TRANSFORMERS, SPLITTER-COMBINERS & HYBRIDS
IMPEDANCE TRANSFORMATION IS REQUIRED FOR SPLITTERS & COMBINERS
N-WAY ISOLATION TERMINATION (3-WAY EXAMPLE)

TERMINATION OF UNBALANCED (NOT IN-PHASE) MODES

STAR TERMINATION (3-WAY IS Y)         RING TERMINATION (3-WAY IS DELTA)
MANY TYPES OF TRANSFORMERS CAN BE USED

- Distributed or lumped
- Symmetric Z inverter or Asymmetric network
- Bandwidth requires more elements
- Ruthroff type transformers
- Conventional transformers
- Even wave-guide realizations!

\[ Z_0 = \sqrt{R_1 R_2} \ \Omega \]

\[ L = \frac{Z_0}{2\pi Freq} \]

\[ C = \frac{1}{2\pi Freq Z_0} \]

\[ R_1 > Z_1 > Z_2 > Z_3 > R_2 \]

\[ \frac{\lambda}{4} \ \text{LUMPED EQUIVALENT} \]

\[ \frac{\lambda}{4} \ \text{LINES} \]

\[ \frac{\lambda}{4} \ \text{QUASI-LOWPASS} \]

\[ \frac{\lambda}{4} \ \text{SHORT-STEP} \]

\[ \lambda/4 \ Z0 = \sqrt{R1*R2} \ \Omega \]

\[ L=Z0/(2\pi Freq) \]

\[ C=1/(2\pi Freq*Z0) \]
• Two-way splitter / combiner
• Quarter –wave line transformer
• Odd mode termination resistor
• Half octave bandwidth performance
LUMPED ELEMENT WILKINSON

- Two-way splitter / combiner
- Lumped LC quarter-wave equivalent
- LC impedance inverter transformer
- Odd mode termination resistor
- Half octave bandwidth performance

LUMPED LC WILKINSON SPLITTER/COMBINER
**STEPPED ¼ λ “MULTISECTION WILKINSON”**

- Half octave performance from single quarter-wave line transformer
- Nearly 2-octave performance from 3 stepped quarter-wave lines
- Comparison for 50Ω to 100Ω transformation (BW also depends on this)

\[ \frac{1}{4} \lambda \quad Z \quad \text{INVERTER} \]

\[ Z_0 = \sqrt{R_1 \times R_2} \]

\[ R_1 > Z_1 > Z_2 > Z_3 > R_2 \]

**STEPPED Z TRANSFORMER**
STEPPED $\frac{1}{4} \lambda$ TRANSFORMER CALCULATION

**ApelSoft Design Tools**

- **Lower Freq.** = 0.14 GHz
- **Upper Freq.** = 0.45 GHz
- **High Z Port** = 100 Ω
- **Low Z Port** = 50 Ω
- **Center Freq.** = 0.295 GHz
- **BW** = 105.08%

**Stepped Quarter-Wave Transformer Calculation**

- **SWR** = 1.18
- **Impedance Transformation** = 2
- **N** = 3 lines
- **Z(0)** = 50.00
- **Z(1)** = 57.84
- **Z(2)** = 70.71
- **Z(3)** = 86.45
- **Z(4)** = 100.00

DOWNLOAD FROM: [http://k5tra.net/](http://k5tra.net/)
• Two-way splitter / combiner
• Stepped quarter-wave transformer
• Odd mode termination resistors
• Two octave bandwidth performance
QUASI-LOWPASS TRANSFORMER and SPLITTER

- Two-way splitter / combiner
- Quasi-lowpass LC transformer
- Odd mode termination resistors
- 1.7 octave bandwidth performance
QUASI-LOWPASS TRANSFORMER CALCULATION

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TRANSMISSION LINE TRANSFORMER – ELEMENTS

1:1 NO NET COMMON MODE CURRENT AKA A CHOKE BALUN = SHORT (< λ/8) LINE

CONVENTIONAL TRANSFORMER

TRANSMISSION-LINE TRANSFORMER

1:1 SYMBOLIC

SHORT (< λ/8) LINE

NO NET COMMON MODE CURRENT AKA A CHOKE BALUN

PHYSICAL
• Transmission line ‘unit’ element
• Physically short lines (length < \( \lambda / 8 \))
• Analysis based on currents
• \( R_1 / R_2 = (I_2 / I_1)^2 = 4 \)
• Ferrite loading extends bandwidth (low end)
• 4-way (6 dB) splitter / combiner
• Four 4:1 transformers
• All ports same impedance
• Isolation shown with resistive ring
RUTHROFF 2-WAY SPLITTER/COMBINER

- Common port is half impedance
- Differential termination is 2 X
- A 4-port hybrid is formed by adding a balun interface to differential terminals
- Ferrite loading extends bandwidth
• Transmission line ‘unit’ elements
• Physically short lines (length < $\lambda / 8$)
• Analysis based on currents
• $R_1 / R_2 = (I_2 / I_1)^2 = 9$
• Ferrite loading extends bandwidth (low end)
GUANELLA (4:1) BALANCED TRANSFORMER

- Two ‘unit’ elements can be used to form a balanced 4:1 transformer
- Analysis based on currents
- \( \frac{R_1}{R_2} = \left( \frac{I_2}{I_1} \right)^2 = 4 \)
- Ferrite loading extends bandwidth (low end)
GUANELLA TRANSFORMER and CHOKE BALUN

- Pushpull PA match example
- Ferrite loaded ‘unit’ elements
- Guanella transformer from coax
- Choke balun (1:1) from coax
GUANELLA 2-WAY SPLITTER/COMBINER

- In-phase combiner from guanella structure
- Common port is half impedance
- Differential termination is also half
- A 4-port hybrid is formed by adding a balun interface to differential terminals
- Ferrite loading extends bandwidth
SUMMARY

- Combiners are splitters
- Transformers are basis of $0^\circ$ and $180^\circ$ combiners
- Bandwidth requires more elements
- Termination of undesired mode provides isolation
- Isolation port connection forms a $0^\circ/180^\circ$ hybrid (this is also known as a ‘magic T’)

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