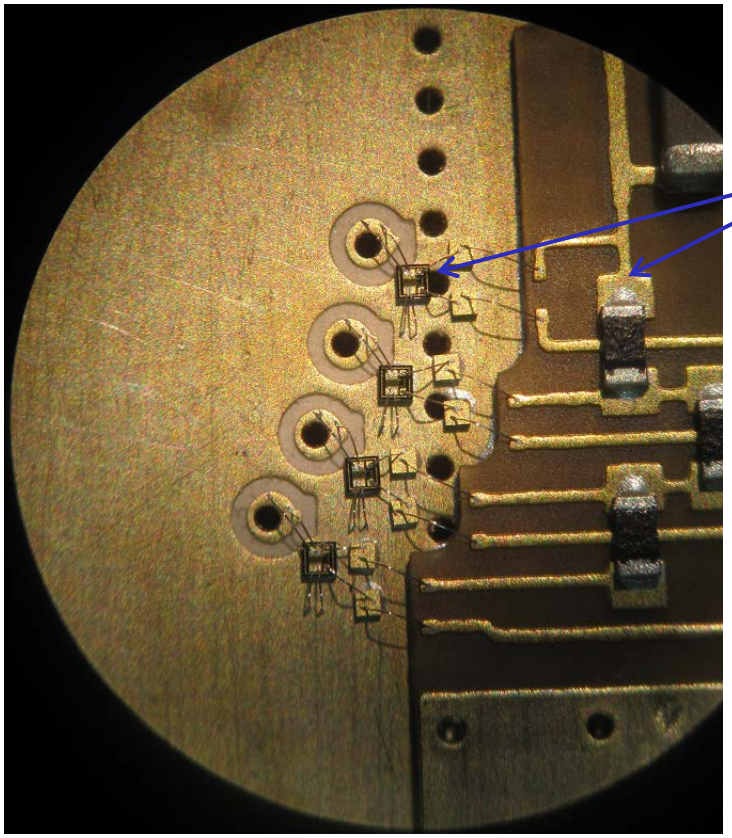
RF Switch Comparison

Enabling Technology: SPST Bare-Die Switches

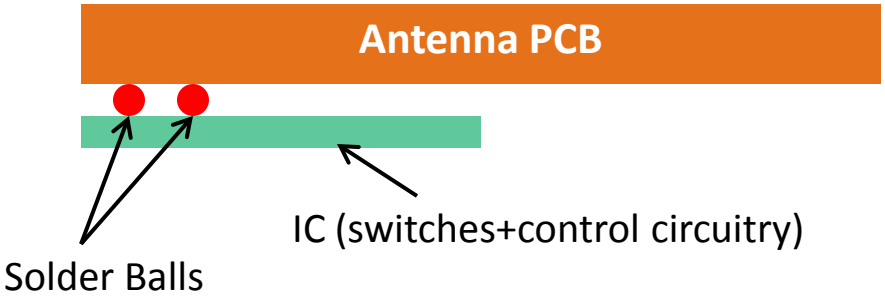
(< 6GHz Applications)

Parameter	DESIRED	HMC550 (Analog)	PE613010 (Murata)
Switch Type	Bare Die, SPST, Reflective, Floating Ground	Bare Die, SPST, Reflective, Floating Ground	Bare Die, SPST, Reflective
Size (mm)	0.4 x 0.4	0.4 x 0.4	1.1 x 1.0
Pad Configuration	2 DC bottom/RF opposite side (preferred)	All four pads on top	All four pads on top
Frequency (MHz)	600 – 6,000	0 - 6,000	100 - 3,000
Ron (Ohms)	2.0	5.9	1.2
Coff (Pf)	.03	0.09	0.4
RF Power (dBm)	30	34	38
Non-Linearity/IP3 (dBm)	50	52	70

Manufacturing Option: Integrated CMOS IC



Switches and the control circuitry are integrated into a thin IC



- More expensive parts but
- Less parasitics and
- Cheaper manufacturing

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5G bands proposed and the ideal antenna sizes

Freq Band (GHz)(*)	Ideal half-wavelength Antenna size (mm)	Antenna Option
< 6	25	Individual Antennas
27.5 - 28.35	5	Antenna Arrays (each with multiple beams)
37 - 38.6 & 38.6 – 40	4	
64 - 71	2.20	

(*) Proposed by the FCC
http://www.fiercewireless.com/tech/story/fcc-proposes-rules-4-different-spectrum-bands-above-24-ghz-5g-networks/2015-10-22

Other Tunable Prototypes

- 2.4GHz band (wearable)
  - *Military*
  - *Law Enforcement*