Baluns, Balance, and Differential Signaling
For Signal Cancellation
Eliminate unwanted signals without filtering.

**Balanced Mixers**
Isolate ports and suppress even order spurious products

**Differential Signaling**
Eliminate common mode noise

**Differential Circuits**
Eliminate even harmonic products and IP2
Power Combining

**In Phase**

Maximize Power

- Increases power handling, linearity, or power generation
- Usually lowest loss for broadband applications

**Quadrature Phase**

Eliminate Reflections

- Increases linearity or power handling
- Improves Return Losses

**Out of Phase**

Eliminates Noise and Harmonics

- Increases linearity and power handling
- Eliminates common mode and even harmonics

**Mixed Phase**

Eliminates Input Signal for Harmonics

- Useful for gathering converted signals
- Used in mixers, doublers, quadruplers, etc.
What does a balun do?

A Balun Creates Equal and Opposite Signals

Mode Converter
A passive balun converts bidirectionally between differential and single ended signals.

Balun Transformer
Transforms between single ended and differential impedance according to the *impedance ratio*.

Isolation
High insertion loss *between* differential ports improves signal integrity.

Balance
Amplitude and phase balance quantify how close to ideal a real balun is.

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Common Mode Rejection

- Amplitude Balance
  - Good baluns provide ±2 dB
  - Marki baluns provide ±1 dB

- Phase Balance
  - Good baluns provide 15-20°
  - Marki baluns provide 5-10°

Common Mode Rejection
- Quantifies how much of a signal in the ‘common mode’ of a differential line will be rejected
Mixed Mode S-Parameters

Three ports with one mode each
Better for isolation and output impedance matching

S-Parameters

+ Differential
- Mode d
+ Common
+ Mode c

Mixed Mode S-Parameters
Two ports, differential port has two modes
Better for differential return loss, common mode rejection, and mode conversion loss

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Importance of Isolation

**Without Isolation**
Lack of isolation causes poor differential return loss

**With Isolation**
Signal integrity improved in Differential to Single ended conversion

Isolated Baluns Allow Complete Measurements

**Marki Isolation Baluns**

- Linear
- Nonlinear

**Signal Integrity**

**Two Port VNA with Post-Processing**
- Linear S-Parameters
- Step Response
- Impulse Response

**Four Port Dual Source VNA**
- Power Compression
- Harmonic Generation
- Two Tone Intermodulation
- Multi-tone Spurious
- Eye Diagrams
- Bit Error Ratio
- Error Vector Magnitude
- Total Harmonic Distortion
- Spectral Regrowth

**VNA**

In 0° 180° 0° Out
Top Three Mistakes

1. Length Matching
   - Any differential trace mismatch produces a linear phase walk
   - Traces, cables, connectors, and other interconnects

2. Trace Isolation
   - Neighboring channels can appear as aggressors
   - Far away channels will be more ‘common mode’ than nearby

3. Lack of Isolation
   - Low differential port isolation = high differential mode RL
   - Bad for differential to single ended conversions
Poll Questions
Balun Types: Transformer Based

**Flux Coupled Balun Transformer**
- All coupling provided by magnetic field
- Provides ground/DC isolation
- Massive bandwidth ratio
- Limited to low frequencies

**Transmission Line Balun**
- Float the ground to create differential output
- Has problematic half wave resonance

**Transmission Line Transformer Balun**
- Combines transmission line balun with magnetic material to eliminate resonance and extend low end
- Massive bandwidth ratio
- High frequency extends >10 GHz
- Typically lossy (>2 dB excess insertion loss)

**New 10 MHz-12 GHz smaller form factor SMT Balun**
Balun Types: Coupler Based

Coupled Lines Based Baluns
Coupled line structures with open/short ports can be designed as baluns
These baluns can be integrated and made in a planar structure
Hundreds of circuit structure options
Low frequency is limited to 1-2 GHz

New 2 GHz-20 GHz MMIC balun SMT MBAL-0220SM
Power Divider – Phase Shift

Differential signaling can be realized by separating the signal first and then applying a phase shift.

Can provide extended high frequency, extended low frequency, and high isolation.
Balun Types: Magic Tee/Hybrid Coupler

**Rat Race Coupler**
- Easy to Design and Fabricate
- Sub-octave bandwidth

**Asymmetric Tandem Coupler**
- Difficult to Design and Fabricate
- Can be very broadband
- Possible but not practical

**Waveguide Magic Tee**
- The original high isolation, low loss
- Limited bandwidth

180° Couplers Can be Used as Baluns, but also Have an Isolation/Sum Port.
Marki Mission Statement
Empower our customers to **design faster, simplify production, eliminate complexity**, and **shatter performance barriers**
Amplifier Biasing Made Easy
Jacob Trevithick and Rob Maurer | April 16, 2020

A Brief Guide to Mixer Spurs
Harley Berman and Christopher Marki | April 30, 2020

Register for our next webinars via links in upcoming email.