Analysis of Passive Balun with Even Mode Loss

S. Weinreb June 16, 2002

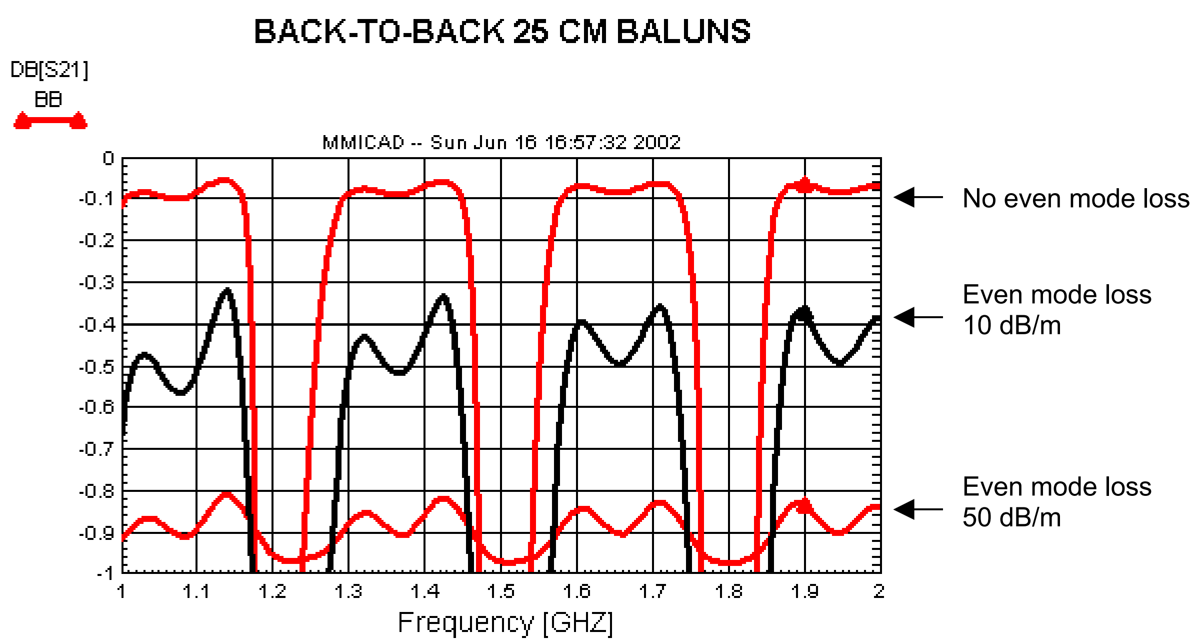
The 1 to 2 GHz transmission curves shown below are for back-to-back 25cm baluns with even mode impedance, Ze, equal to 10 times the odd mode impedance, Zo. The top curve is for no loss in the even mode and the bottom curve is for 50 dB/m loss in the even mode (12.5 dB within the 25cm length of the balun). Increasing the loss beyond 50 dB/m does not further increase the transmission loss.

The one-way loss in the case of high even mode loss is 1/2 of the back to back loss, 0.45 dB, or a loss of 10% which is equal to the ratio of odd mode to even mode impedance. If this loss was at a temperature of 70K it would contribute 7K plus 10% of the noise temperature without the loss, a total increase of approximately 10K.

The ratio of odd to even mode impedance is limited by dimensions. The odd mode impedance must be 100 ohms to match the 200 ohm feed impedance and the even mode impedance is approximately twice the coaxial line impedance considering the balun as the inner conductor of a coaxial line with the balun enclosure as the outer conductor. Thus the even mode impedance is 2 * 138 log (D/d) where d and D are these outer and inner conductor diameters. To achieve a ratio of 10 an even mode impedance of 1000 ohms is required which means D/d must be 4200. Thus if the balun conductors are .01" wide a box that is 42" in diameter is required. More reasonable values are D=1", D/d=100, Ze=552, and a noise temperature contribution of 20K. Spiral winding of the balun strip or introduction of high permeability material may help.

These results were computed using the coupled transmission line model, CLINP, in the MMICAD software. The model is based upon G.I. Zyman and A. K. Johnson, *Coupled Transmission Line Networks in an Inhomogeneous Dielectric Medium*, MTT-17, No. 10, October, 1969, pp, 753-759. The circuit description file is attached.

The spacing between frequency resonances in the lossless balun depends upon its length which is determined by the desired 0.5 GHz lower frequency of operation.



```
!BALUN STUDY
!JUNE 16, 2002  BALUN3.CKT

!
GLOBAL
 DIM FREQ=1e+009 RES=1 COND=0.001
CAP=1e-015  &
  IND=1e-012 LNG=1e-002 TIME=1e-012
 MSUB ER=12.2 H=50 T=1 RHO=1.2 TAND=0.001
 CPWSUB ER=11.5   H=50  T=1  RHO=1.2
TAND=.001 HC=250

MODE FREQ NOiSE

VAR
ATE=0
!
CKT
CLINP 1 2 3 4 ZE=250 ZO=25 L=25 KE=1 KO=10
AE=ATE AO=0.1
DEF4P 1 2 3 4 CPLINE

CPLINE 1 2 3 4
RES 2 0 R=0.01
DEF4P 1 2 3 4   BALUN

CPLINE 1 2 3 4
RES 2 0 R=.01
BALUN  5 6  3 4
RES 6 0 R=.01
DEF2P  1 5 BB

CPLINE 1 2 3 4
RES 2 0 R=.01
CPLINE  5 6  4 3
RES 6 0 R=.01
DEF2P  1 5 BXB

CPLINE 1 2 3 4
RES 2 0 R=.01
TLIN4 3 4  5 6 Z=50 E=90 F=0.133 !LENGTH 7" IN
EPS=10
TLIN4 5 6 7 8 Z=50 E=90 F=0.133 !2ND LINE
CPLINE  7 8   9 10
RES 10 0 R=.01
DEF2P  1 9  BLLB

CPLINE 1 2 3 4
RES 2 0 R=.01
TLIN4 3 4  5 6 Z=50 E=90 F=0.133 !LENGTH 7" IN
EPS=10
TLIN4 5 6 7 8 Z=50 E=90 F=0.133 !2ND LINE
CPLINE  8 7    9 10
RES 10 0 R=.01
DEF2P  1 9  BLXLB

TERM

PROC
A= BALUN ANG[S31]
B=BALUN ANG[S41]
DIF=(A-B)
!
FREQ
SWEEP  0  4 .005

MARKER
STEP .1 .5   1.9


OUT
BALUN DB[S31] GR1
BALUN DB[S41] GR1
BALUN ANG[S31] GR1 R
OUTVAR RE[DIF]  GR1 R
BALUN DB[S11] GR1
BALUN DB[S31] GR2
!BALUN ANG[S31] GR2 R
OUTVAR RE[DIF]  GR2 R
BALUN DB[S41] GR2
BALUN DB[S11] GR2
BALUN SMI[S33] SM1
BALUN SMI[S44] SM1
!BIASD13 SMI[S11] SMI
!BB DB[S11] GR3
BB DB[S21] GR3
!BXB DB[S11] GR3
!BXB DB[S21] GR3
BLLB DB[S11] GR4
BLLB DB[S21] GR4
BLXLB DB[S11] GR4
BLXLB DB[S21] GR4
!
GRID
  GR1 0 12 2  -40  0  5 R -360 360 45
  GR2 0 4 .50 -40 0 5 R -200 200 50
    GR3 1 2 .1  -1  0 .1
     GR4 0 1 .1  -40 10  5

LABEL
BACK-TO-BACK 25 CM BALUNS
```