Adding an Input Balun in AAA-1 in Dipole Mode to Reduce 2nd Order IMD Distortions when Asymmetric Signal Source (antenna) is Used

When using large loops as dipole arms with AAA-1 active antenna amplifier or totally asymmetric electric antennas such as ground plane (GP), some 2-nd order IMD distortion might occur due to asymmetric signal source combined with the strong signals. The vertical dipole is partially asymmetric antenna – the lower arm has higher capacitance to ground than the upper one. Also nearby conducting objects can influence the dipole symmetry additionally. The dipole amplifier itself has very high OIP2 to symmetric signal sources – in order of +90 dBm but it can not be accomplished since the signals in the two arms of the amplifier might have different amplitudes due to input asymmetry.

How to localize 2nd order IMD distortions?

The easiest way is to check the 2nd order products (F1+F2 and 2F) which might exist as a spurious signals in 14.400 – 15.200 MHz band as result of action of strong broadcasting stations on 41 m band with frequencies 7.200-7.600 MHz. Night time is most suitable for this experiment. The RX must have good dynamic range and a good input band pass filter which must stop the fundamental signals at 41 m band to avoid generation of 2nd order products in the RX itself. All candidate spurious frequencies in 14-15MHz zone should be multiples of 5 KHz since this is the distance between broadcasting frequencies. If there are 2nd order spurious signals they will appear as a weak carriers usually with strong fading. Switch the AAA-1 to loop mode - if the carriers disappear they are probably spurious signals generated by the dipole amplifier (the loop mode has very high 2nd order dynamic range and it is not likely that there will be any distortions except for exceptionally strong signals). Another check frequency is 25 m BC band (fundamental 11.8 – 12.2 MHz and 2nd order 23.6- 24.4 MHz). Also MW BC band might give spurious frequencies at 1.8 MHz amateur band.

Reducing the spurious signals

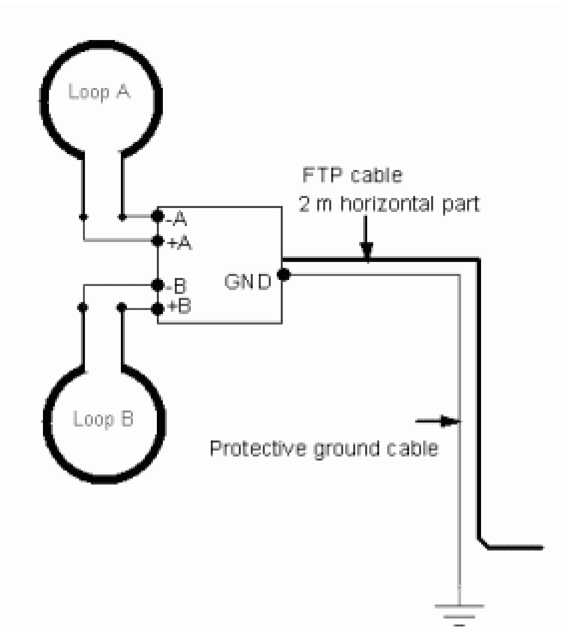

Fig.1 *Loops are used as vertical dipole arms. To improve the symmetry, the FTP and protection ground cables should run horizontally at least 1 - 2 m from the loops. Also exchanging terminals of Loop A and B might give better symmetry. These measures refers only for dipole mode and do not influence the loop modes.*

In the case of 2nd order IMD distortions the first measures which have to be taken are shown on ***Fig.1***. Usually these measures are sufficient instead you are using very large loops as dipole arms, separate dipole with large arms or asymmetric GP antenna.

Adding input balun

In the case of bigger antennas and strong signals a balun should be connected to the amplifier input as shown on ***Fig.2*** . It will force the two arms of the balanced amplifier to see always symmetric signal source. In this way the amplifier dynamic range will not depend from the nature of the signal source. This additional balun must have high inductance not to impair the amplifier performance. The balun size and the loss of the core are not critical - only the inductance must be high - 5 to 20 mH.

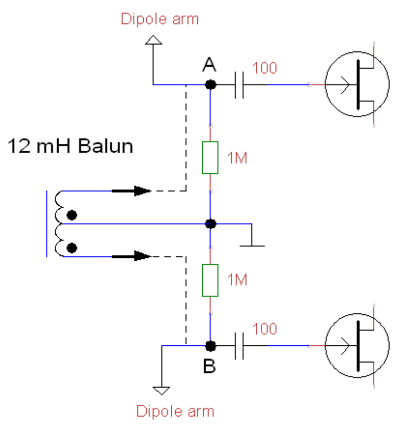

Fig.2 *The input balun ensures equal voltages referred to the amplifier common point irrespective of capacitive imbalance of dipole arms.*

Side effects

1. With balun the total gain of the dipole amplifier is reduced with 1 to 3 dB from that given in the specifications. This is not so important since this balun should be used when large dipole arms or GP are used. The reason is the parasitic capacitance of the balun. The smaller the number of turns the smaller is this capacitance.

2. The lower cut-off frequency response of the amplifier is shifted to higher frequencies due to the shunt action of the inductance of the balun.

The balun inductance combined with the input antenna capacitance and the stray capacitances acts as a high-pass filter which limits the lower frequency response of the amplifier. Combined with the frequency response of the amplifier, a second order filter is formed with 12 dB/octave slope. This means that LF frequencies below cut-off frequency will be attenuated sharply. If you are not interested in LF reception and want to preserve the sensitivity smaller values of inductance should be used. The practical results with 12mH balun are that there is normal reception from the LW band (150 KHz) and up. DCF77 time standard station (77.5KHz, Germany) can still be heard at a distance of 2000 km.

If you do not have problems with 2-nd order IMD in dipole mode <u>do not use the balun</u>. This balun does not influence the loop amplifier.

Construction

Wind the balun with two wires on the toroidal ferrite core (***Fig.3***). There are no requirements to twist the two wires - you can do that just for ease of winding. Thin magnet wire 0.18 – 0.22 mm diameter might be used. 10x6x4 mm toroidal cores are most convenient. On such a core not more than 30 double winding (0.2 mm diam. wire) can be wound. Larger cores can be used – the smaller are difficult to wind. Connect the beginning of 1st wire to the end of the 2nd wire to form the center tap. If you are not sure of the type of material of the core, measure the inductance of the balun – this is the only important parameter. The inductance must be between 4 to 20 mH. Use cores with high permeability. Too many turns will increase the stray inductance and capacitance and the efficiency of the balun as a symmetric device will be reduced especially at higher frequencies. u= 10 000 is a suitable material in order to reduce the number of turns.

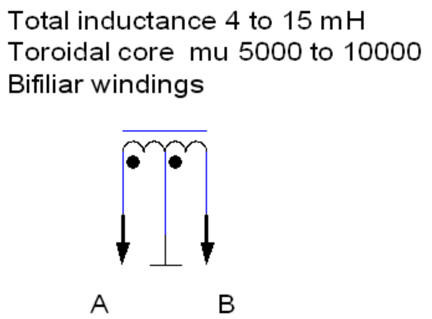

Fig. 3 The inductance is measured between A – B points

A balun with reduced parasitic capacitance

The schematic is shown on ***Fig. 4.*** The balun should be winded with two pairs (4 conductors). Prepare two separately twisted pairs. Then wind the balun with the two pairs simultaneously without twisting them. Connect the leads of the first pair and then the leads of the second pair as shown on the ***Fig.3***. Then connect the two windings as shown to form the central lead. This way of winding reduces the parasitic capacitance almost twice. Using 10x6x5 mm core with mu=10 000 will give 12 mH inductance and the gain reduction will be only 1.5 dB.

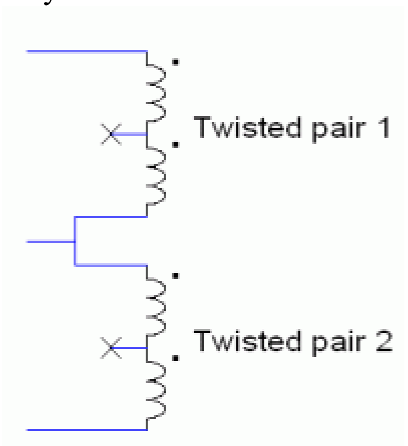

Fig.4 *A balun with reduced parasitic capacitance. The dots mark the beginning of each winding.*

Tested toroidal cores

10 x 6 x 4 mm Epcos Siferit N30 u= 4200 , 20 bifilar turns L= 5 mH

- works well but the inductance is low and the frequency response low cutoff frequency is raised to 800 KHz.

10 x 6 x 4 mm Kaschke K10000 u= 10000 , 30 bifilar turns ; L= 12 mH

- low cutoff frequency is 300 KHz.

10 x 6 x 5 mm Kaschke K10000 u= 10000 , 11 4-filiar turns ; L= 12 mH

- very good results, low parasitic capacitance

Other suitable ferrite materials:
FairRite 75, u =6000
FairRite W, u =10000
Ferroxcube 3E25 or 3E27 , u=6000
Ferroxcube 3E5 , u=10000 (*Farnell order code : 309 6560 10x6x4 mm size*)
Epcos Siferit T35, T37 u= 6000
Epcos Siferit T38 u= 10000

Mounting the Balun

For preliminary tests connect the balun to V1, GND and V2 terminals. (if GND terminal is used, disconnect temporarily the protection ground and connect there the center tap). Then set Jumper J5 at ON to connect GND terminal directly to the amplifier common point. (***Fig. 4***) Jumpers J3, J4 must be on.

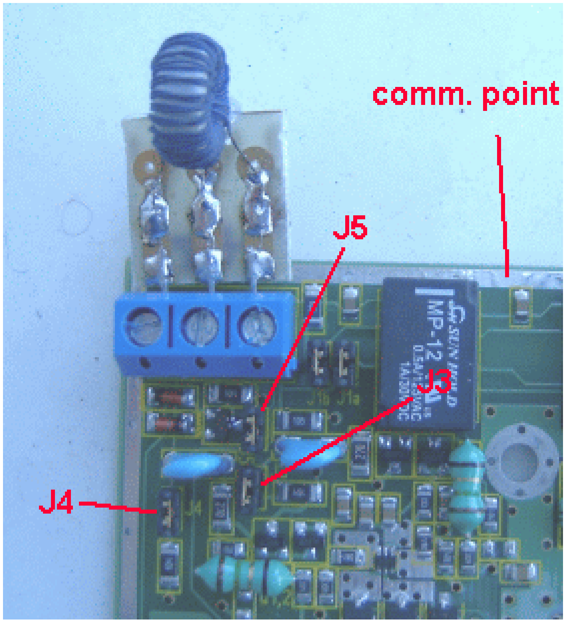

Fig.4

*Permanent solution***:** Solder the center tap of the balun to the common point of the amplifier at any convenient place to free the GND terminal for protection ground and set J5 back to OFF position.

How it works?

Usually the OIP2 of a well designed non-balanced amplifier is somewhere at +60 dBm. The additional 30 dB are coming from canceling of all even order products (e.g. 2^{nd}

harmonic) at the summing stage of the balanced amplifier (wideband transformer). In the case of asymmetry, the 2nd order products will be not equal in both arms and the canceling is not effective. The most effective way is to balance the signal at the input so the canceling process to be performed at the earliest stages.

The two windings of the balun have common magnetic flux ***Fi*** – they are coupled very tightly. They have the same number of turns ***N***. According to Faraday law the induced voltage ***E*** is equal to:

$$E = N * dFi/dt$$

So equal voltages across each winding will always exist - irrespective in which part of an arbitrary electrical circuit the balun is placed.

Conclusion

The dipole balanced amplifier combined with the balun can work successively with larger and very asymmetrical antennas – such as ground plane. The amplifier will have very high IP2 in real circumstances where a careful balance of the dipole antenna can not be reached easily. The demand for long horizontal part of the cables as shown on ***Fig.1*** is reduced and 0.5 m is usually sufficient.