BALUNS AND FERRITES

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- REASONS FOR USING A BALUN

- TYPES OF BALUNS

- CHECK YOUR BALUN WITH AN SWR ANALYZER

- RESULTS

- MEASURING THE IMPEDANCE OF A NUMBER OF FERRITES

- IMPEDANCE MEASUREMENT RESULTS

- USING FERRITES ON A FEEDER AND HOUSE CONDUCTORS
REASONS FOR USING A BALUN?

BALUN = BALanced to Unbalanced - It’s a transformer

Used to feed a balanced load, Ex: dipole

Decreases feeder radiation

The feed line becomes independent of the antenna:
  We can change its length … move it around

Without causing SWR change.
With a balun, radiation picked up by the feeder from each side of the dipole cancels at the feeder. This will decrease feedline current.

The feedline’s outer shield becomes "floating" and independent of the antenna.

A non symmetrical antenna Ex: Windom… Will require the use of a current balun

The feedline should run away from the dipole at right angle. The dipole should be parallel to the ground.
BALUN TYPES

VOLTAGE

- TRANSFORMER WITH WINDINGS GIVING A BALANCED OUTPUT

- IN-OUT IMPEDANCES ARE DETERMINED BY THE TURNS RATIO. A WIDE RANGE OF RATIOS IS POSSIBLE.

- OPERATES OVER A SOMEWHAT LIMITED BANDWIDTH (100 TO 1)

CURRENT

- USES TRANSMISSION LINES WOUND ON A CORE

- MAY USE A COAXIAL CABLE OR A PARALLEL WIRE LINE WITH OR WITHOUT FERRITES.

- COMMON IMPEDANCE RATIOS: 1:1 AND 4:1

- OPERATE OVER A MUCH WIDER BAND OF FREQUENCIES
1:1 VOLTAGE BALUN

- 3 IDENTICAL WINDINGS
- GENERALLY 50 : 50 ohms

Measured Inductance: ~13.4 uH

We should have ~ the same inductance at the input and at the output.

~29.2 µH

~3.3 µH

SO-239 Mesured Inductance ~13.4 uH
VOLTAGE BALUN 4:1

- 2 IDENTICAL WINDINGS

The measured inductance at the output is ~4X the input inductance as a result of inductance coupling.
TESTING A BALUN WITH AN SWR ANALYZER

These tests verify:
- Winding inductance
- Winding distributed capacitance
- The quality of the insulation between conductors

Load resistance:
- 50 ohms (balun 1:1)
- OR: 200 ohms (balun 4:1)

The minimum SWR should be below 1.5 in the middle of the balun’s frequency range.
Indicates low losses
CONNECTING THE LOAD RESISTANCE 50 Ω HERE

IT IS IMPORTANT TO USE SHORT and LARGE CONDUCTORS
MEASURED SWR WITH A 50 ohms LOAD

BALUN 1:1
UNADILLA
W2AU

Min SWR ~ 1.1
IMPEDANCE vs Frequency with a 50 ohm load

BALUN 1:1
UNADILLA
W2AU

20 Sep 2003 21:30:28

CH1 S1: 400 mU FS 1: 44.363 Ω 16.041 Ω 1.4183 μH

1.800 000 MHz

SCALE
400 mUnits FS 1

2: 48.547 Ω 9.668 Ω 3.5 MHz
3: 50.387 Ω 7.0801 Ω 7 MHz
4: 55.604 Ω 2.8164 Ω 21 MHz
5: 58.953 Ω 2.1828 Ω 30 MHz

50 Ω

freq
reactance
resistance

START 1.000 000 MHz

STOP 50.000 000 MHz
MEASURED SWR WITH A 50 ohms LOAD

Min SWR ~ 1.3

KENPRO KA50

1.8 MHz

24 Oct 2003 17:28:28

VE2AZX
OPEN CIRCUIT TESTS WITH THE SWR ANALYZER

These tests verify:
- Winding inductance
- Winding distributed capacitance
- Quality of the winding insulation

The minimum SWR should be below 1.1 in the middle of the balun’s frequency range

Indicates low losses
Always 50Ω whatever the Z ratio

OPEN CIRCUIT TESTS WITH THE SWR ANALYZER

Measured SWR

200 m /div

SCALE

CH1 S11 SWR 200 m / REF 1

Prm

Cor

PRm

23 Sep 2003 11:17:02

1: 1.3601

1.8 MHz

2: 1.1036

3: 1.0999

3.5 MHz

7.562 MHz

4: 1.3392

14 MHz

5: 2.1619

30 MHz

50 ohms

Balun 1:1 or 4:1

Unadilla W2AU

Coax Tee

Ve2azx
OPEN CIRCUIT TESTS WITH A VNA

Winding Inductance at 1.8 MHz

MARKER 1
1.8 MHz

BALUN 1:1
UNADILLA
W2AU

Complex Impedance vs Frequency

SHOWS open circuit between around 5 MHz
Winding inductance resonates with its distributed capacitance
QUESTION: How many independent conductors at RF frequencies do we have in a coaxial cable? 1, 2, 3 or 4 conductors?

There are 3 independent conductors:
- The center conductor
- The inner surface of the shield
- The outer surface of the shield

Note that the RF current that flows on the outer surface of the shield is independent of the inner shield current.

This is so because at RF frequencies, the current penetrates very little inside the conductors. This is called SKIN EFFECT.

Note also that the **SWR only applies to the inner shield currents (and center cond).** The SWR is basically independent of the outer shield currents.
SHIELDED LOAD

With a shielded load, the current stays inside the coax.

There is no current on the outside of the coax, whatever the load (open, short or terminated).

Adding ferrites on the outside of the coax has NO effect, since no current flows on the outside of the shield.
A dipole is an unshielded load

An unshielded load causes current to flow on the outer surface of the coax, since it picks up radiated currents. In fact it is part of the antenna. The radiation pattern changes.

Note that the inner conductor and inner shield currents are equal.

Current flowing on the outer shield modify the basic dipole by adding a third conductor and will generally change its impedance.
UNSHIELDED LOAD

Adding a ferrite core adds resistance (at RF) only on the OUTSIDE of the coax. The ferrite core reduces the shield currents

The ferrite core has NO effect on the internal coax currents, besides restoring the dipole impedance and normal radiation pattern. Note that the inner conductor and inner shield currents are equal.

Shield currents encounter a high impedance and are attenuated.

A dipole is an unshielded load

Most antennas tend to "spray" RF on their feeding coax too.
How much Resistance is Required when Feeding a dipole with a coaxial cable?

A coax cable feeds a dipole at its center, or with an offset.

Equivalent Circuit
The coax is part of the antenna

λ/4 open stub
Is the WORST length – since it reflects a short

For simulation purposes, the TX (source) is very small and floating.
Feeding a dipole with a coaxial cable

To decrease the stub current:
A current balun is inserted.
It adds a series impedance on the outside of the coax.

Balun Equivalent Circuit

What is the minimum value of Impedance that I can have …

That will have little effect on the gain and impedance of the dipole antenna?
CURRENT BALUNS

Feeding a dipole with a coaxial cable

If feeding at the center (50%): \( R > 1000 \) ohms
If feeding at 33% from end: \( R > 10000 \) ohms

It’s easier to feed at the center
The RF resistance caused by the ferrite impedance should be high (> 1000 ohms)
- To minimize the RF transmitted and received by the feeder.
- Minimize temperature increase in the ferrite at high power by using Z ferrite > 5000 ohms.
FERRITE IMPEDANCE

DEPENDS ON...
- MATERIAL
- LENGTH
- VOLUME OF MATERIAL
- VARIES WITH FREQUENCY

- TO CALCULATE THE IMPEDANCE Z: (approx.)

IMPEDEANCE OF ONE TURN FOR ONE FERRITE
multiplied by...
NUMBER OF FERRITES
multiplied by ...
(NUMBER OF-turns) squared

- NOTE: 1 TURN = FERRITE ON A STRAIGHT WIRE
- FERRITES VS IRON POWDER ... TWO DIFFERENT MATERIALS

- **FERRITE**: HAS A HIGH PERMEABILITY (10 to 15000)
  GIVING A HIGH INDUCTANCE FOR A SMALL NUMBER OF TURNS

  BUT THE INDUCTANCE OBTAINED IS NOT STABLE AND Q FACTOR IS LOW

  OK FOR TRANSFORMERS AND BALUNS

- **IRON POWDER**: LOWER PERMEABILITY ... LOWER INDUCTANCE,
  GIVES A STABLE, HIGH Q INDUCTANCE (EX.: VFO, FILTERS, TUNERS)

EXAMPLE: **AMIDON** -> FERRITES and IRON POWDER

PART # - EXAMPLE: FT240-43

  FT: FERRITE
  240: External diam in inches X 100 (here 2.4 in.)
  43: TYPE OF FERRITE, PERMEABILITY = 850
IMPEDEANCE MEASUREMENTS

FREQUENCY RESPONSE MODE

- Does NOT allow measuring separately the Resistive and Inductive components
- Ease of sweeping the frequency
- Reference level = 0 dB = short in place of ferrite

RS and RL are generally 50 ohms

To calculate Zx from attenuation readings in + dB’s:
(assumes that Zx is resistive)

\[ Z_x = (R_L + R_S) \cdot \left(10^{\frac{\text{dB}}{20}} - 1\right) \]
CHECK YOUR FERRITES WITH YOUR SWR ANALYZER
FROM SWR MEASUREMENTS

Coax cable shield
Allows for many turns.

Ferrite under test

Insulating Sleeve

Male UHF Connector

SWR ANALYZER

Conductor, Cu or Al

The ferrite is in parallel with the 50 ohms (1%) termination
FERRITE IMPEDANCE VS MEASURED SWR

FERRITE IMPEDANCE PURELY INDUCTIVE

FERRITE IMPEDANCE PURELY RESISTIVE
MEASUREMENT OF FERRITE IMPEDANCE

USING AN SWR ANALYZER OR A VECTOR NETWORK ANALYZER

Allow measuring separately the Resistive and Inductive Components

SWR ANALYZER
With IMPEDANCE CAPABILITY
- OR -
VECTOR NETWORK ANALYZER
IMPEDANCE MEASUREMENTS

CLAMP ON FERRITE FOR RG-8

YIELDS 80 ohms at 10 MHz for 1 turn
IMPEDEANCE MEASUREMENTS

- ABOVE 20 MHz THE Q FACTOR < 1
  THE IMPEDANCE BECOMES RESISTIVE
IMPEDANCE MEASUREMENTS

- THE INDUCTANCE DECREASES AS THE FREQUENCY IS INCREASED

- THE INDUCTANCE DISAPPEARS WHEN F > 100 MHz
IMPEDANCE MEASUREMENTS

- THIS IMPEDANCE CURVE IS SIMILAR TO THE PREVIOUS CORE
IMPEDANCE MEASUREMENTS

- THIS IMPEDANCE CURVE IS SIMILAR TO THE PREVIOUS CORE
- GIVES ~ 10% IMPEDANCE OF PREVIOUS CORES (8 ohms at 10 MHz for 1 turn)
- COVERS MUCH WIDER FREQUENCY RANGE
- SHOULD USE MANY TURNS: 10 TURNS GIVE 800 ohms AT 10 MHz
IMPEDEANCE MEASUREMENTS

RECTANGULAR CLAMP-ON FERRITE

- THE INDUCTANCE DISAPPEARS ABOVE 6 MHz
IMPEDANCE MEASUREMENTS

STACKED RECTANGULAR CLAMP-ON FERRITE

4 TURNS WILL YIELD ~ 800 ohms
TESTING A FERRITE BEAD

FERRITE BEAD APPROX. 0.1 PO. LONG.

Ferrite bead Impedance

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>Impedance (Ω)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 MHz</td>
<td>28</td>
</tr>
<tr>
<td>10 MHz</td>
<td>32</td>
</tr>
<tr>
<td>100 MHz</td>
<td>36</td>
</tr>
<tr>
<td>1000 MHz</td>
<td>Ω</td>
</tr>
</tbody>
</table>
IMPEDEANCE MEASUREMENTS  
(Done in frequency response mode)
IMPEDANCE MEASUREMENTS (Done in frequency response mode)

6 toroids  6 turns

VE2AZX 41
IMPEDANCE MEASUREMENTS

(Done in frequency response mode)

2 toroids
1 turn

Impedance increase caused by lead inductance
IMPEDANCE MEASUREMENTS (Done in frequency response mode)

2 toroids  5 turns
IMPEDANCE MEASUREMENTS

(Done in frequency response mode)

Coax with 25, #43 beads

![Coaxial cable image]

![Graph showing impedance measurements over frequency range]
IMPEDANCE MEASUREMENTS

#14 Wire with 50 beads #73

Excellent at HF
CURRENT BALUN GIVING A 4:1 IMPEDANCE RATIO

- USES 2 PARALLEL WIRES INSTEAD OF A COAX
- MAKES A COMPACT TRANSMISSION LINE

NOTE: THIS 4:1 CURRENT BALUN IS SUPERIOR TO THE 4:1 VOLTAGE BALUN

From: W1CG
CURRENT BALUN GIVING A 4:1 IMPEDANCE RATIO

Parallel wires make up a transmission line

COAX SIDE 50 Ω

BALANCED SIDE 200 Ω
CURRENT MEASUREMENTS

MEASURE CURRENT AT A, B, C.

CURRENTS AT B AND C SHOULD BE < 10% THE CURRENT AT POINT A

YOU CAN MAKE YOUR OWN CURRENT METER

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FERRITES MAY BE USED WITH A VOLTAGE BALUN

- Measure the shield current

- Put the ferrites at points of maximum current

- Will further isolate the feeder from the antenna

- Will stabilize the antenna impedance

- May reduce the noise pick-up by the feeder

- Use ferrites at every quarter wavelength or at current maxima
CURRENT BALUN MADE UP OF COAX CABLE

- COIL DIAMETER 6 - 12 in. / 5 - 10 TURNS
USING A BALUN ON A VERTICAL ANTENNA

The coax should not be part of the antenna!

Do not connect to an earth ground at this point, if only a few radials are used.

Earth ground is OK here.
USING FERRITES ON THE FEEDER OF VERTICAL YAGI

PREVENT INTERACTION BETWEEN COAX + MAST WITH YAGI

Ref: QEX Sept – Oct. 2006

#43 FERRITE SLEEVES HELD WITH TAPE OR TIE WRAPS

~ λ/2

FIBERGLASS INSULATED MAST
- USING A BALUN UNDER HIGH SWR:

- VERIFY HEATING OF THE CORE
- DECREASE THE POWER
- USE MIX 73 ($\mu=2500$) OR 31 ($\mu=1500$)  
  FOR HIGH POWER USE MIX 43 ($\mu=850$) See Ref. 4
- BALUN LOSSES MAY / WILL INCREASE UNDER HIGH SWR
- VOLTAGE BALUN NOT RECOMMENDED IF SWR > 5:1 UNLESS
  DESIGNED FOR HIGH SWR

- BALUNS NORMALLY PROVIDE A VERY LOW ATTENUATION,
  NORMLLY < 0.3 dB ... WHEN THE LOAD IS MATCHED
- A QUARTER WAVELENGTH (OR ODD MULTIPLES) SHORTED AT THE BOTTOM END WILL GENERATE A HIGH IMPEDANCE AT THE DIPOLE AND MINIMIZE COMMON MODE CURRENTS ON THE COAX OUTER SHIELD.

- USE A VELOCITY FACTOR OF 95% IN CALCULATING THE COAX LENGTH

- THIS TECHNIQUE WILL NOT WORK AT FREQUENCIES WHERE THE FEEDER IS A MULTIPLE OF $\lambda/2$

GROUNDING POINT
(Building Entrance Common Plate, Radio ground point, etc.)

Add the length of the grounding wires when computing the quarter lambda.
CANNOT LOCATE BALUN AT DIPOLE FEEDPOINT: TOO HEAVY!

- SETTING THE FERRITES A HALF WAVELENGTH (OR MULTIPLES) FROM THE DIPOLE WILL GENERATE A HIGH IMPEDANCE AT THE DIPOLE AND MINIMIZE COMMON MODE CURRENTS ON THE COAX OUTER SHIELD.

- THE FERRITE IMPEDANCE SHOULD BE 500Ω OR MORE. (CHECK FOR HEATING)

- THE LENGTH BETWEEN THE TX AND THE FERRITES IS NON CRITICAL

- USE A VELOCITY FACTOR OF 95% IN CALCULATING THE COAX LENGTH

GROUNDING POINT (Building Entrance Common Plate, Radio ground point, etc.)

These lengths are not critical.
FERRITES ARE USED EVERYWHERE
THINGS TO REMEMBER...

- **VOLTAGE BALUN**S cover a very wide range of impedances

- Set equal voltages at the output

- Generally provide no protection against currents flowing on coax exterior

- May be combined with a current balun

- **CURRENT BALUN**S create an impedance on the outside of the coax (or any conductor)

- Also called common mode chokes

- Decrease coax radiation and pick-up

- Stabilize the antenna impedance

- Generally 50:50 ohms ratio (also 50:200 possible)
THINGS TO REMEMBER...

- DECREASE COAX RADIATION ON TRANSMIT
- AND PICK-UP ON RECEIVE

Extract from Ref. 4:

The most common reasons for using common-mode chokes are:

(1) to reduce the fraction of the RF power that is fed to your antenna from your transmitter, but then is conducted back to your shack via common-mode current on your feedline, causing RFI trouble in the shack or elsewhere in your house;

(2) to keep the transmitted RF power that 60-Hz power, telephone, TV, and other cables in the field of your antenna pick up, from bothering susceptible devices connected to these cables in your own and neighbors’ houses.
Extract from Ref. 4:

(3) to keep the RF noise that all the electronic devices in your house generate, from being conducted via 60-Hz power, telephone and other cables to the outer shield of your radio, and from there along your feedline(s) to your antenna(s), in common-mode.
REFERENCES

1- General informations on baluns – Index of good articles:
   http://www.nonstopsystems.com/radio/frank_radio_baluns.htm

2- Transmission Line Transformers, by Jerry Sevick W2FMI

3- Cost effective ferrite chokes and baluns

4- Reducing interferences inside the house: Chuck Counselman W1HIS.
   http://www.yccc.org/Articles/W1HIS/CommonModeChokesW1HIS2006Apr06.pdf

5- FERRITE SUPPLIERS
   Digikey http://www.digikey.com
   Fair-Rite http://www.fair-rite.com
   Aimdon http://www.amidoncorp.com
   The Toroid King http://www.kitsandparts.com/index.php