

The present invention concerns a broad-band, low-noise VHF amplifier. It is applied particularly to producing receivers operating close to transmitter aerials.

Conventionally, this type of amplifier comprises a transistor configured as a common emitter, associated with a feedback transformer between the output and the input of the amplifier, that is, between the transistor's collector and its base. This configuration makes it possible to obtain a considerable high-frequency voltage at the terminals of the transformer, but the stray capacitance of the feedback windings limit the pass-band.

A solution to this problem was described by the Applicant in French patent application no. 84 17295. The amplifier described therein comprises a transistor associated with a feedback circuit, comprising two transformers. The primary winding of the first transformer is wired between the transistor's emitter and its base, the primary winding of the second transformer is wired between the transistor's collector and the common potential point. The secondary windings of both transformers are connected in series with the emitter circuit of the transistor. The output signal of the amplifier is tapped from a portion of the primary winding of the second transformer and the number of turns of the two secondary windings is very low so as to limit stray inductance.

In these conditions, an inverse gain for the amplifier is obtained which is almost identical and with the opposite sign to its direct gain. But the coupling of the source and charge circuits leads to problems of matching the source and load circuits which are difficult to master, particularly when these circuits are composed of filters, when the mismatching of the circuits entails modifications in the response curves.

The aim of the invention is to overcome the aforementioned disadvantages.

For this purpose, the subject-matter of the invention is a broad-band, low-noise VHF amplifier comprising a transistor in a common emitter configuration connected via its emitter to the power supply earth of the amplifier by means of two secondary windings, connected in series, of a first and a second transformer and coupled between its base and its emitter by the primary winding of the first transformer, one end of the primary winding of the second transformer being connected to the collector of the transistor and the other end being connected to the power supply, the amplifier output being tapped from all or part of the primary winding of the second transformer and the number of turns of the secondary windings of the transformers being very small in order to limit the leakage inductance, characterised in that it comprises a first resistor connected in series with the two secondary windings and a second resistor connected between said amplifier output and the base of the transistor, said resistors being calculated as a function of the turn ratios of the two transformers and the input and output impedances so as to divide the input voltage applied to the base of the transistor on the first resistor and the secondary winding of the second transformer connected in series with the first resistor, in a specific ratio.

Other characteristics and advantages of the invention will become apparent below with the aid of the description given with reference to the attached drawings which represent:

- Figure 1, a basic circuit diagram of an embodiment of the amplifier according to the invention;
- Figure 2, an adaptation of the diagram in Figure 1 to the embodiment of a broad-band, low-noise amplifier receiving metric or VHF waves.

The amplifier which is shown in Figure 1 organised around an earth circuit M serving as a potential reference comprises a transistor Q1 coupled to a feedback circuit formed of two transformers T1 and T2 represented inside the dotted lines. The primary winding 1 of the transformer T1 is disposed between the emitter 2 and the base 3 of the transistor Q1. The emitter 2 is connected to the earth circuit M across a secondary winding 4 of

the transformer T1, a secondary winding 5 of the transformer T2, and a resistor 6 with the value r , these three elements together being connected in this order in series between the emitter 2 and the earth circuit M. The transformer T2 has a primary winding 7, the ends 8 and 9 of which are connected respectively on the one hand to the earth circuit M, if appropriate across a direct current power supply source for the amplifier, not shown, and on the other hand to the collector 10 of the transistor Q1. A feedback resistor 11 with the value R connects an intermediate connector 12 of the primary winding of the transformer T1 to the base 3 of the transistor Q1. The voltage V_e to be amplified is applied between the base 3 and the earth circuit M. The output voltage V_s is tapped between the intermediate connector 12 and the earth circuit M.

In order not to introduce stray inductance which is too great into the emitter circuit of the transistor Q1, the two secondary windings 4 and 5 are each formed of a winding comprising a single turn. The primary winding 1 of the transformer T1 comprises p turns and the primary winding of the transformer T2 comprises N turns. The primary winding 7 of the transformer T2 comprises, between its end 8 and the intermediate point 12, M turns, at the terminals of which the output voltage V_s of the amplifier is tapped.

The operation of the amplifier is described below in the hypothesis where the transistor Q1 is an ideal transistor, that is, its input impedance Z_i is infinite in the configuration considered and its base/emitter voltage is zero. In these circumstances, the voltage at the terminals of the secondary winding 4 is zero and the voltage V_e is divided into the emitter circuit at the terminals of the secondary winding 5 and the resistor 6 with the value r . In the embodiment example in Figure 1, the value r is determined such that the voltage V_e is divided equally at the terminals of the resistor 6 and in the secondary winding 5. The output voltage V_s is equal to $-M(V_e/2)$ which gives a gain G in amplifier voltage of $-M/2$. Similarly, the value R of the resistor 11 is determined such that the current i generated at

the input of the amplifier by the voltage V_i is divided equally into two currents of intensity $i/2$ in the two branches of the circuit formed by the resistor 11 and the primary winding 1. The current flowing through the turn of the secondary winding 4 is then equal to $p.i/2$ and it is also equal to the current flowing through the secondary winding 5. The emitter current flowing through the transistor is therefore equal in these conditions to

$$I_e = p.i/2 - i/2, \text{ that is, } I_e = (p-1).i/2 \quad (1)$$

Since in the hypothesis the current I_b flowing through the base of the transistor Q1 is zero, the collector current I_c is equal to the emitter current I_e , which gives:

$$I_c = (p-1).i/2 \quad (2)$$

By writing that the number of ampere-turns produced by the currents in the primary and secondary windings of the transformer T2 are opposed, this gives the relationship:

$$p.i/2.1 = -|(p-1).i/2.N - M.i_x| \quad (3)$$

where i_x denotes the current entering through the intermediate connector 12.

If the further hypothesis is taken that the input and output impedances Z_o of the amplifier are identical, this gives:

$$V_o/i_o = V_e/i = Z_o \quad (4)$$

where i_o denotes the output current of the amplifier.

Like $V_o = (-M/2).V_e$, the relationship (4) is verified if i_o is equal to $(M/2).i$, resulting in $i_x = (M/2).i + i/2 = (M+1).i/2$. By re-inserting the value of i_x into the equation (3), this gives:

$$N = (M.(M+1) -)P/(p-1) \quad (5)$$

Since the value of M sets the voltage gain of the amplifier, the relationship (5) shows that, for each value for gain set, there is a large number of solutions for N .

For example, by choosing a voltage gain $M/2 = 4$, a number of solutions are possible for choosing the numbers of turns P and N of the primary windings of the transformers $T1$ and $T2$:

where $M = 8$, the expression (5) becomes

$N = (72-p)/(p-1)$ and the following solutions are possible:

if $p = 2$, $N = 70$
 if $p = 3$, $N = 34.5$
 if $p = 4$, $N = 22.6$
 if $p = 5$, $N = 16.7$
 if $p = 6$, $N = 13.4$
 if $p = 7$, $N = 10.8$
 if $p = 8$, $N = 9.1$
 if $p = 9$, $N = 7.8$

By, for example, setting the solution $M = 8$, $p = 9$ and N rounded to 8 ($M = N$) and for Z_0 the value 50 ohms, this gives:

$$R = (V_s + (M/2) \cdot V_s) / (i/2) = 2 \cdot Z_0 (G+1) = 500 \text{ ohms}$$

and

$$r = (V_s/2) / (p \cdot (i/2)) = 5.5 \text{ ohms.}$$

In practice a higher value will be taken for R so as to compensate the current in the base of the transistor and a lower value for r to take account of the input impedance of r_i .

The adaptation of the amplifier which has just been described to the embodiment of a broad-band, low-noise amplifier receiving VHF waves, is shown in Figure 2 where elements homologous to those of the amplifier shown in Figure 1 are denoted with the same references. In comparison with the circuit in Figure 1, the amplifier in Figure 2 also comprises means for matching the amplifier's consumption to the unwanted signals received for example from a transmission aerial located nearby, so as to obtain at any time the best possible noise figure. Again, in relation to Figure 1, the amplifier further comprises coupling capacitors $C1$, $C2$ and $C3$. The capacitor $C1$ connects the input E of the amplifier to the base of the transistor $Q1$, the capacitor

C2 connects the end 9 of the primary winding 7 to the end of the resistor 11 which is not connected to the base of the transistor Q1, and the capacitor C3 connects the emitter of the transistor Q1 to the end of the primary winding 1 which is not connected to the base of the transistor Q1. The means for matching the amplifier's consumption to the unwanted signals are constituted by a transistor Q2 controlled at its base by a current control circuit 13, the input of which is connected to the collector of the transistor Q1. The base of the transistor Q2 is connected on the one hand to the output of the current control circuit 13 and on the other hand to the emitter of the transistor Q2 across two resistors 14 and 15 configured in series. In the embodiment shown the point common to the resistors 14 and 15 is polarised at a power supply potential of +5 volts. A capacitor C5 decouples the resistor 14. The end 8 of the primary winding 7 is connected on the one hand to the emitter of the transistor Q2 across a surge inductor L1 and on the other hand to the common point between the resistor 6 and the secondary winding 5 through a decoupling capacitor C4. The collector of the transistor Q2 is connected to the end common to the decoupling capacitor C3 and to primary winding 1 across a resistor 16 in order to act on the base current of the transistor Q1. The collector of the transistor Q2 is on the other hand decoupled to the earth circuit by a capacitor C6.

According to a particular embodiment of the invention, a configuration in accordance with that of Figure 2 gave the following results for a band of explored frequencies comprised between 30 and 90 MHz. The measurements were taken for two current consumptions, one at 7 milliamps and the other at 26 milliamps. In both cases it was possible to obtain direct gains of 10.7 dB and 11.6 dB and inverse gains going from 26 dB to 33 dB as a function of frequency. For a current consumption $I = 7$ milliamps, it was possible to measure the complex input impedance Z_i comprised between $56 \text{ ohms} \times \text{Exp.j.5}^\circ$ and $62 \text{ ohms} \times \text{Exp.j.3}^\circ$, and it was possible to measure the output impedance Z_o comprised between $58 \text{ ohms} \times \text{Exp.j.6}^\circ$ and $60 \text{ ohms} \times \text{Exp.j.4}^\circ$, the noise figure F being equal to 2.3 decibels. For a current consumption

I = 26 milliamps it was possible to measure the input impedance Z_i comprised between $50 \text{ ohms} \times \text{Exp.}j.7^\circ$ and $60 \text{ ohms} \times \text{Exp.}j.11^\circ$, and it was possible to measure the output impedance Z_o comprised between $51 \text{ ohms} \times \text{Exp.}j.7^\circ$ and $57 \text{ ohms} \times \text{Exp.}j.2^\circ$, the noise figure being equal to 2.5 decibels. Furthermore, with the high current of 26 milliamps the compression point at 1 decibel was obtained for an input voltage of 280 millivolts.

It goes without saying that the invention is not limited to the embodiments previously described. Other variants are of course possible depending in particular on the performance as to frequency, pass-band, and signal-to-noise ratio which it is desired to obtain and the person skilled in the art will easily agree that the embodiments in Figures 1 and 2 may very well be subjected to modifications as a function of need, without leaving the scope of the invention.



CLAIMS

1. A broad-band, low-noise VHF amplifier comprising a transistor (Q1) in a common emitter configuration connected via its emitter to the power supply earth (M) of the amplifier by means of two secondary windings (4, 5), connected in series, of a first (T1) and a second (T2) transformer and coupled between its base and its emitter by the primary winding of the first transformer (T1), one end (9) of the primary winding (7) of the second transformer (T2) being connected to the collector of the transistor (Q1) and the other end (8) being connected to the power supply, the amplifier output (12) being tapped from all or part of the primary winding (7) of the second transformer (T2) and the number of turns of the secondary windings (4 and 5) of the transformers (T1, T2) being very small in order to limit the leakage inductance, characterised in that it comprises a first resistor (6) connected in series with the two secondary windings (4, 5) and a second resistor (11) connected between said amplifier output (12) and the base of the transistor, said resistors being calculated as a function of the turn ratios of the two transformers and the input and output impedances so as to divide the input voltage applied to the base of the transistor on the first resistor and the secondary winding (5) of the second transformer (T2) connected in series with the first resistor, in a specific ratio.
2. An amplifier according to Claim 1, characterised in that the secondary windings (4, 5) and two transformers (T1, T2) each have a single turn.
3. An amplifier according to Claims 1 and 2, characterised in that the voltage gain of the amplifier is equal to $-M/2$, the output voltage being tapped at the M-turn terminals of the primary winding (7) of the second transformer (T2), the primary windings of the two transformers having p and N turns respectively, p, M, N being whole numbers which satisfy the expression $N = (M(M+1)-p)/(p-1)$.



4. An amplifier according to any one of Claims 1 to 3, characterised in that the number M is equal to the number N.
5. An amplifier according to any one of Claims 1 to 4, characterised in that it also contains a current control circuit (13) for the transistor (Q1) in order to regulate the current drain of the amplifier as a function of the amplitude of any unwanted signals which might be received in order to obtain the best possible noise figure at all times.