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ATSC 3.0 Ready
Designing Antennas for Higher OFDM PAPR

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Trusted for Decades. Ready for Tomorrow.

OFDM - Peak to Average Power Ratio

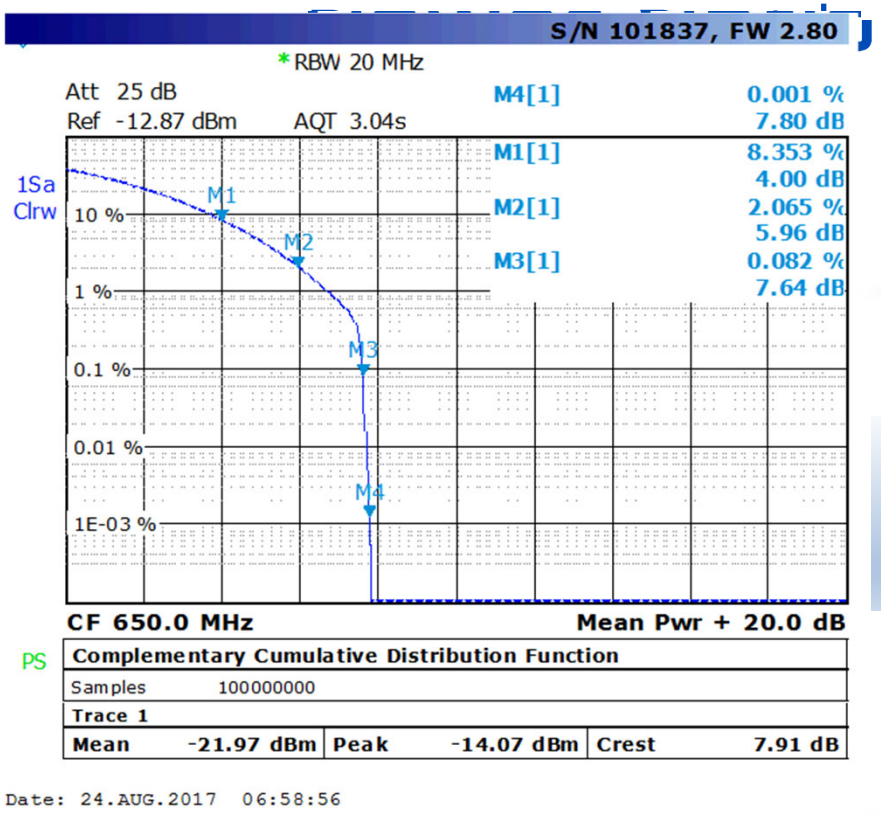
OFDM based modulation will present higher PAPRs than are currently observed in the 8-VSB standard.

ATSC 1.0 ≈ 6dB ATSC 3.0 ????

The ATSC 3.0 standard includes tone reservation (TR) and active constellation extension (ACE) as PAPR reduction techniques

Not being used….. *Most Tx manufactures will likely implement their own proprietary solutions*

OFDM - Peak to Average



Comfortable stating the statistical maximum PAPR at the output of the transmitter is 9 dB (Probably closer to 8 dB)

Courtesy of Rohde & Schwartz

OFDM - Probability of Co-phased Voltage Additions

- Consists of several closely spaced orthogonal sub-carriers
  - Each modulated in both amplitude and phase
- Finite probability that all carriers will add in phase at their max amplitude

What should be the design criteria?

Dielectric - One over voltage event in 100 years

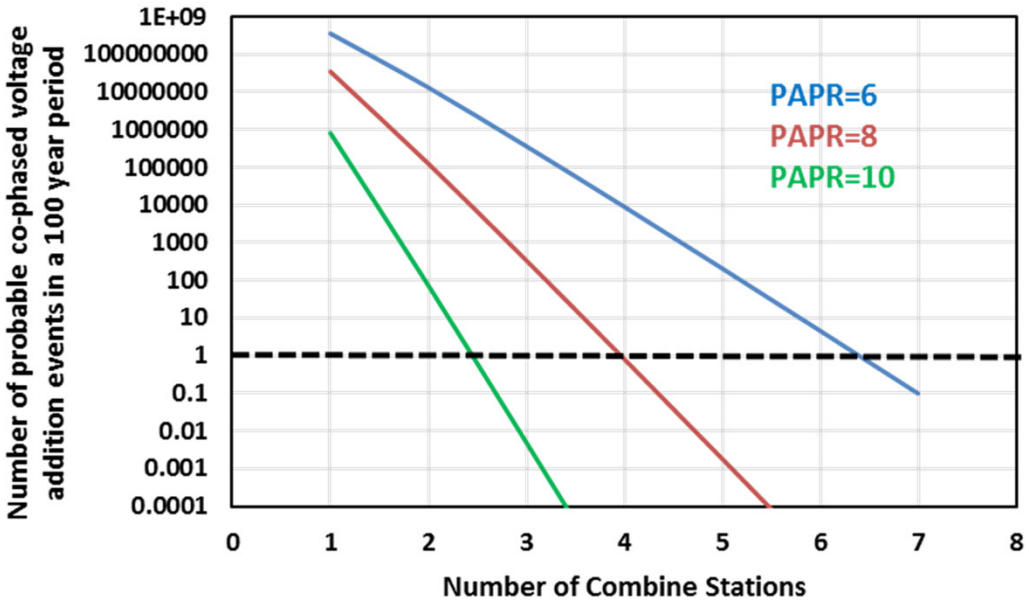
The total number of probable events in a 100 year period is

$$N_e = 3.15x10^9 nB(e^{-PAPR_{linear}})^n$$

The number of combined stations is key

www.Dielectric.com

OFDM - Probability of Co-phased Voltage Additions

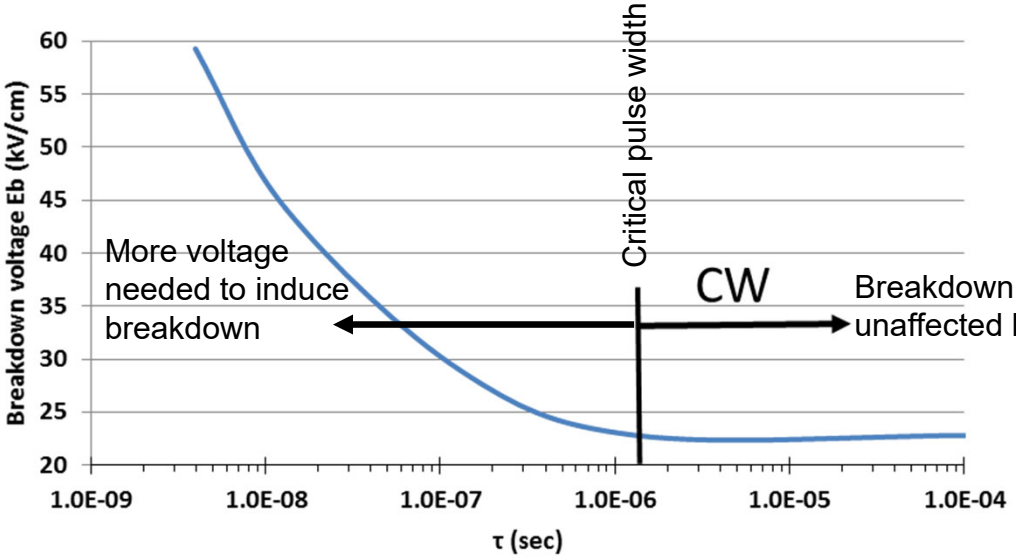


Example:

- Assume 8 dB PAPR
- 4 stations must be taken into account in the voltage handling analysis
- If more than 4 stations are combined, the voltage analysis can be limited to 4

Pulse Width Dependence on Breakdown

- Physical process that determines breakdown – Well defined
- Shorter pulse durations require higher amounts of voltage to induce breakdown



Critical pulse width $\tau_c = \frac{10^{-3}}{p}$

At sea level where p=760 torr, the critical pulse width is 1.315 micro-seconds.

$$E_b\left(\frac{kV}{cm}\right) = 22.22 + \frac{87.24}{1 + \left(\frac{\tau}{2.47x10^{-9}}\right)^{.648}}$$

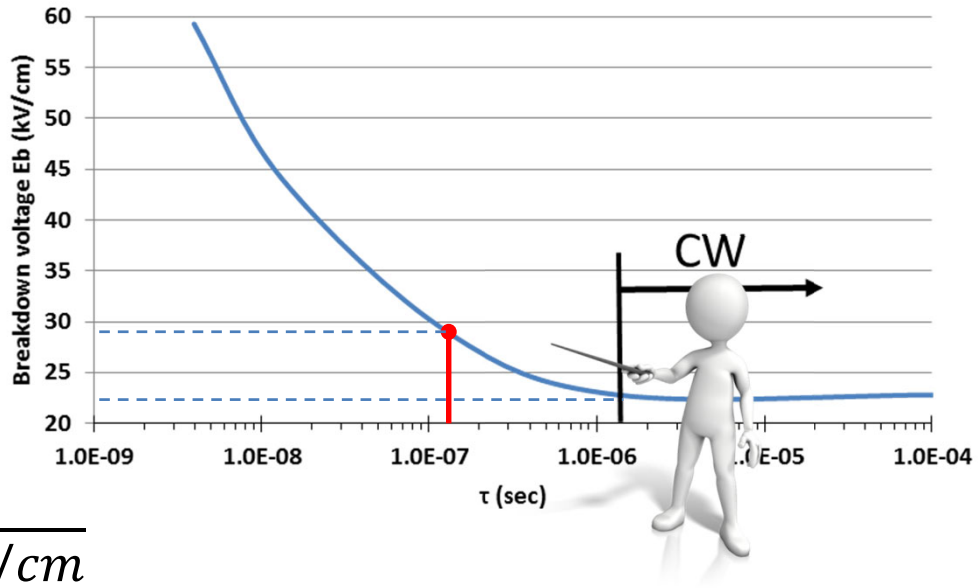
Pulse Width Voltage Rating Factor

$\tau_{p_{ATSC\ 3.0}} \approx .17\ to\ .18\ usec$

$\tau_{p_{ATSC\ 3.0}} < \tau_c$

Therefore a voltage rating factor can be used

The RF standard accepted breakdown voltage has been experimentally measured at 22.8 kV/cm



Voltage improvement factor $F_v = \dfrac{E_b}{22.8\ kV/cm}$

$E_{b_{ATSC\ 3.0}} \approx 27.5\ kV/cm$

Fv allows for a 20% increase over the standard accepted breakdown level

Pulse Width Voltage Rating Factor

As stations are combined, the total occupied bandwidth increases

This decreases the pulse width

$$\tau_p \approx \frac{1}{n * BW}$$

This increases the voltage to induce breakdown

$$B_T \uparrow \tau_p \downarrow E_b \uparrow$$

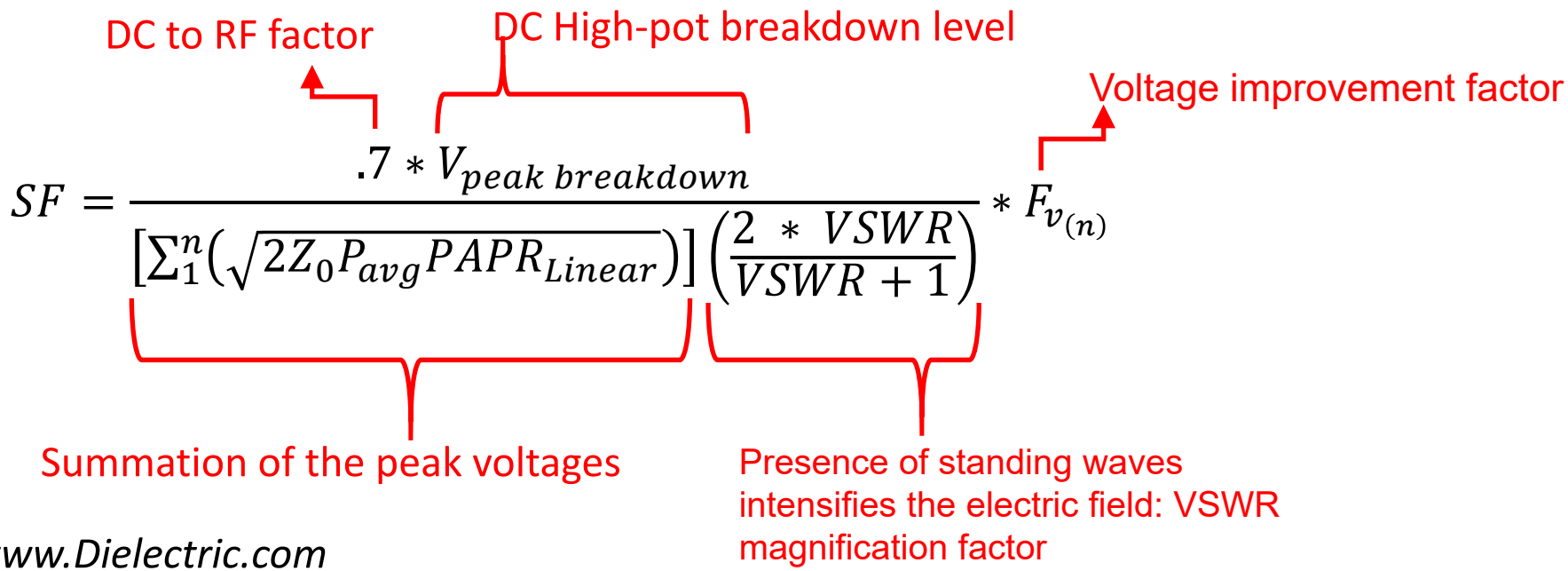
Voltage improvement factor

$$F_v = \frac{E_b}{22.8\ kV/cm}$$

# Combined Stations	Eb	Fv
1	27.47	1.20
2	30.18	1.32
3	32.3	1.42
4	34.08	1.49
5	35.64	1.56

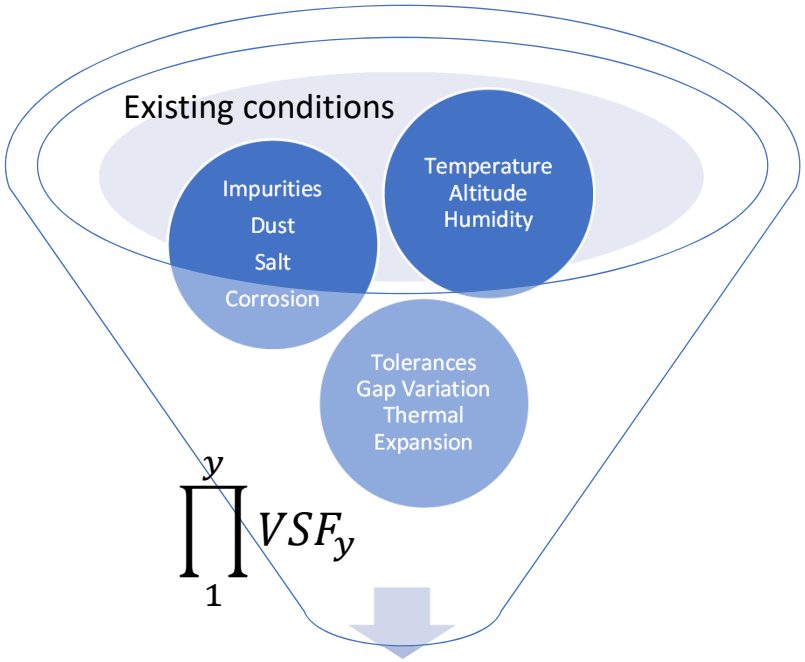
Defining the Voltage Safety Factor

When combining (n) stations the voltage safety factor is given by:



www.Dielectric.com

Recommended Voltage Safety Factor for Broadcast Antennas



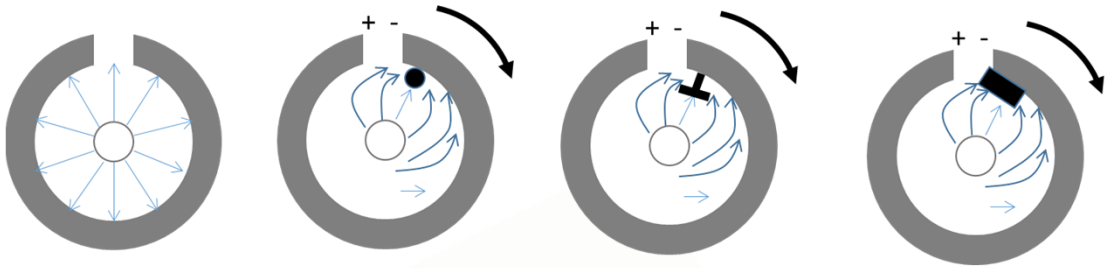
Composite VSF = 5:1

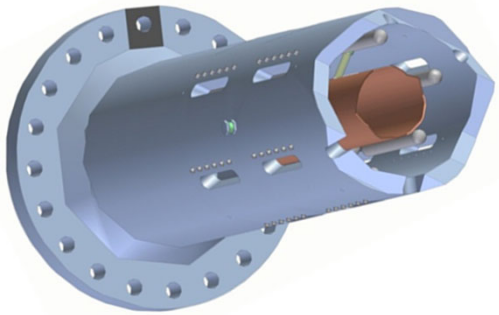
Dielectric criteria
VSF > 5:1

"-10 dBc IBOC at Combined Transmission Sites"- www.Dielectric.com

Improving Voltage Handling – Slotted Coaxial Antennas

Coupling a slotted coaxial antenna

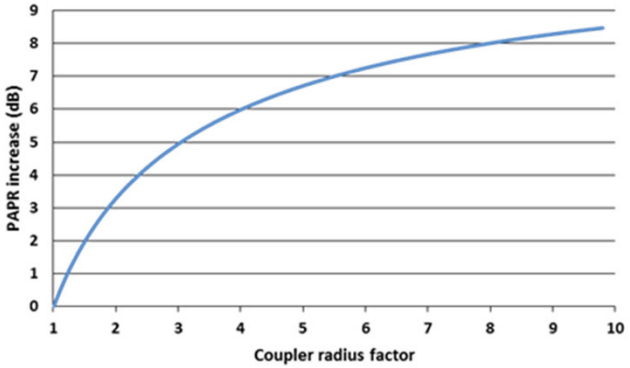


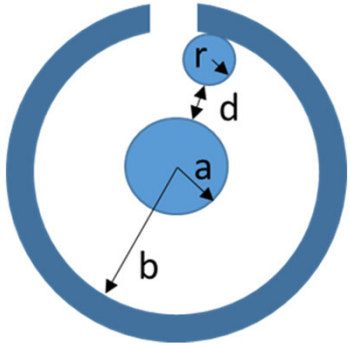


Improving Voltage Handling – Slotted Coaxial Antennas

The maximum PAPR is directly proportional to the internal radius of the coupling structure and the gap to the inner conductor

$$PAPR_{max} = \frac{\left(\frac{2a\left[ln\left(\frac{b}{a}\right)\right]}{r\left[ln\left(1+\frac{4d}{r}\right)\right]}\right)^2 F_V{}^2}{2n^2SF^2Z_0P_{avg}C_{vswr}{}^2}$$



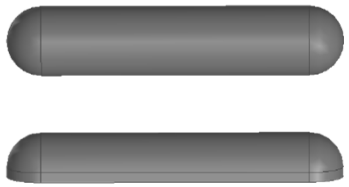


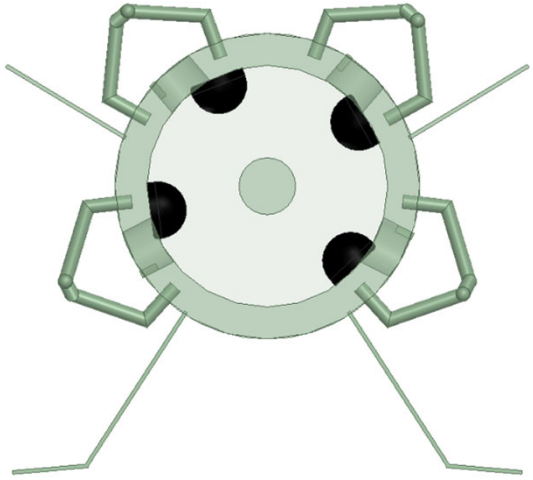
3 dB increase in PAPR can be applied as a result of doubling the coupling device radius in a slotted coaxial antenna

As long as the distance between the inner and coupler is not decreased…….

Improving Voltage Handling – Slotted Coaxial Antennas

"D" shape coupling





Allows large radiuses without decreasing the gap to the inner conductor

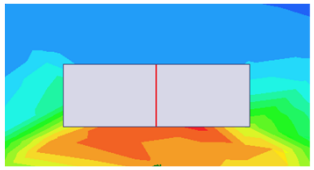
Substantially increases the voltage handling capability

ATSC 3.0 Ready → *It's all about geometry and eliminating sharp edges*

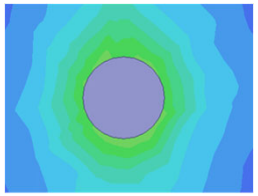
Improving Voltage Handling – PanelAntennas

TUM / APT Panel

- High voltage handling
  - Coaxial feed system
    - Eliminates sharp edges associated with microstrip



Microstrip

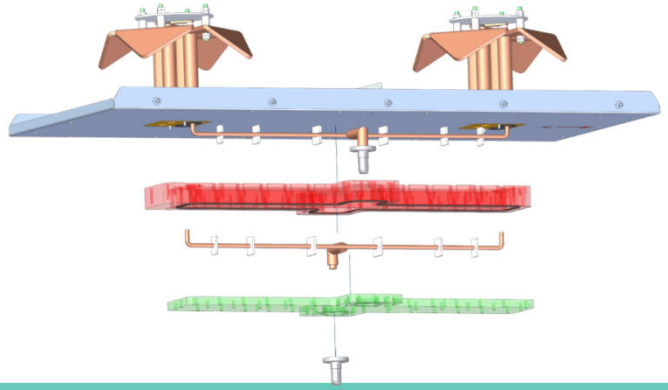


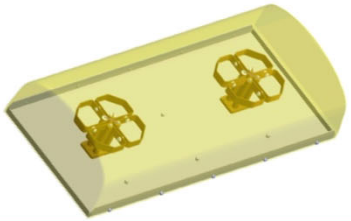
Coax

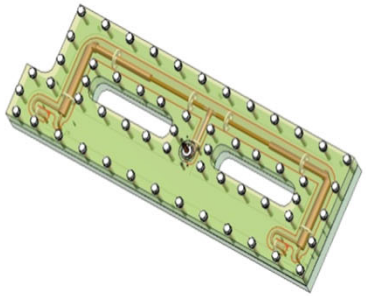
- Pressurized to dipole feed point
  - Increases voltage breakdown threshold

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

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







Improving Voltage Handling – Panel Antennas

- Maximum E field in microstrip is reduced by 35% with equivalent coax design
- 5 psi increases the voltage breakdown by 13%

By using a pressurized coaxial feed system in the panel, the effective voltage safety factor is increased 50%

$$SF \propto \frac{V_{peak}}{\sqrt{PAPR}}$$

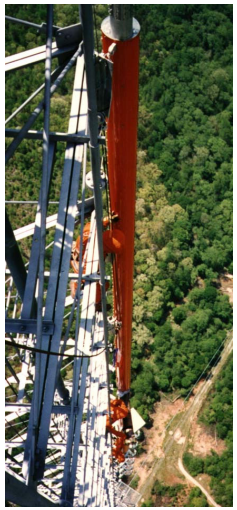
50% increase in voltage safety factor translates to being able to handle a 3.5dB increase in PAPR

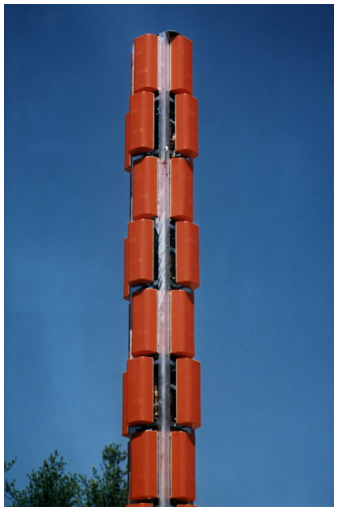
ATSC 3.0 Ready

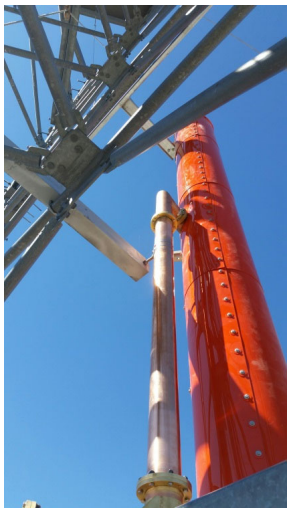
Wide Band Pylon Antenna

- Aimed at channel transitioning during repack
- Permanent standby post repack

Pylon Antenna + Panel Antenna = TFU-WB





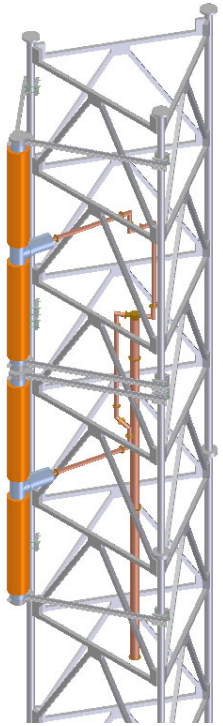


Key Features:

- Broadband : Channels 14-51
- Economical alternative to panel antennas
- 75% Less windload than panels
- 20 kW per 8 bay section
- Available in HPOL or EPOL
- W/G slot cavity technology
- 8, 16 and 24 bays
- Skull or broad cardioid azimuth pattern
- Quick delivery

Panel Performance in a Pylon Package

Wide Band Pylon Antenna

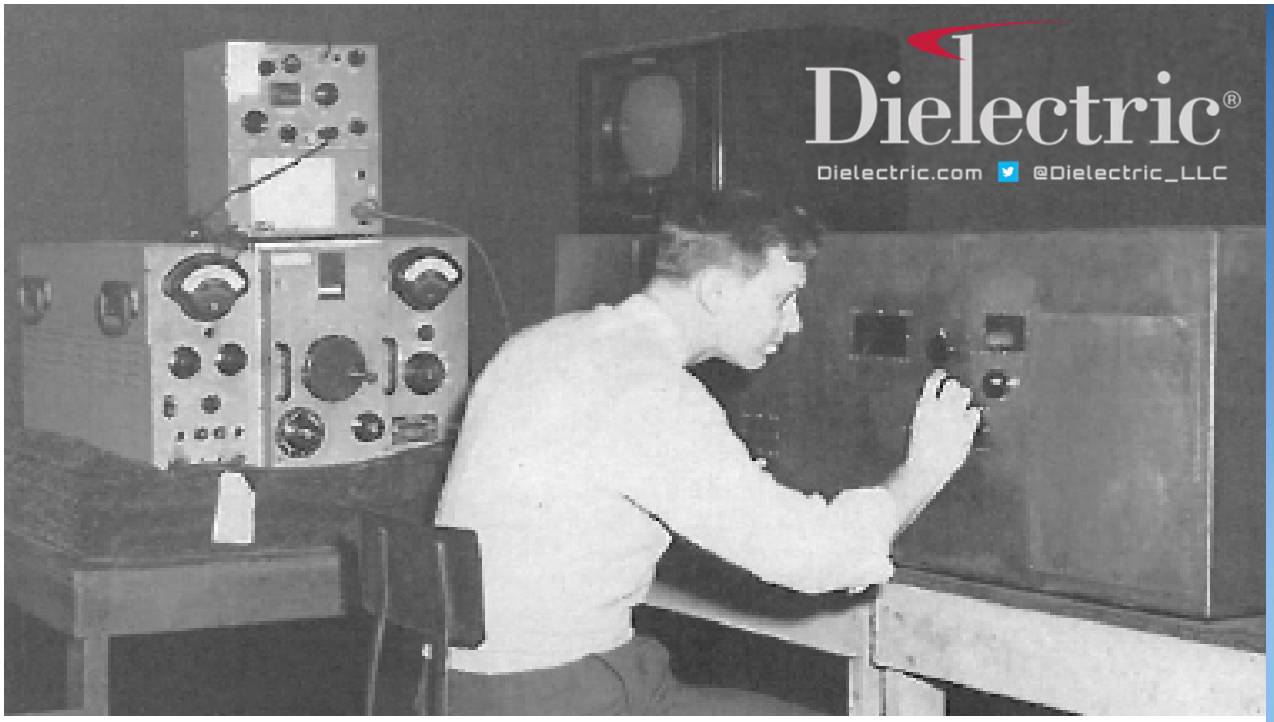


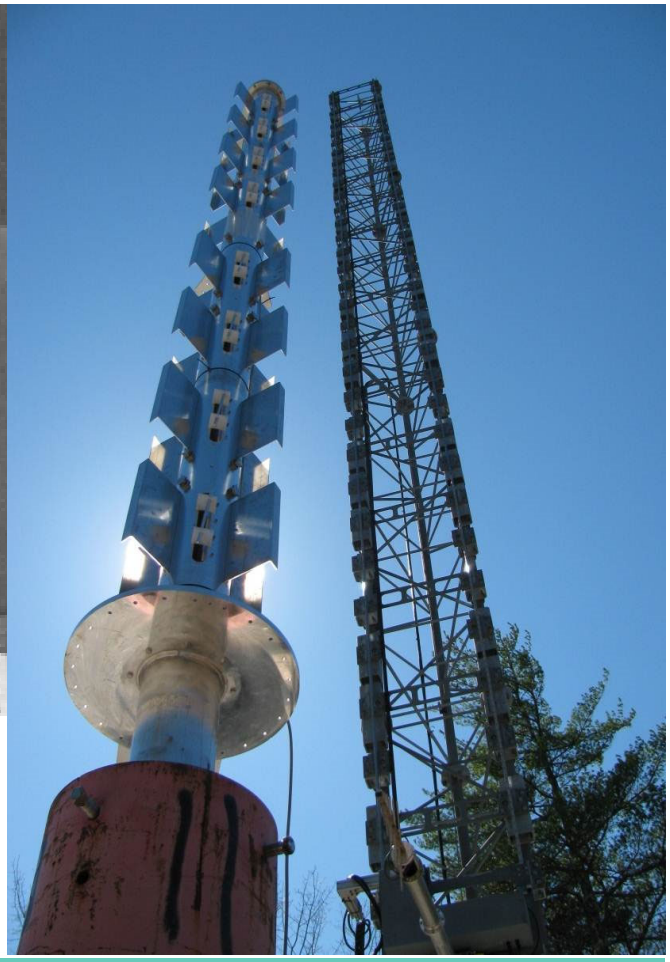
- Structure – I beam
- Basic building block – **W/G to coax transition**
  - High power / voltage capability
  - Over 35% bandwidth
- VPOL – Broadband floating dipole
  - Simple – No connections

ATSC 3.0 Ready

Conclusions

- ATSC 3.0 will place new limits on RF components due to voltage breakdown
- Multi-station operation makes these limits more severe
- The probability of co-phased voltage additions must be taken into account
- Appropriate design criteria must be applied
- The pulse widths of ATSC 3.0 are less then the critical pulse width allowing for a voltage improvement factor to be used in the voltage safety factor calculations
- When designing to meet the “ATSC 3.0 ready” criteria, geometry is key





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