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

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

Dielectric

NABSHOW Where Content Comes to Life
#NABShow
How Much V-Pol?

Greatest Margin at 33% Vertical Component

4 dB margin improvement with 20% < Vpol < 50%

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 $\approx 1.375 \times$ 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

Circular Polarization
Dipoles fed in quadrature
Axial ratio dependent on phase

$H = V$

$AR = \frac{H}{V}$
Horizontal/Vertical Crossed Dipoles

Elliptic Polarization

Dipoles fed in quadrature
Axial ratio dependent on phase

\[ H > V \]

\[ AR = \frac{H}{V} \]
Horizontal/Vertical Crossed Dipoles

**Elliptic Polarization w Tilt**

Dipoles NOT fed in quadrature
Axial ratio tilted

\[ V \cos(\omega t + \theta) \]

\[ H \cos(\omega t + \pi/2) \]

\[ OA/OB = AR \neq H/V \]

\[ H > V \]

\[ AR = H/V \]
Horizontal/Vertical Crossed Dipoles at 45°

\[ E_v = E_{v1} + E_{v2} \quad E_h = E_{h1} - E_{h2} \]

\[ E_h = A e^{i\Phi_1} \cos \theta - B e^{i\Phi_2} \cos \theta \]

\[ E_v = A e^{i\Phi_1} \sin \theta + B e^{i\Phi_2} \sin \theta \]

\( \theta = 45° \) and dipoles are fed with equal amplitude

\[ E_h = 0.707 (A \cos \Phi_1 + j A \sin \Phi_1 - B \cos \Phi_2 - j B \sin \Phi_2) \]

\[ E_v = 0.707 (A \cos \Phi_1 + j A \sin \Phi_1 + B \cos \Phi_2 + j B \sin \Phi_2) \]
Circular Polarization

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

$\Phi_1 = 0^\circ$
$\Phi_2 = 90^\circ$

$H = V$

$AR = \frac{H}{V}$

$E_h = 0.707 (A \cos \Phi_1 + j A \sin \Phi_1 - B \cos \Phi_2 - j B \sin \Phi_2)$

$E_v = 0.707 (A \cos \Phi_1 + j A \sin \Phi_1 - B \cos \Phi_2 - j B \sin \Phi_2)$
Horizontal/Vertical Crossed Dipoles at 45°

Elliptic Polarization

Dipoles fed with equal amplitude
AR dependent on amplitude

\[ \Phi_1 = 0° \]
\[ \Phi_2 = 110° \]

\[ H > V ; 66% / 34% \]

\[ AR = \frac{H}{V} \]
Horizontal/Vertical Crossed Dipoles at 45°

Elliptical Polarization

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

\[ E_v = 0.707 (A \cos \Phi_1 + j A \sin \Phi_1 - B \cos \Phi_2 - j B \sin \Phi_2) \]
\[ E_h = 0.707 (A \cos \Phi_1 + j A \sin \Phi_1 - B \cos \Phi_2 - j B \sin \Phi_2) \]

\[ A \neq B \]
\[ \Phi_1 = 0° \]
\[ \Phi_2 = 110° \]

\[ H > V \]
\[ AR = H/V \]
45° Crossed dipole:

- Congruent azimuth patterns
- Axial ratio equals polarization ratio with 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

\[ \Delta \phi = 360 \times \frac{L \propto \Delta T}{\lambda} \]

L = Total length of the transmissions lines
\( \alpha \) = Coefficient of thermal expansion
\( \alpha_{Cu} = 16 \times 10^{-6} \text{ in/in/C} \)
\( \alpha_{Al} = 24 \times 10^{-6} \text{ in/in/C} \)
\( \Delta T \) = Temperature difference between lines
\( \lambda \) = Wavelength

2000’, \( \Delta T = 2^\circ \text{C} \)

<table>
<thead>
<tr>
<th>Nominal</th>
<th>Hpol ERP (kW)</th>
<th>Vpol ERP (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T/L A Hotter</td>
<td>805</td>
<td>695</td>
</tr>
<tr>
<td>T/ L B Hotter</td>
<td>1180</td>
<td>320</td>
</tr>
</tbody>
</table>
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:
  - \( \approx 1500' \)
  - Solar coated
  - Optimized for VSWR
  - Shorted at tower top
  - Max deviation b/w runs \( \approx 2.1 \) degrees

Courtesy of Matthew Sanderford
Phase Verification

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:

\[ \Delta \phi = 360 \times \frac{L \propto \Delta T}{\lambda} \]

\[ \Delta \phi = 360 \times \frac{(1500 \times 12)16 \times 10^{-6} 8.4}{18.6} \]

\[ \Delta \phi = 46.8° \]
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

$S_{21}$ Log Mag

Freq

Dielectric

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Adjacent Channel Deviation through Combiner Chains

Phase

Difference in Magnitude

Dielectric

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Adjacent Channel Deviation through Combiner Chains

![Graph showing the adjacent channel deviation through combiner chains. The x-axis represents MHz, and the y-axis represents % Power. Two lines are visible: one in red and one in blue. The red line is mostly horizontal, indicating minimal deviation, while the blue line shows a slight increase in deviation as MHz increases.]
Reliability and Parts Count

The definition of failure rate is

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

- \( n \) = # of part categories
- \( N_i \) = Quality of \( i^{th} \) part
- \( \lambda_i \) = Failure rate of \( i^{th} \) part
- \( \pi_{Qi} \) = Quality factor of \( i^{th} \) 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

Keep it simple stupid
**Fixed vs Adaptive Polarization**

**System Complexity**

- **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

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*NEED SOME GOOD PICS OF EACH*
**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
Pressurized to the panel feed point

- Peak power / voltage can be increased with pressurization

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

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

\[ p = p_0 \frac{273}{273 + T_0} \]

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)

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

Maximum E field reduced by 35% for equivalent coax design

Microstrip  Coax