DASpedia – 5G Forum
Getting ahead of External PIM

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“Safe Harbor” Statement

NOTE: In this presentation we have made forward-looking statements. These statements are based on our estimates and assumptions and are subject to risks and uncertainties. Forward-looking statements include the information concerning our possible or assumed future results of operations. Forward-looking statements also include those preceded or followed by the words “anticipates,” “believes,” “estimates,” “hopes” or similar expressions. For those statements, we claim the protection of the safe harbor for forward-looking statements contained in the Private Securities Litigation Reform Act of 1995. The following important factors, along with those discussed in our filings with the Securities and Exchange Commission (the “SEC”), could affect future results and could cause those results to differ materially from those expressed in the forward-looking statements: adverse conditions in the U.S. and international economies; the effects of competition in the markets in which we operate; material changes in technology or technology substitution; disruption of our key suppliers’ provisioning of products or services; changes in the regulatory environment in which we operate, including any increase in restrictions on our ability to operate our networks; breaches of network or information technology security, natural disasters, terrorist attacks or acts of war or significant litigation and any resulting financial impact not covered by insurance; our high level of indebtedness; an adverse change in the ratings afforded our debt securities by nationally accredited ratings organizations or adverse conditions in the credit markets affecting the cost, including interest rates, and/or availability of further financing; material adverse changes in labor matters, including labor negotiations, and any resulting financial and/or operational impact; significant increases in benefit plan costs or lower investment returns on plan assets; changes in tax laws or treaties, or in their interpretation; changes in accounting assumptions that regulatory agencies, including the SEC, may require or that result from changes in the accounting rules or their application, which could result in an impact on earnings; the inability to implement our business strategies; and the inability to realize the expected benefits of strategic transactions.

"You can't fix problems you don't talk about and you don't know about. Far too often, those issues don't get raised. We are not as transparent with each other as we need to be."

Joe Russo, Verizon
EVP & President of Global Networks

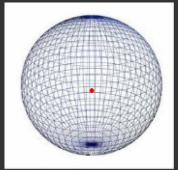
Why DASpedia?

- Collaborate
- Get Feedback
- Get Stuff Done

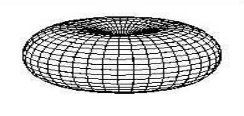
What's on my radar!

- Reducing OPEX
- Spectrum Monitoring – Regulatory
- Non-Compliant Boosters
- RF Knowledge Transfer

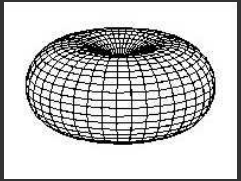
Let’s start forming some Beams!



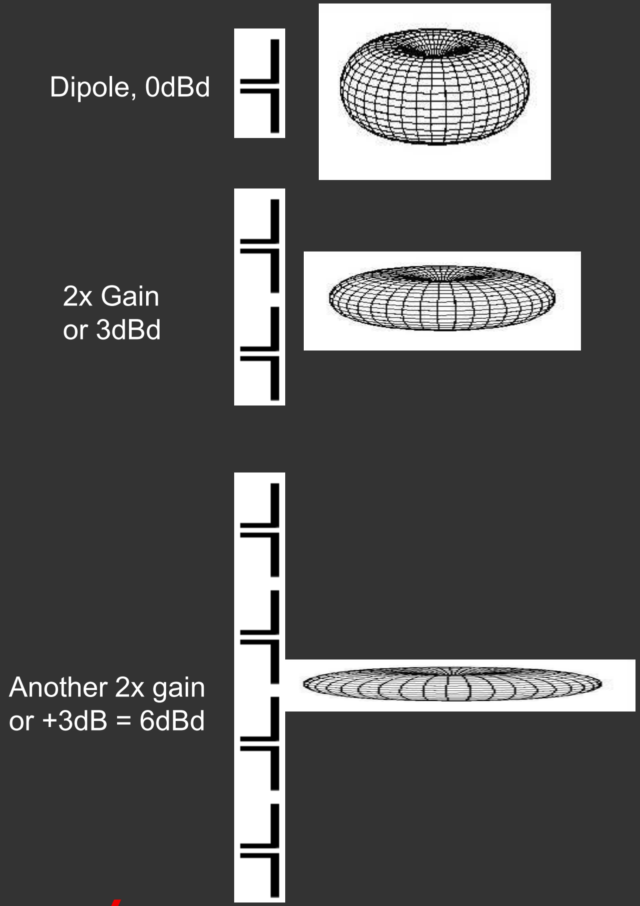
Isotropic antenna
Gain = 0dBi



Quarter-wave Paperclip (aka monopole on a ground plane)
Gain= 5.15dBi, but is highly dependent on the ground plane



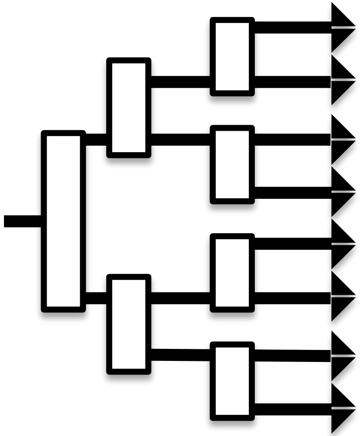
Dipole (the fundamental element of virtually all traditional industry antennas) Gain = 2.15dBi or 0dBd

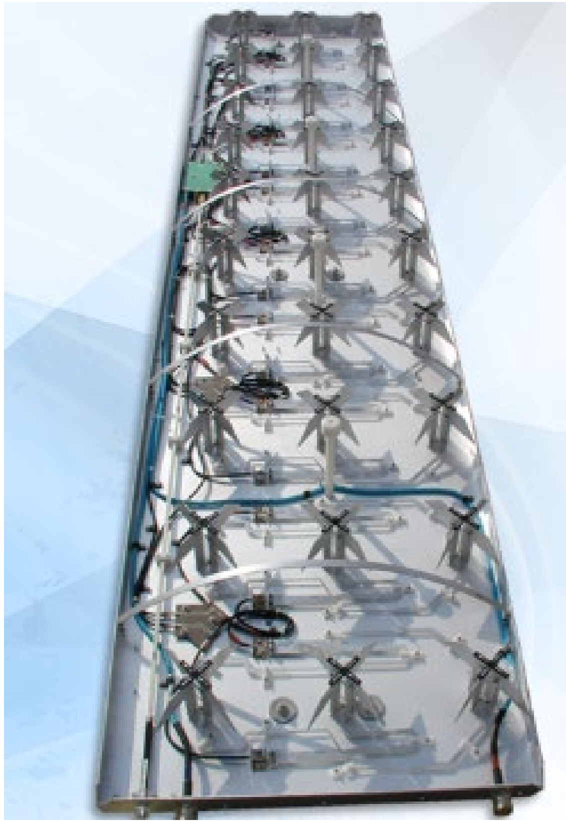


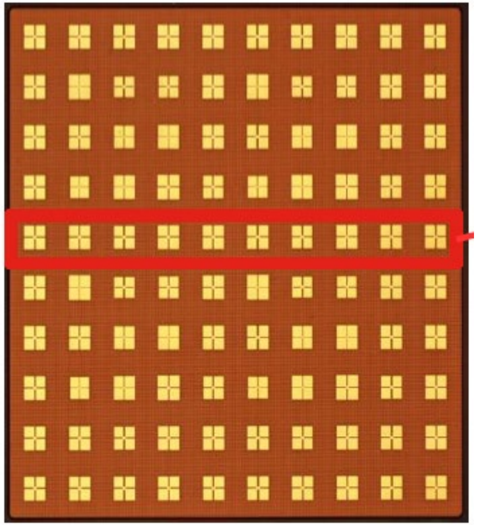
Antenna Game – Rules

- Half-wave dipoles are one-half wavelength (λ) long…ish
- The vertical beamwidth of a dipole is 80˚ and the gain is 0dBd
- When stacking vertically, the gain is doubled and the vertical beamwidth (BW) is halved every time the number of stacked dipoles doubles
- Vertical space between dipoles is typically 0.5 λ
- The horizontal beamwidth of a dipole is 360˚. When a reflector is placed behind the dipole it adds 3dB of gain and halves the horizontal BW to 180˚
- When dipoles are stacked horizontally, the gain is doubled and the horizontal BW is halved every time the number of stacked dipoles doubles.
- Changing path lengths (delays) to individual elements allows beam steering

Antenna Example







Modern corporate fed antennas

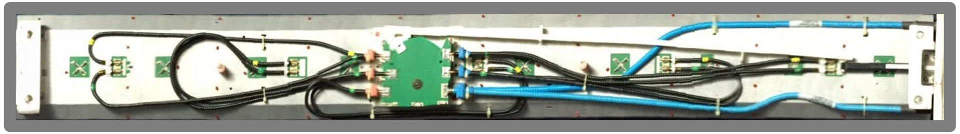
Year: 2000
Cables: 12
Solder Joints: 186

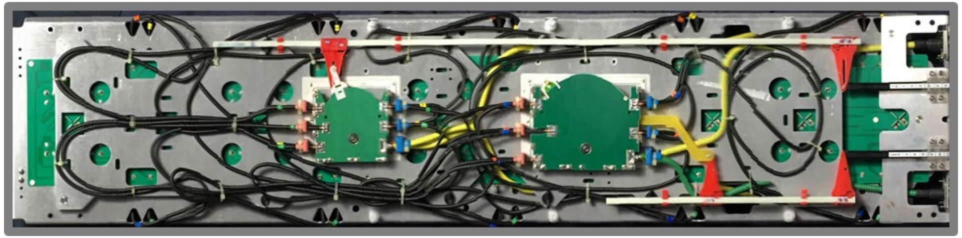
Year: 2003
Cables: 24
Solder Joints: 186

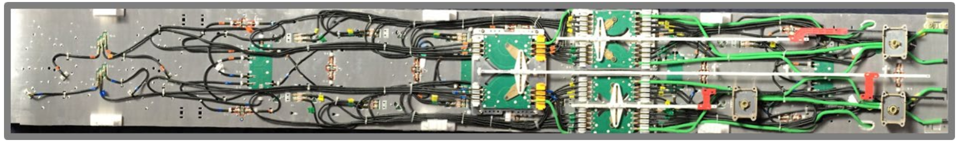
Year: 2008
Cables: 56
Solder Joints: 548

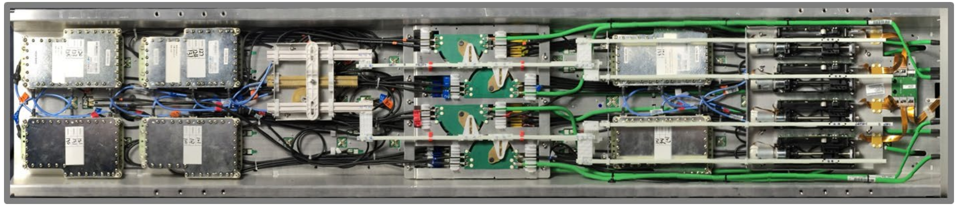
Year: 2014
Cables: 98
Solder Joints: 680

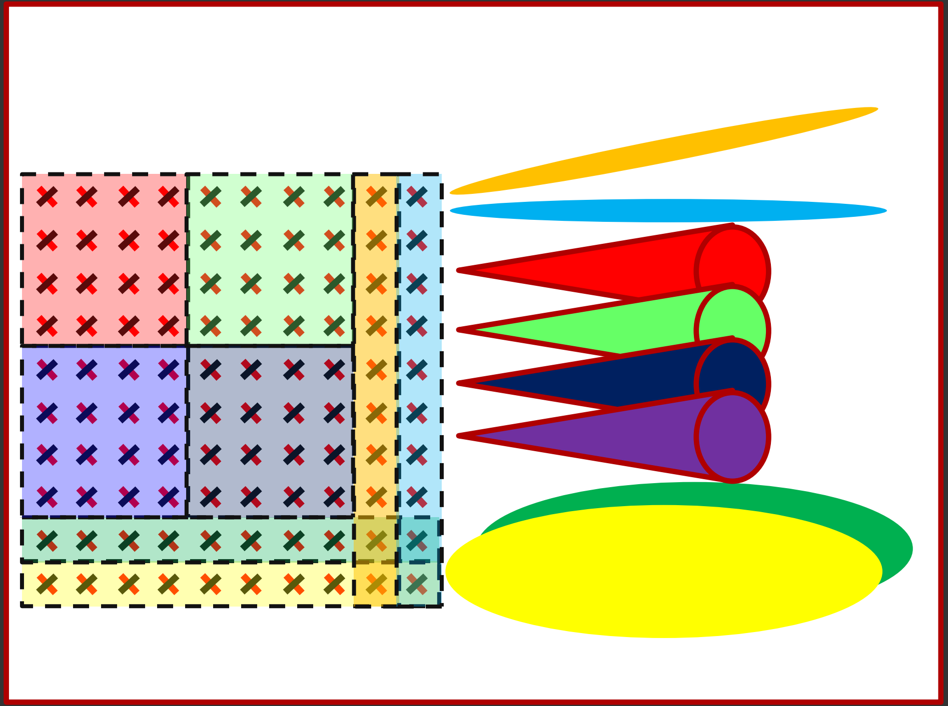
Modern antennas are complex phased systems with numerous discontinuities that cannot be characterized by traditional methods











TXRUs can be applied to each element, each array, or groups of elements depending on the application.

Digital Beamforming –

- Every element has an individual TXRU
- The ultimate in flexibility for beam and capacity
- Very expensive

Analog Beamforming –

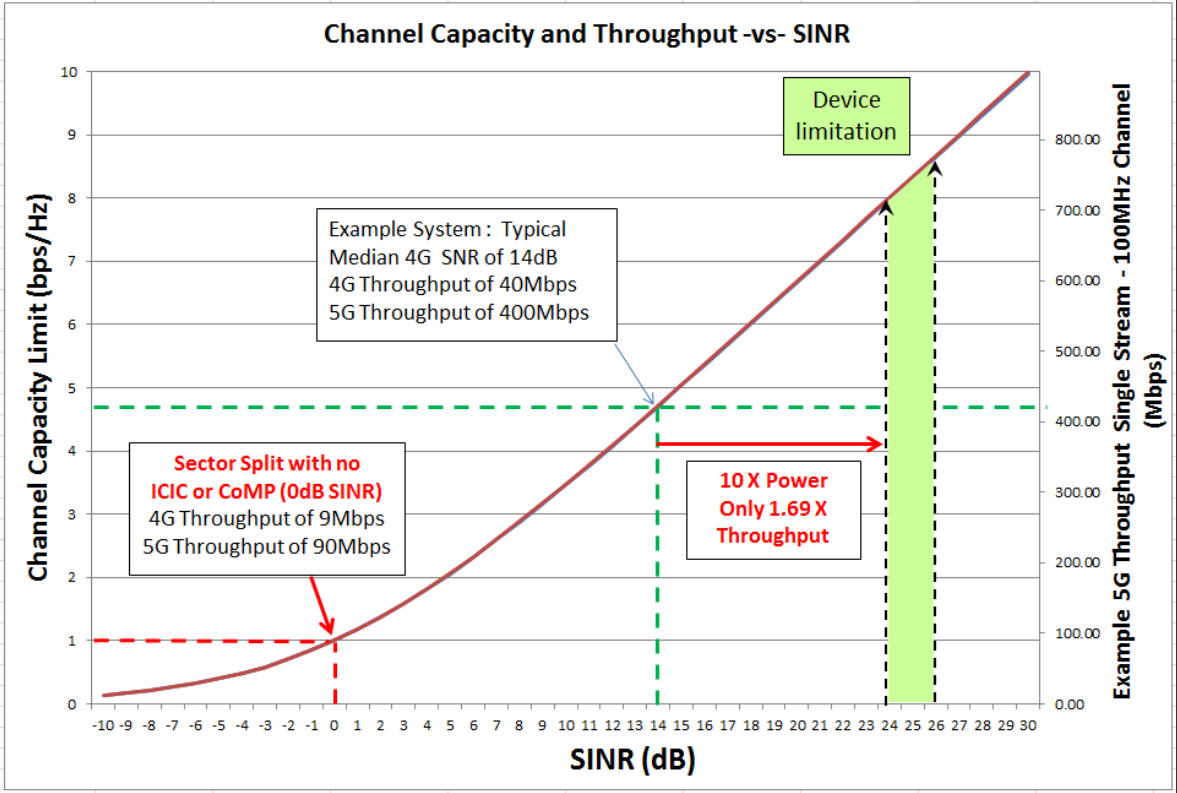
- Each sub-array is fed by an RF cable
- Beam definition is hard wired
- Steering is either hard wired or requires manual or remote adjustment

Hybrid Beamforming –

- A mix of digital and analog methods
- Connects multiple sub-arrays to individual TXRUs
- Sub-arrays form beams that can work independently or together

Power, Capacity, SINR

- Signal to Noise plus Interference (SINR)
- Managing interference yields 5X throughput/capacity
- Just say no to more power!
- Beamforming is all about focusing signal and eliminating noise



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RSSI Improvement

2x1 to 2x2 = 7.5dB (5.6x)
2x2 to 2x3 = 3dB (2x)
2x3 to 2x4 = 2.5dB (1.8x)
2x2 to 2x4 = 5.5dB (3.5x)

SNR Improvement

2x1 to 2x2 = 3.0dB (2.0x)
2x2 to 2x3 = 1.8dB (1.5x)
2x3 to 2x4 = 1.2dB (1.3x)
2x2 to 2x4 = 3.0dB (2.0x)

✓ Data from “Microwave Mobile Communications”, edited by William C Jakes

More power, more problems

- Increased weight, energy, cost
- Exponential increases in PIM, especially with enclosures
- Extra power doesn’t stop, it bleeds into your entire network increasing noise faster than signal away from the cell
- More power is detrimental to capacity and performance (SINR)
- Adjacent sectors with path loss differentials require more integration to avoid self induced UE interference
- Understanding objectives and impediments is critical

6 Ways to Get Ahead External PIM

- Understand the problem
  - ➢ IEC 62037-1:2012 – 2x20W Test?
  - ➢ Customer Affecting PIM Interference?
- PIM Hygiene
- Hire <u>EXTERNAL PIM</u> Certified Crews
- Site Selection – PIM condition, allowable antenna locations, pretest?
- Site Configuration – DON'T SKEW, Edge mounting, Height above Roof
- Don't illuminate rooftops and parapets. Reduce affected areas

One more way!

- Frequency selection – Avoid critical combinations (IM2/IM3)

2nd Order IM With Significantly Higher Potential for PIM Related Interference	
F1 Tx Band-Block-Freq.	F2 Rx = 2*F1 Rx Impacted
800-A'' 869-870MHz	**AWS-D** 1735-1740MHz
800-A 870-880MHz	**AWS-E-F-G** 1740-1760MHz
800-B 880-890MHz	**AWS-H-I-J** 1760-1780MHz

3rd Order PCS-AWS IM Combinations With Higher Potential for PIM Related Interference		
F1 Tx PCS Band-Block Frequency	F2 Tx AWS Band-Block Frequency	F2 Rx 2*F1-F2 Band-Block Impacted
PCS_A2	**AWS_C**	**AWS_C**
PCS_A2	**AWS_D**	**AWS_D**
PCS_A1	**AWS_D**	**AWS_D**
PCS_A1	**AWS_E**	**AWS_E**
PCS_A3	**AWS_C**	**AWS_C**
PCS_A4	**AWS_D**	**AWS_D**
PCS_A5	**AWS_E**	**AWS_E**
PCS_D	**AWS_F**	**AWS_F**
PCS_B2	**AWS_F**	**AWS_F**
PCS_B2	**AWS_G**	**AWS_G**
PCS_B1	**AWS_G**	**AWS_G**

3rd Order PCS-AWS IM Combinations With Higher Potential for PIM Related Interference		
F1 Tx PCS Band-Block Frequency	F2 Tx AWS Band-Block Frequency	F2 Rx 2*F1-F2 Band-Block Impacted
PCS_B1	**AWS_H**	**AWS_H**
PCS_B3	**AWS_F**	**AWS_F**
PCS_B4	**AWS_G**	**AWS_G**
PCS_B5	**AWS_H**	**AWS_H**
PCS_E	**AWS_I**	**AWS_I**
PCS_F	**AWS_J**	**AWS_J**
PCS_C2	**AWS_J**	**AWS_J**
PCS_C3	**AWS_J**	**AWS_J**
PCS_C4	**AWS_J+**	**AWS_J+**
PCS_C5	**AWS_J+**	**AWS_J+**

3rd Order PCS-PCS IM Combinations With Higher Potential for PIM Related Interference		
F1 Tx PCS Band-Block Frequency	F2 Tx PCS Band-Block Frequency	F2 Rx 2*F1-F2 Band-Block Frequency
PCS_A3	**PCS_F**	**PCS_F**
PCS_A3	**PCS_C3**	**PCS_C3**
PCS_A5	**PCS_C4**	**PCS_C4**
PCS_D	**PCS_C5**	**PCS_C5**

End of slides