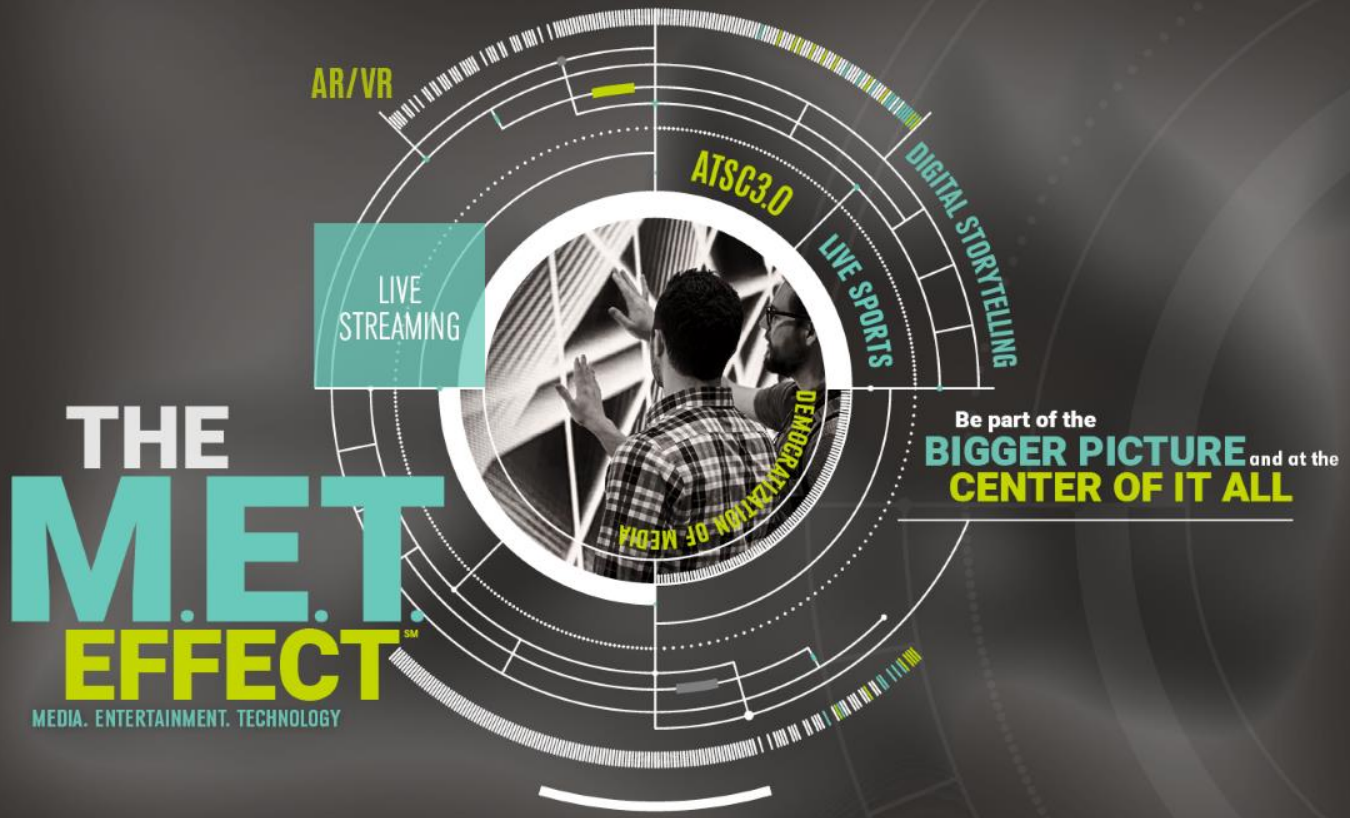


NABSHOW® Where Content Comes to Life

#NABShow

Adaptive Polarization Technology

Adaptive Polarization Technology

- Next Gen TV and how much V-pol
- V-Pol Implementation
  - Fixed and Variable
- Differential Phase and Amplitude
  - Line Run
  - Combiner Chain
- Adaptive Technology
- Serviceability

Attentive crowd

Next Gen TV and Signal Strength

ATSC 3.0

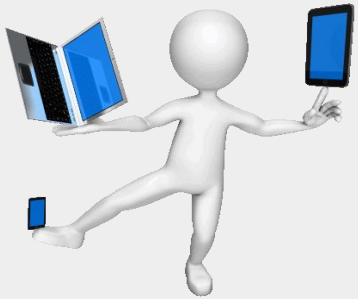
Changing the way Broadcast TV is delivered.

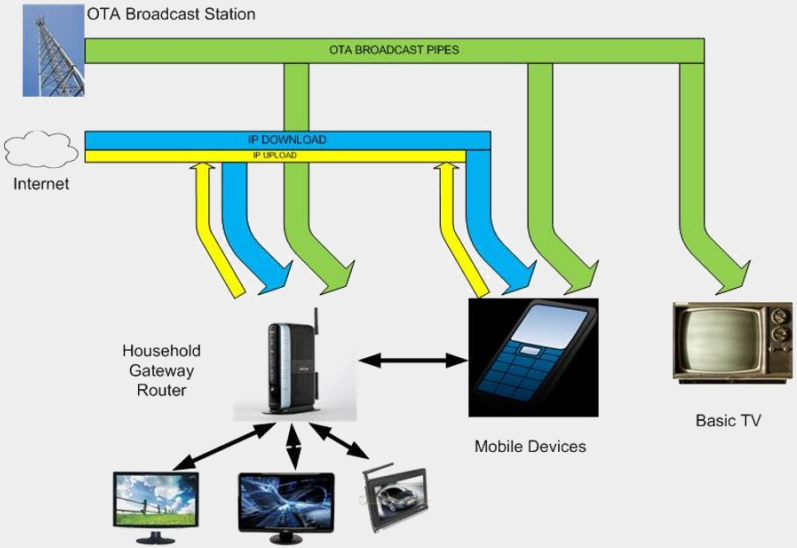
Merging internet with broadcast with

- More flexibility
- More services
- More robust delivery
- More platforms

More bits to more places

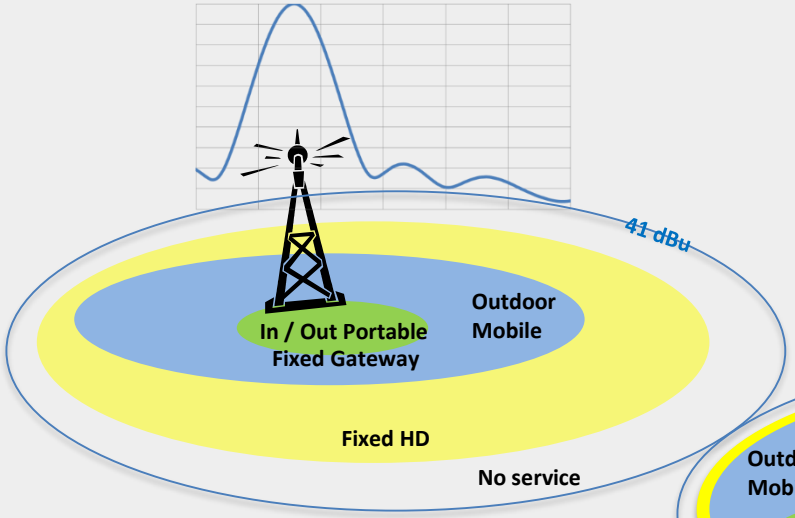
More signal strength

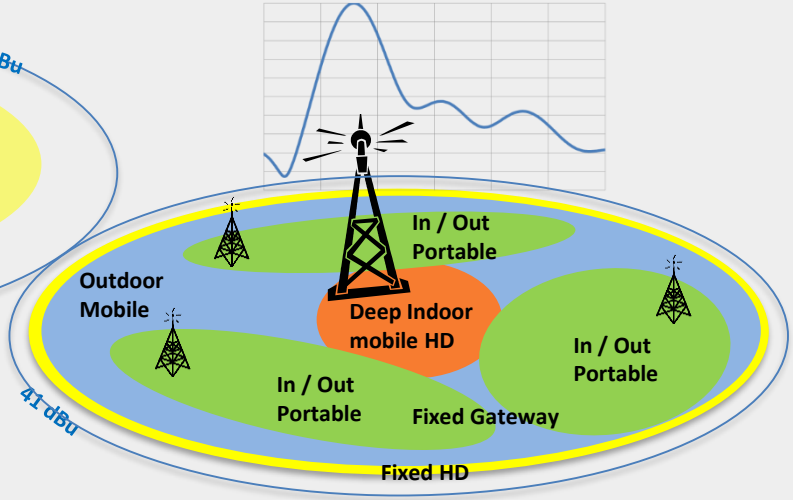




Increasing Signal Strength

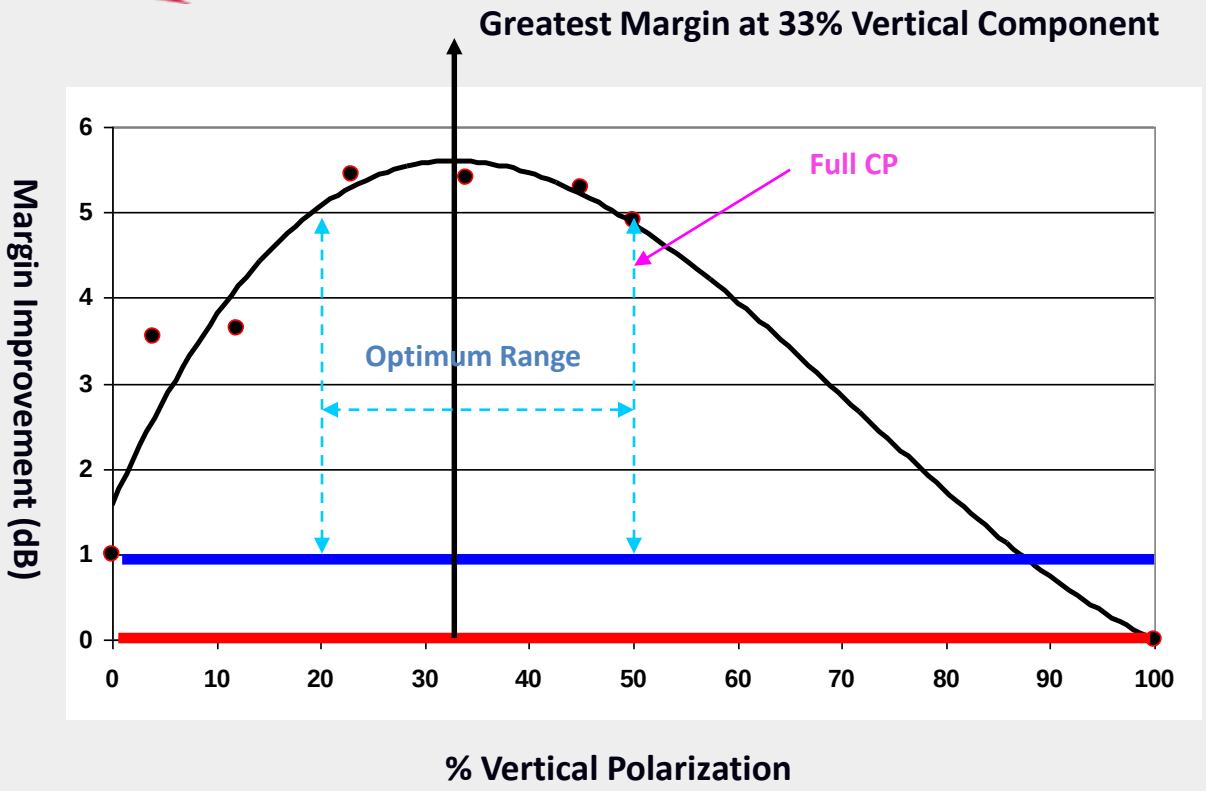
1. Add V-Pol
   - Help with depolarized signals due to multipath
2. Increase null fill
   - Additional signal strength closer to antenna
3. SFN
   - Increased signal for portable and fixed gateway





Power coverage

How Much V-Pol?



4 dB margin improvement

with 20% < Vpol < 50%

Horizontal Polarization Baseline

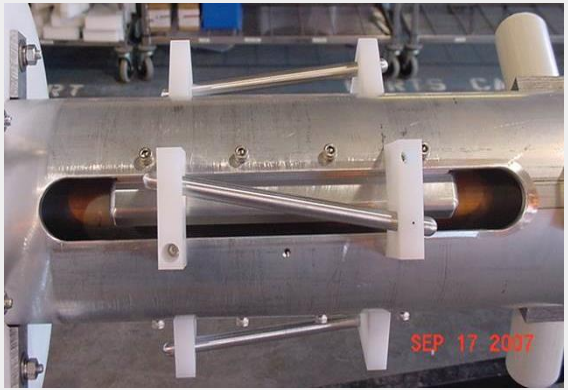
Vertical Polarization Baseline

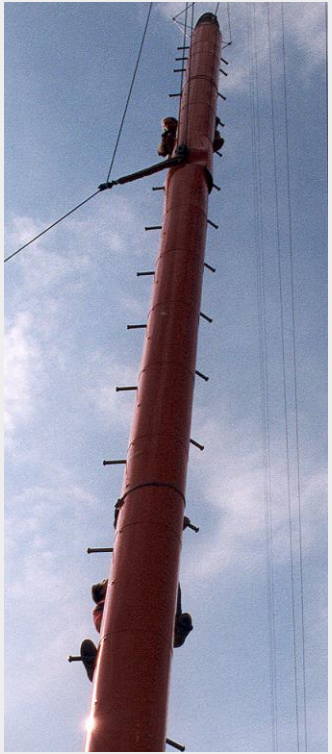
Ref: Doug Lung, "Polarized Power for TV Broadcasting", TV Technology, 29,Oc t2008

Vertical Polarization, Pylon Antenna

Parasitic dipole over slot radiator

- Fixed, elliptical or circular polarization
  - V-Pol percentage depends on angle between slot and dipole
- TPO increase to maintain H-POL ERP
- Lowers the Q of the circuit
  - Increases the operating bandwidth
- Grounded dipole for higher power
  - > 1kW per slot

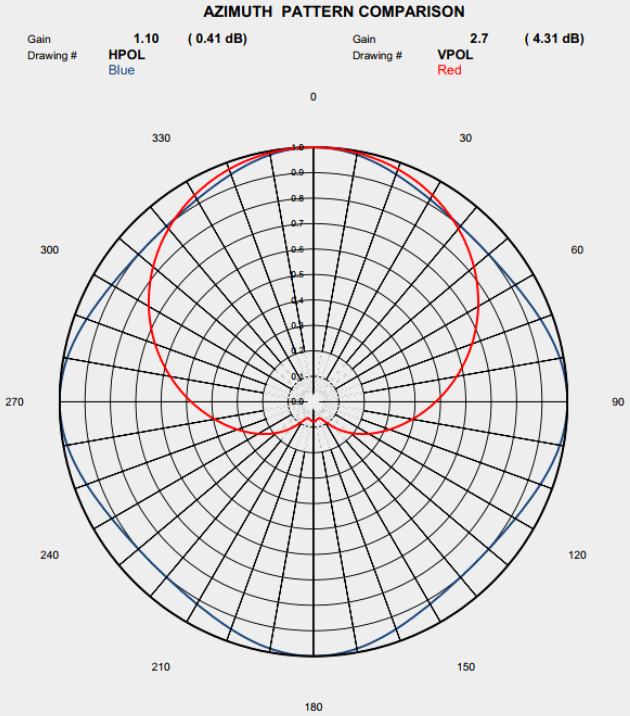


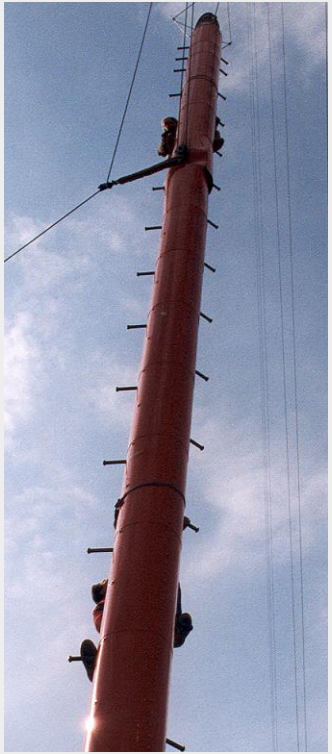


Vertical Polarization, Pylon Antenna

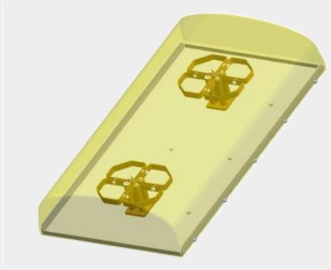
Customize V-pol

- Direct V-POL toward highly populated area
- TPO ≈ 1.375 x H-POL only
  - 25% vertical



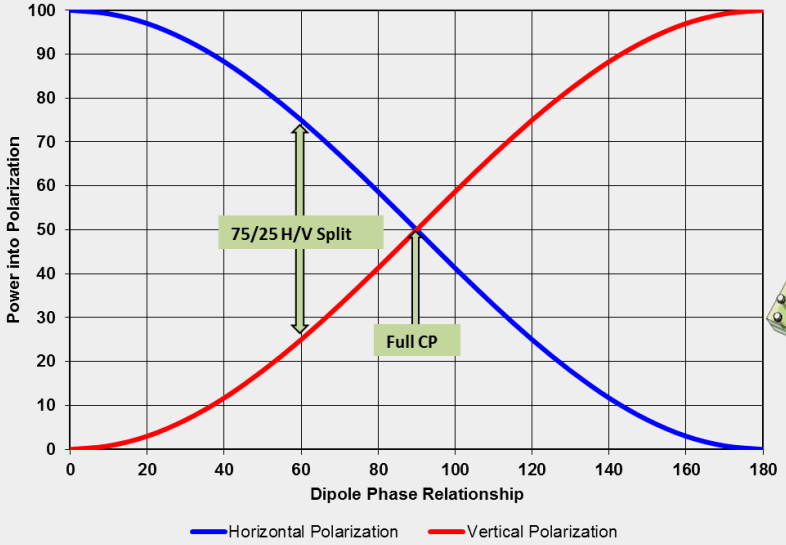


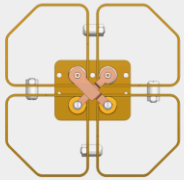
Vertical Polarization, Panel Antenna

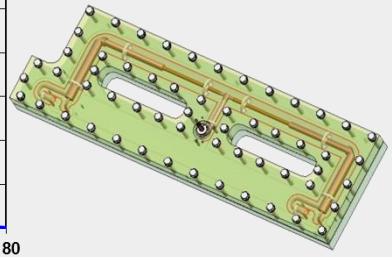


Orthogonal dipoles

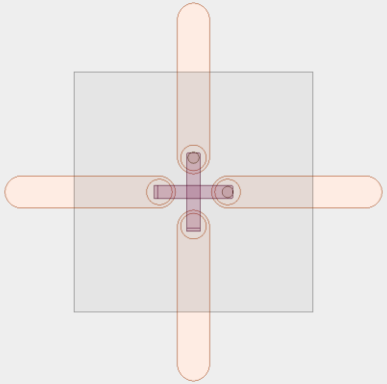
- Amount of V-pol a function of signal phase or amplitude fed to dipoles
- V-pol can be tailored as with pylon
- Fixed V-pol panel has single input
- Adaptable V-pol requires dual inputs

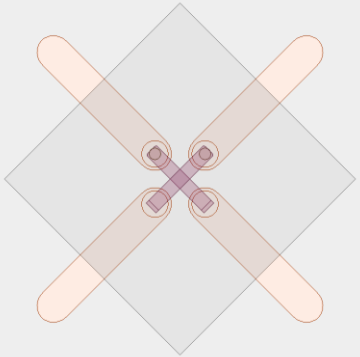






Orthogonal Dipoles Configurations





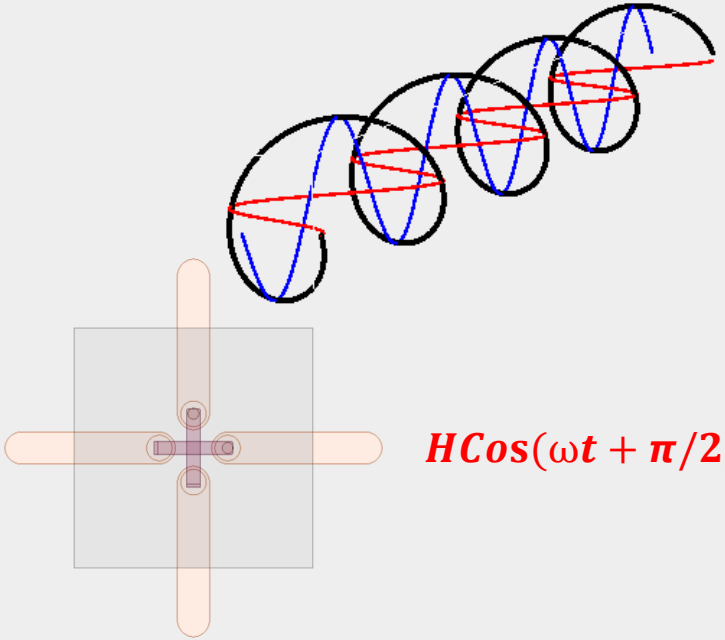
Horizontal/Vertical Crossed Dipoles

- H/V azimuth patterns differ
- Axial ratio dependent on phase quadrature
- Amplitude controls H/V ratio
- Power limited by horizontal dipole

Crossed Dipoles at 45°

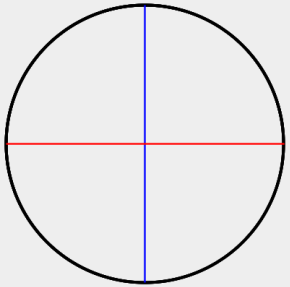
- H/V azimuth patterns similar
- Axial ratio independent power split
- Phase controls H/V ratio
- Power divided b/w dipoles, higher power handling

Horizontal/Vertical Crossed Dipoles



$VCos(\omega t)$

$HCos(\omega t + \pi/2)$



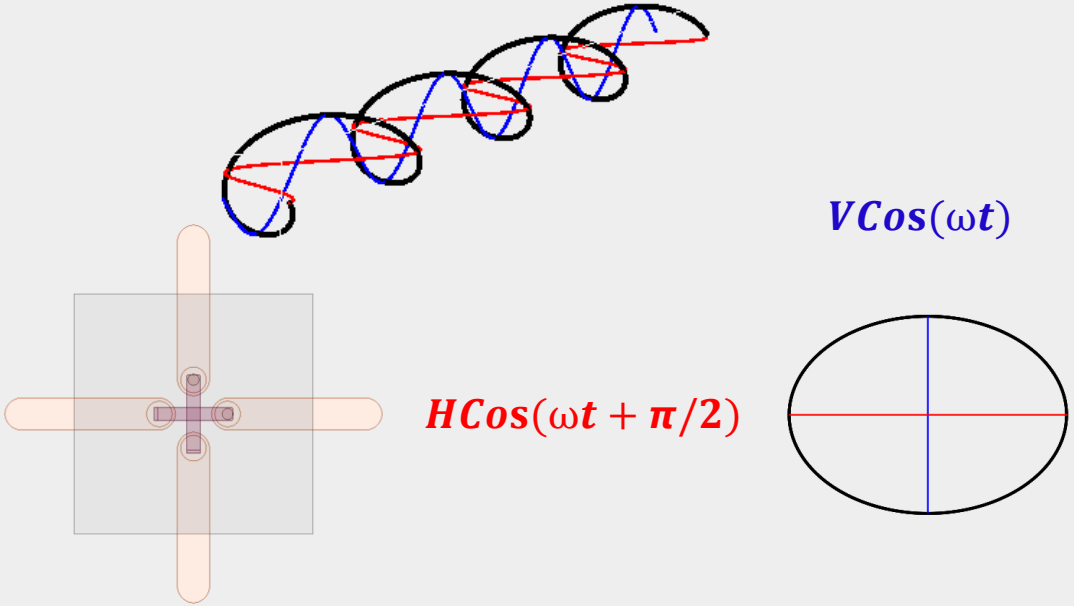
Circular Polarization

Dipoles fed in quadrature
Axial ratio dependent on phase

H = V

AR = H/V

Horizontal/Vertical Crossed Dipoles



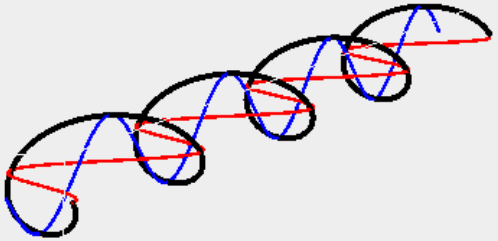
Elliptic Polarization

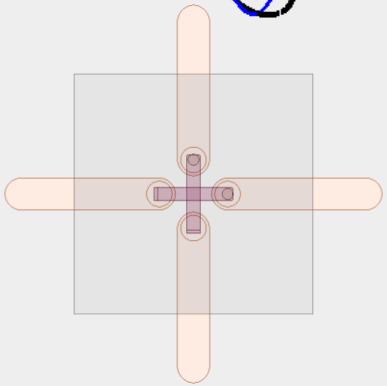
Dipoles fed in quadrature
Axial ratio dependent on phase

H > V

AR = H/V

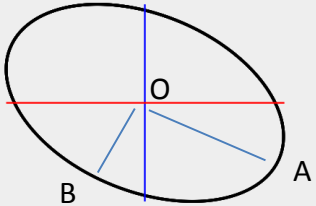
Horizontal/Vertical Crossed Dipoles





$VCos(\omega t + \theta)$

$HCos(\omega t + \pi/2)$



OA/OB = AR ≠ H/V

Elliptic Polarization w Tilt

Dipoles NOT fed in quadrature
Axial ratio tilted

H > V

AR = H/V

Horizontal/Vertical Crossed Dipoles at 45°

$E_v = E_{v1} + E_{v2}$ $E_h = E_{h1} - E_{h2}$

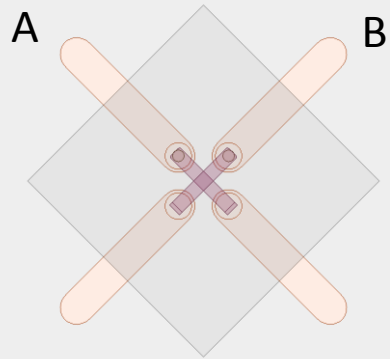
$E_h = A\, e^{j\varnothing 1} \cos\Theta - B\, e^{j\varnothing 2} \cos\Theta$

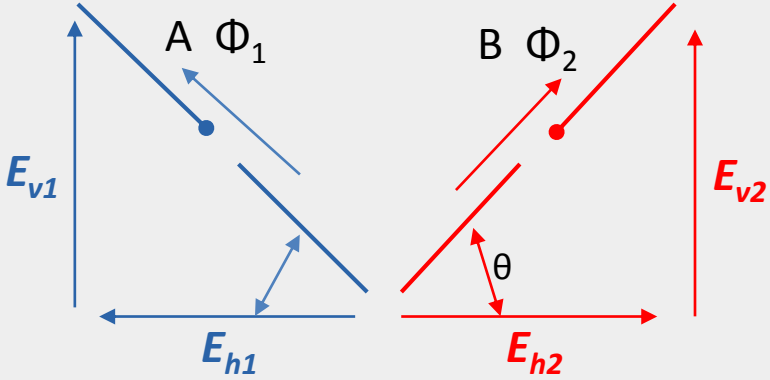
$E_v = A\, e^{j\varnothing 1} \sin\Theta + B\, e^{j\varnothing 2} \sin\Theta$

$\Theta = 45°$ and dipoles are fed with equal amplitude

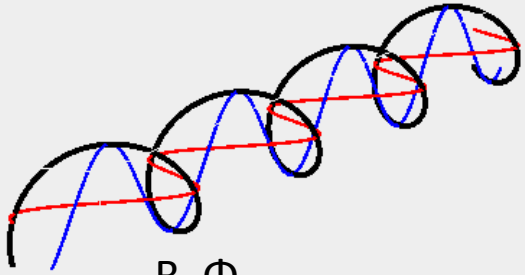
$E_h = .707\,(A \cos\varnothing_1 + j\, A \sin\varnothing_1 - B \cos\varnothing_2 - j\, B \sin\varnothing_2)$

$E_v = .707\,(A \cos\varnothing_1 + j\, A \sin\varnothing_1 + B \cos\varnothing_2 + j\, B \sin\varnothing_2)$

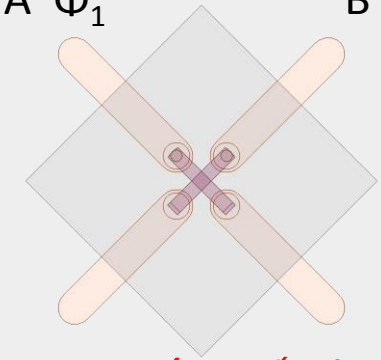




Horizontal/Vertical Crossed Dipoles at 45°

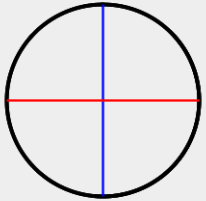


A Φ_1 B Φ_2



E_v

E_h



$E_h = .707\,(A\cos\varnothing_1 + j\,A\sin\varnothing_1 - B\cos\varnothing_2 - j\,B\sin\varnothing_2)$

$E_v = .707\,(A\cos\varnothing_1 + j\,A\sin\varnothing_1 - B\cos\varnothing_2 - j\,B\sin\varnothing_2)$

Circular Polarization

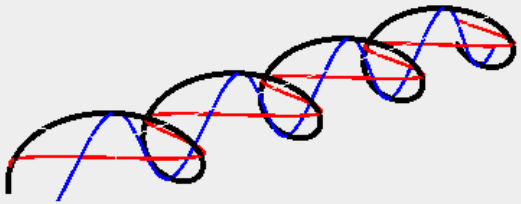
Dipoles fed in quadrature
Axial ratio (AR) dependent on amplitude

$$\Phi_1 = 0°$$
$$\Phi_2 = 90°$$

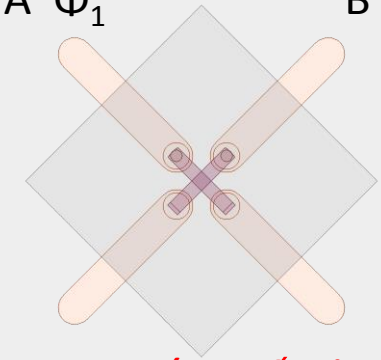
H = V

AR = H/V

Horizontal/Vertical Crossed Dipoles at 45°

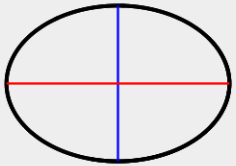


A Φ_1 B Φ_2



E_v

E_h



$E_h = .707\ (A \cos\emptyset_1 + j\ A \sin\emptyset_1 - B \cos\emptyset_2 - j\ B \sin\emptyset_2)$

$E_v = .707\ (A \cos\emptyset_1 + j\ A \sin\emptyset_1 - B \cos\emptyset_2 - j\ B \sin\emptyset_2)$

Elliptic Polarization

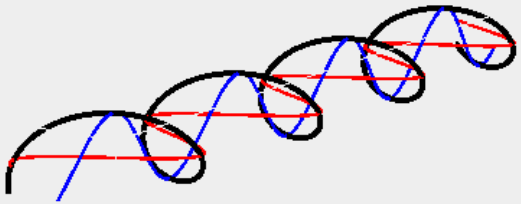
Dipoles fed with equal amplitude
AR dependent on amplitude

$$\Phi_1 = 0°$$
$$\Phi_2 = 110°$$

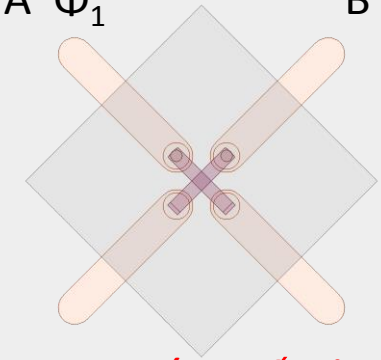
H > V ; 66%/34%

AR = H/V

Horizontal/Vertical Crossed Dipoles at 45°

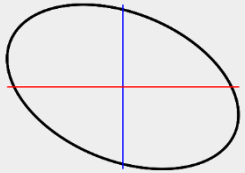


A Φ_1 B Φ_2



E_v

E_h



$E_h = .707\,(A\cos\varnothing_1 + j\,A\sin\varnothing_1 - B\cos\varnothing_2 - j\,B\sin\varnothing_2)$

$E_v = .707\,(A\cos\varnothing_1 + j\,A\sin\varnothing_1 - B\cos\varnothing_2 - j\,B\sin\varnothing_2)$

Elliptical Polarization

Dipoles fed with unequal amplitude
AR differs from H/V ratio

$A \neq B$

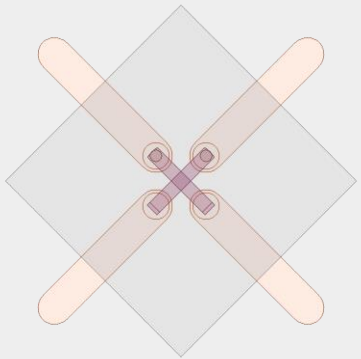
$\Phi_1 = 0°$
$\Phi_2 = 110°$

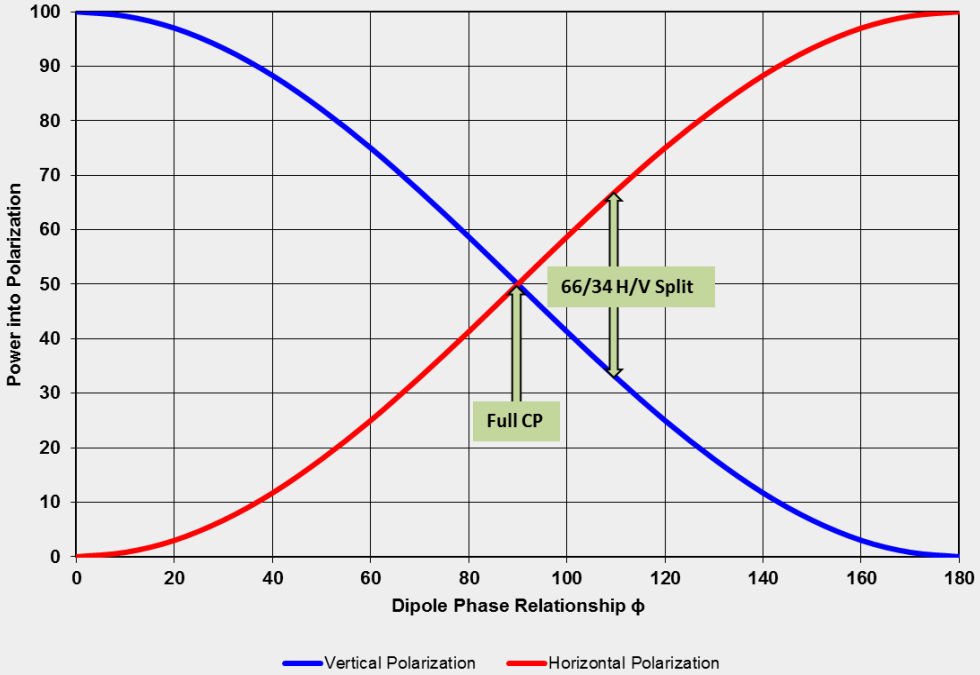
H > V
AR = H/V

Horizontal/Vertical Crossed Dipoles at 45°

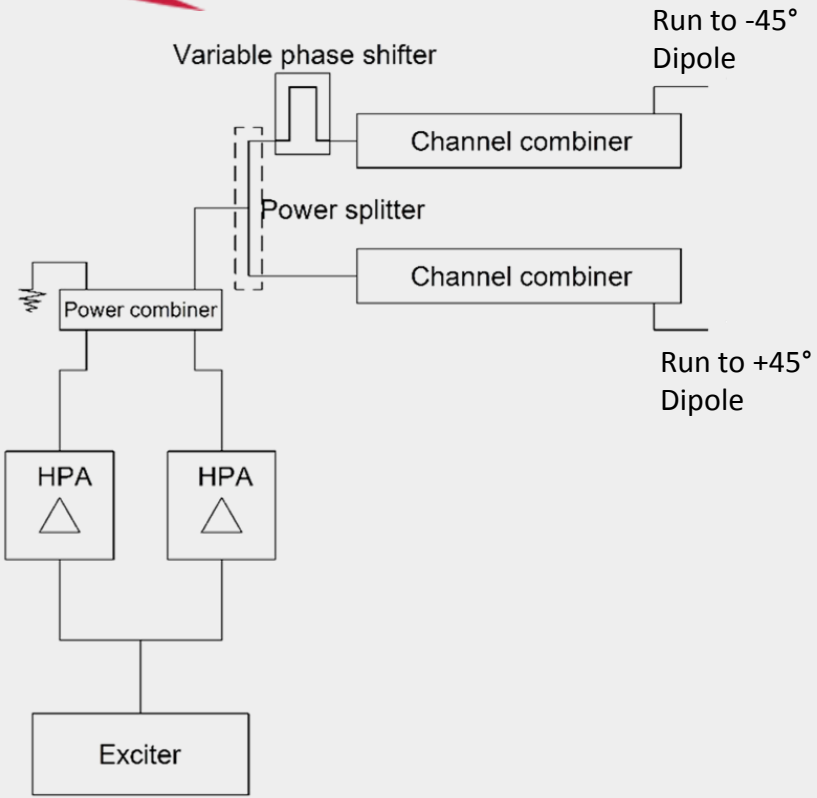
45° Crossed dipole:

- Congruent azimuth patterns
- Axial ratio equals polarization ratio w equal power to dipoles
- Higher power handling





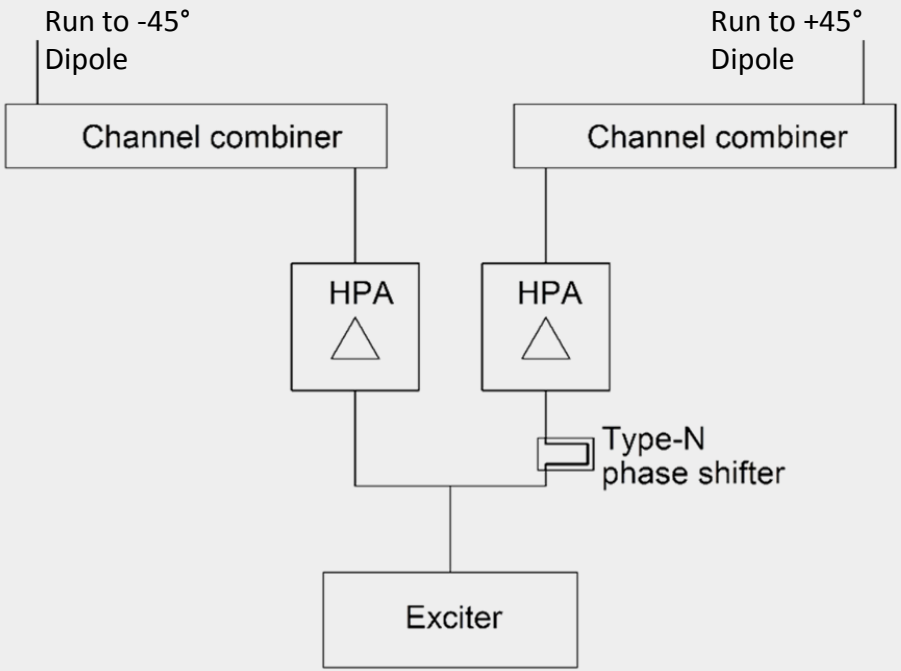
Varying Polarization



- Combine HPA's, then split to vary phase with high power RF phase shifter
- Feed dual combiner chains
  - *Verify combiner chain S-parameters are similar*
- Feed dual line runs
  - Similar physical/electrical length to avoid phase run-out
  - Layout/precautions must be observed
  - System proof for differential phase
  - Monitor line runs for differential phase if required
- Feed crossed dipoles

Adaptive Polarization

- Phase at HPA output tuned using trombone
  - Variations adaptively handled electronically in HPA
- Phase can be monitored by injecting an out-of-channel signal that can be monitored in combiner reject load line
- Observe same amplitude and phase precautions in combiner chain and line runs



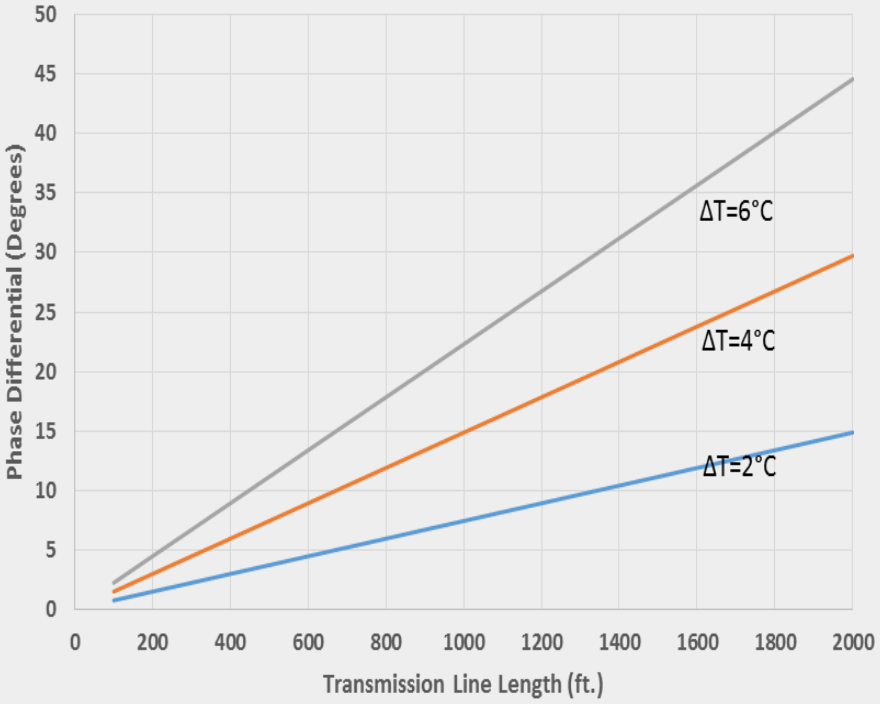
Solar Heating of Transmission Line

$$\Delta\emptyset = 360 * \frac{L \propto \Delta T}{\lambda}$$

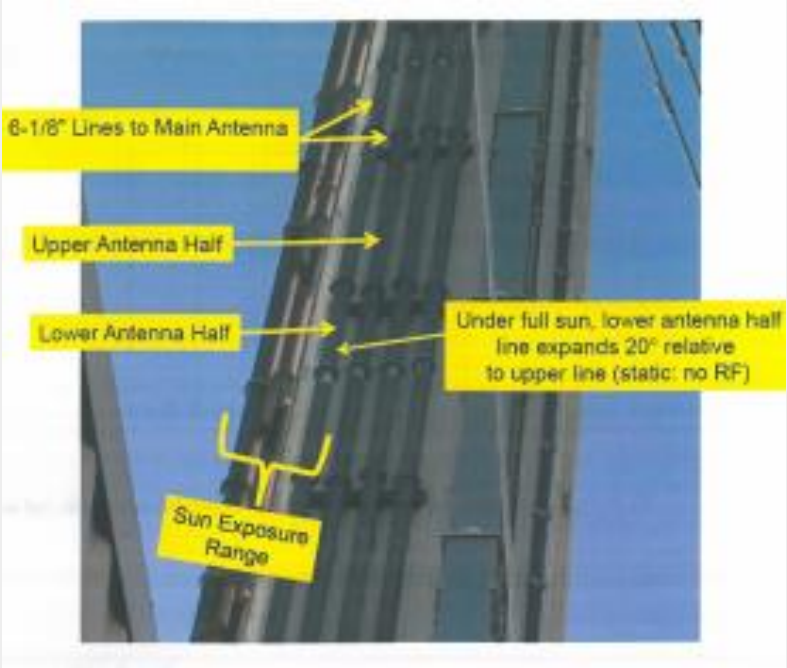
L = Total length of the transmissions lines
α = Coefficient of thermal expansion
$\alpha_{Cu} = 16 \times 10^{-6}$ in/in/C
$\alpha_{Al} = 24 \times 10^{-6}$ in/in/C
ΔT = Temperature difference between lines
λ = Wavelength

2000', ΔT = 2°C

	Hpol ERP (kW)	Vpol ERP (kW)
Nominal	1000	500
T/L A Hotter	805	695
T/ L B Hotter	1180	320



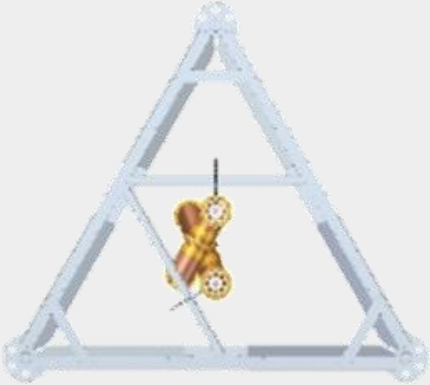
Solar Heating of Transmission Line



- Upper/lower antenna line run
- One line exposed, other shaded
- ***20 degree phase differential***

Minimizing Effect of Solar Heating

Solar Paint



North/South Layout

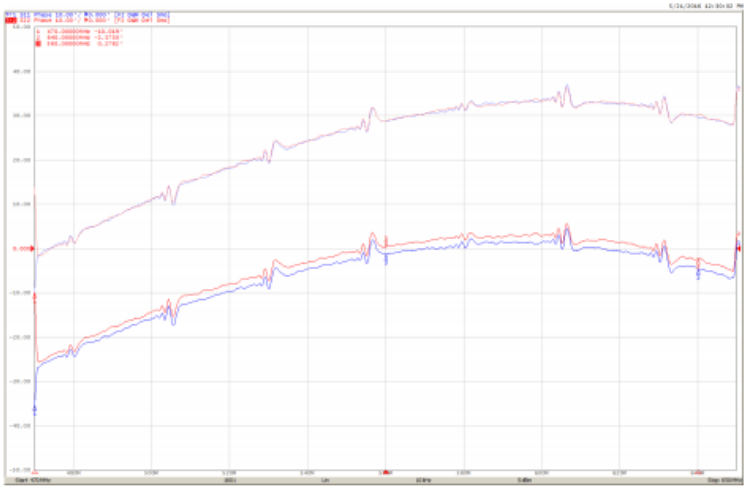
Cross Line Runs

Phase Verification

- Dual 7 inch line runs:
  - ≈ 1500’
  - Solar coated
  - Optimized for VSWR
  - Shorted at tower top
  - Max deviation b/w runs ≈ 2.1 degrees

MARSAND, INC.
Matthew A. Sanderford, Jr., P.E.

5.27 Figure 27 – 5-21-16 12:30 pm Phase Measurement



Courtesy of Matthew Sanderford

Phase Verification

$$\Delta\emptyset = 360 * \frac{L \propto \Delta T}{\lambda}$$

Measured max. deviation through day

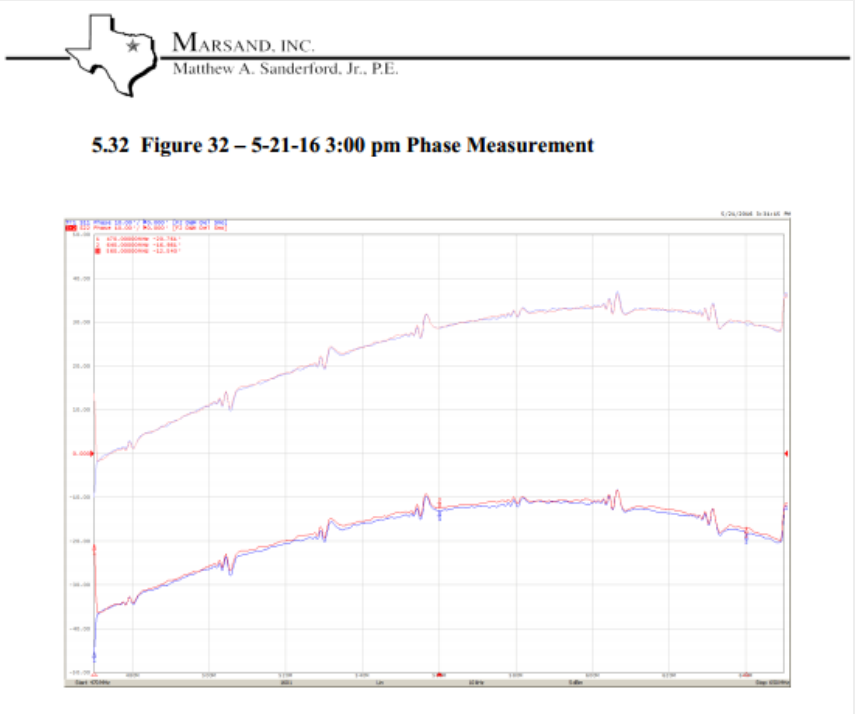
CH 41
L = 1500’ run
Ambient dT = 8.4° C
dθ ≈ 48 degrees

Blue -> + 45 degree line
Red -> - 45 degree line

Calculated:

$$\Delta\emptyset = 360 * \frac{(1500x12)16x10^{-6}\ 8.4}{18.6}$$

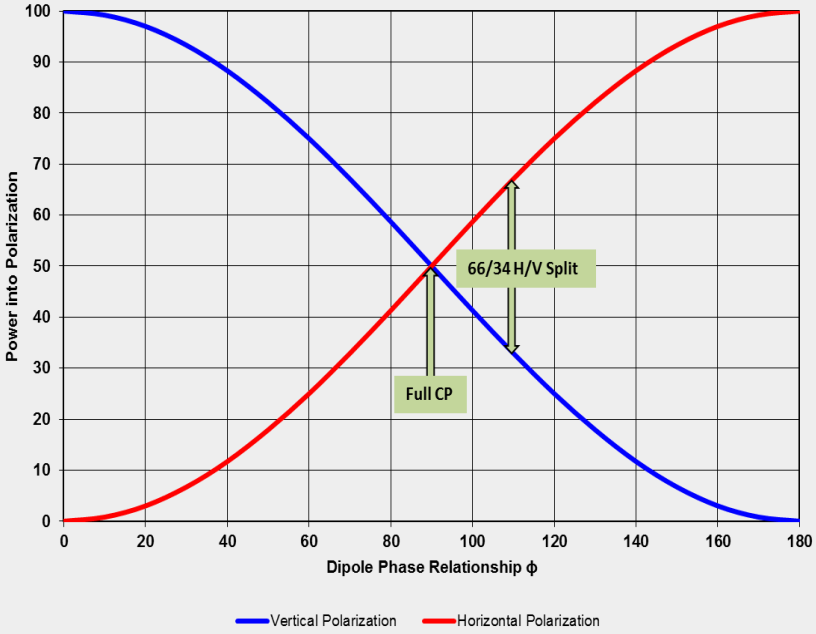
$$\Delta\emptyset = 46.8°$$



Courtesy of Matthew Sanderford

Monitoring Line Phase and Adaptive Adjustment

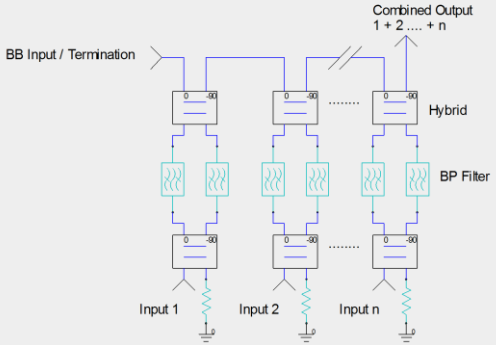
- Proper planning can minimize differential phase
- Verify phase differential over time with VNA testing
- Excessive phase deviation can be monitored and controlled within transmitter
  - HPA phase can be adjusted using a monitoring system
  - Difficult using high power phase shifters

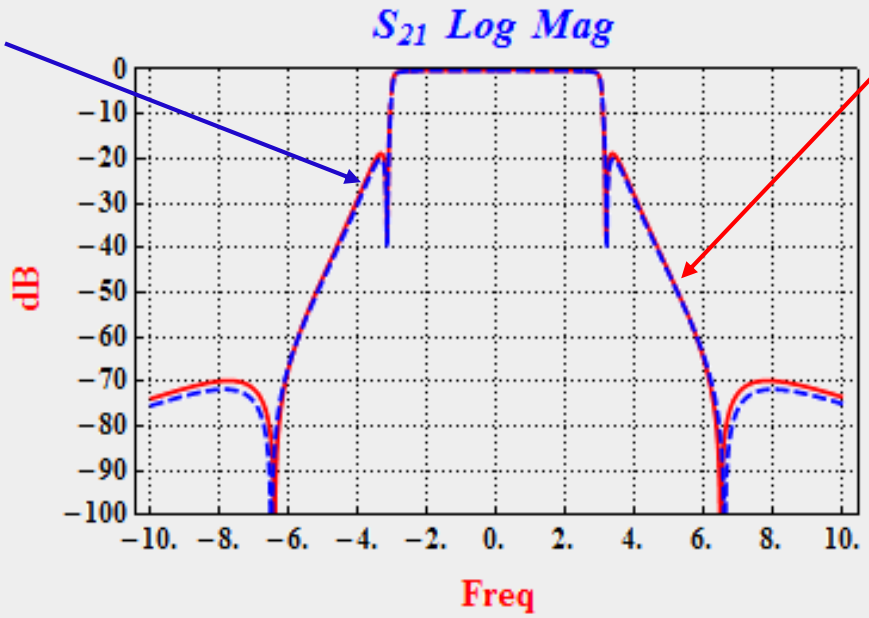


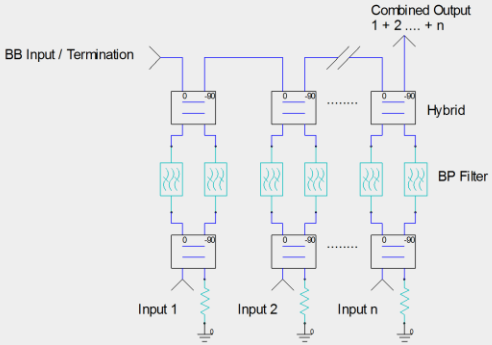
Differential Phase and Amplitude through Combiner Chains

Blue trace

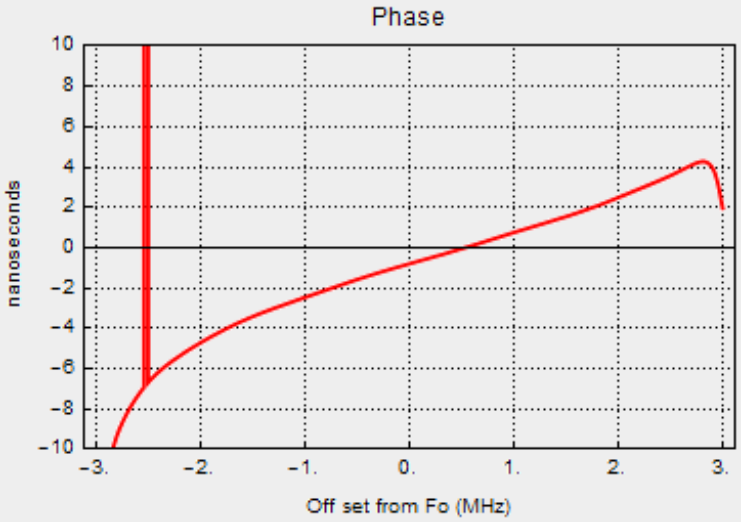
Red trace

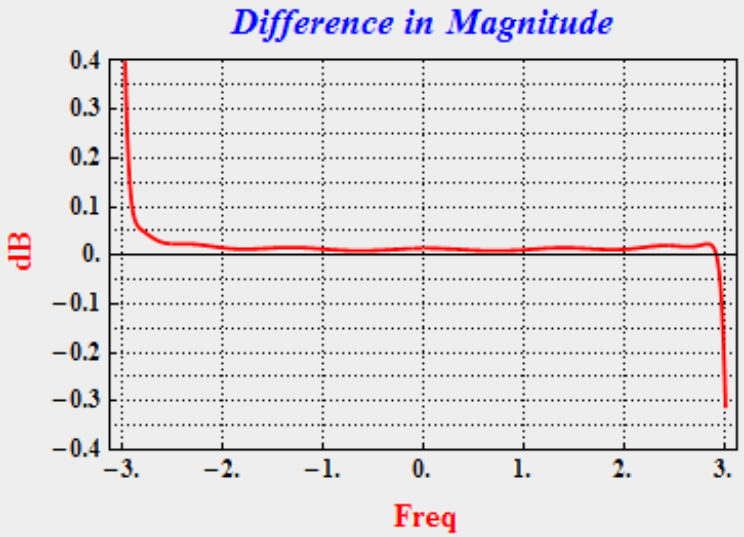




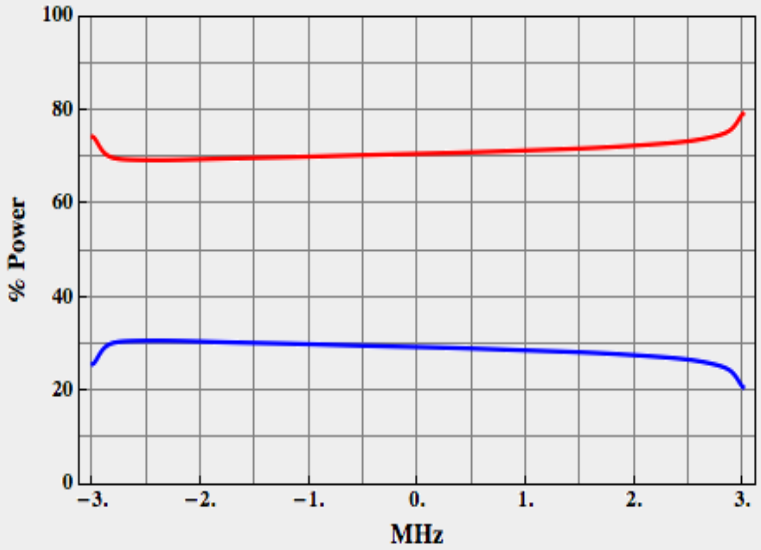


Adjacent Channel Deviation through Combiner Chains





Adjacent Channel Deviation through Combiner Chains



Reliability and Parts Count

The definition of failure rate is

(MIL-217 standard)

$$\lambda = \sum_{i=1}^{n} N_i \lambda_i \pi_{Qi}$$

n = # of part categories
N_i = Quality of ith part
λ_i = Failure rate of ith part
π_{Qi}= Quality factor of ith part

Product failure rate is simply the summation of the base failure rates of each component.

Our goal is to **design for the highest performance** with the minimum number of parts

KEEP IT SIMPLE

- Few Connections
- Highly Engineered Designs
- Ease of Installation

Fixed vs Adaptive Polarization

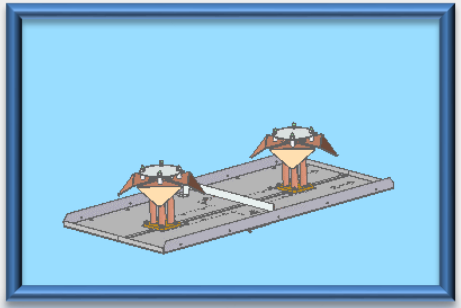
System Complexity

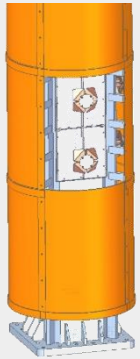
NEED SOME GOOD PICS OF EACH

- Adaptive Polarization
  - Two combiner chains
  - Two line runs
  - Two panel inputs
- Fixed Polarization
  - Panel with fixed phase
    - One combiner chain
    - One line run
    - One input per panel
  - Pylon antenna
    - One combiner chain
    - One line run, one input

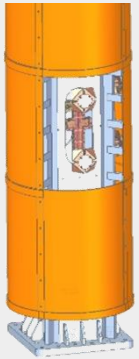
Maintenance

- Radome easily removed
- Removable panel back screens
- Feed system access
  - Cables
  - Power divider access

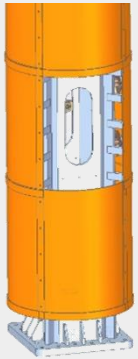




1. REMOVE RADOME PANEL



2. REMOVE PANEL BACKPLANE



3. REMOVE PANEL FLATPACK TO ACCESS INTERNAL COMPONENTS

Next Gen, ATSC 3.0 Ready

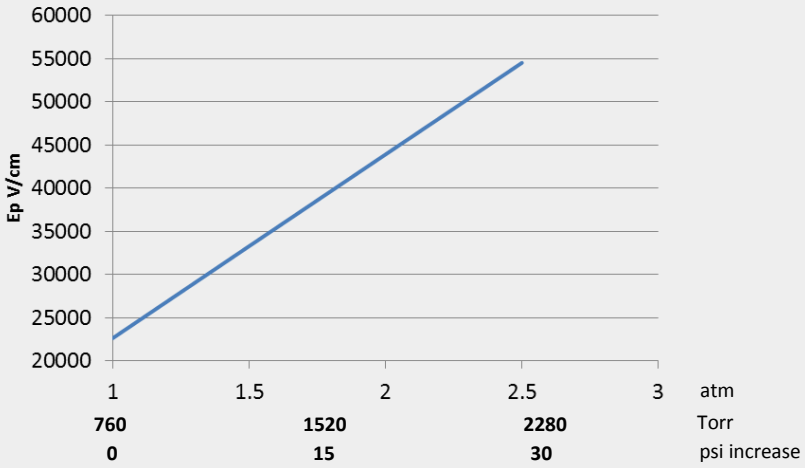
Pressurized to the panel feed point

- Peak power / voltage can be increased with pressurization

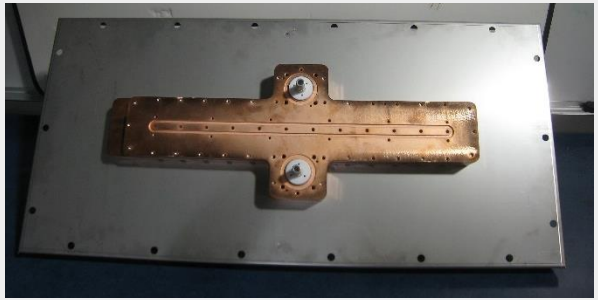
$$E_p = 3.75p\left(1+\frac{\omega^2}{25x10^{18}p^2}\right)^{1/2} x \left(\frac{10^6}{p^2{L_{eff}}^2}+6.4x10^4+\frac{20}{p\tau_p}\right)^{3/16}$$

$$p = p_0\frac{273}{273+T_0}$$

Air ionization threshold can be calculated in terms of the frequency, pulse width and pressure



5 psi increases the voltage breakdown by 1.13X

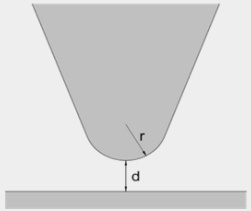


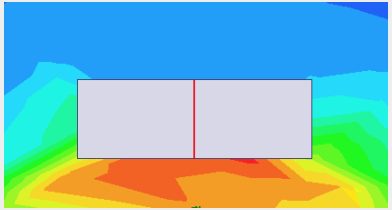
Next Gen, ATSC 3.0 Ready

Competitive designs use microstrip to internally feed the radiators in each panel

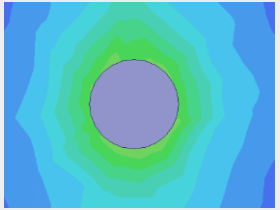
- Sharp edges intensify the E field
  - Reduces allowable voltage breakdown
  - The electric field intensity near a conductor is inversely proportional to the radius of curvature (r)

$$E_m \approx \frac{2V}{r\,ln\left(1+\frac{4d}{r}\right)}$$

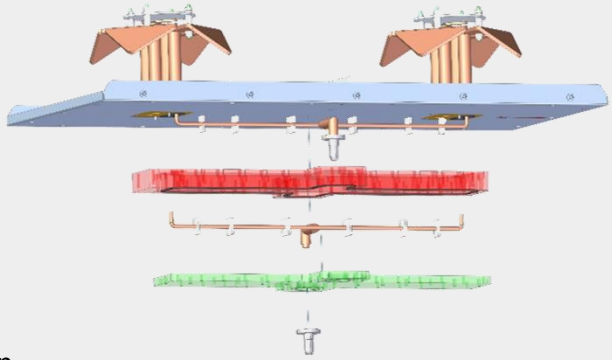




Microstrip



Coax



Maximum E field reduced by 35% for equivalent coax design

Summary