TRANSFORMERS and 0°/180° SPLITTER-COMBINERS & HYBRIDS





N-WAY SPLITTERS & COMBINERS (3-WAY EXAMPLE)

IMPEDANCE TRANSFORMATION IS REQUIRED FOR SPLITTERS & COMBINERS



3-WAY EXAMPLE: N = 3



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

R1

- Conventional transformers
- Even wave-guide realizations!









BASIC WILKINSON

- Two-way splitter / combiner
- Quarter –wave line transformer
- Odd mode termination resistor
- Half octave bandwidth performance





WILKINSON SPLITTER/COMBINER

LUMPED ELEMENT WILKINSON

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



LC Z INVERTER



LUMPED LC WILKINSON SPLITTER/COMBINER



STEPPED $1\!\!\!/_4$ 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)







STEPPED $1\!\!\!/_4$ λ TRANSFORMER CALCULATION

🔜 Stepped QuarterWave Transformer				
ApelSoft Design Tools Lower Freq.= Upper Freq.= High Z Port = Low Z Port = Center Freq. = BW = N = 3	.14 GHz .45 GHz 100 Ω 50 Ω 295 GHz 05.08 % Calculate	STEPPED QUARTER-WAVE TRANSFORMER VSWR=1.118 Impedance Transformation = 2.8 N= 3 Lines 2(0) = 50.00 2(1) = 57.84 2(2) = 70.71 2(3) = 86.45 2(4) = 100.00		
About Stepped QuarterWave Lines				

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STEPPED $1\!\!\!/_4 \ \lambda$ "MULTISECTION WILKINSON"

R1

- Two-way splitter / combiner
- Stepped quarter-wave transformer
- Odd mode termination resistors
- Two octave bandwidth performance



STEPPED Z SPLITTER/COMBINER

STEPPED Z TRANSFORMER

R1 > Z1 > Z2 > Z3 > R2

Z2 Ω

λ/4

λ/4 Z1 Ω

λ/4 Z3 Ω

-•) R2

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QUASI-LOWPASS TRANSFORMER and SPLITTER

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



R1 > R2

LC IMPEDANCE TRANSFORMER



STEPPED Z SPLITTER/COMBINER

QUASI-LOWPASS TRANSFORMER CALCULATION

Pseudo Bano	dpass Matc	hing Ne	twork	
ApelSof Design To	t ols	Print	% Bandwidth = 105.08 % Lower Stopband Loss = .5115 dB Passband Ripple Loss = .0436 dB Passband Ripple VSWR = 1.222:1	
Lower Freq.=	.140	GHz	61.001	
Upper Freq.=	.45	GHz	···· QUASI-LOWPASS MATCH ···	
High Z Port =	100	Ω	R=50 Ohm L=22.728 Nano-Henry C=8 EAAS Biog Exced	
Low Z Port =	<mark>5</mark> 0	Ω	L= 8.5446 Pico-Parad L= 49.02 Nano-Henry C= 9.804 Pico-Farad	
O 2	O Yes No O		L=42.7229 Nano-Henry C=4.5456 Pico-Farad R=100 Ohm	
 ● 6 ○ 8 	 Quasi-LowPass Quasi-HiPass 			
O ₁₀	Calculate			
About Pseudo Bandpass				

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TRANSMISSION LINE TRANSFORMER – ELEMENTS



SYMBOLIC

PHYSICAL

K5TRA

RUTHROFF TRANSFORMER

- Transmission line 'unit' element
- Physically short lines (length < λ / 8)
- Analysis based on currents
- $R_1 / R_2 = (I_2 / I_1)^2 = 4$
- Ferrite loading extends bandwidth (low end)



RUTHROFF 4-WAY SPLITTER/COMBINER



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



RUTHROFF TYPE 9:1 TRANSFORMER

- Transmission line 'unit' elements
- Physically short lines (length < λ / 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
- $R_1 / R_2 = (I_2 / I_1)^2 = 4$
- Ferrite loading extends bandwidth (low end)



CONVENTIONAL 4:1 BALANCED TRANSFORMER

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GUANELLA 4:1 SYMBOLIC GUANELLA 4:1 PHYSICAL

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





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