

**LOW-NOISE RADIO-FREQUENCY POWER AMPLIFIER AND TRANSMISSION AND
RECEPTION SYSTEM COMPRISING SUCH AN AMPLIFIER**

5 The present invention relates to an RF power amplifier in which the noise transmitted is greatly reduced. It also relates to an RF transmission and reception system comprising such an amplifier.

The invention applies for example in co-located RF transmission and reception systems belonging to different telecommunication networks, where each system is liable to pollute the other.

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In the field of UHF or VHF telecommunications notably, certain missions require that transmission and reception systems each belonging to a specific network be stationed at the same geographical place, the two networks being independent and operating at close frequencies. These systems are said to
15 be co-located, or else one speaks of co-site systems. Such is the case notably when two antennas, and their associated transmission and reception means, are disposed on one and the same vehicle. Jamming between the two systems and a degradation in range then occur. More particularly, in such a situation of proximity between a transmitter of one network and a
20 receiver of another network, the receiver is polluted by the out-of-band noise transmitted by the transmitter. The orders of magnitude of power involved can attain 5 Watts intercepted at reception for 50 Watts transmitted by the transmitter.

In the known solutions for solving this problem of geographical proximity, the
25 transmission noise is processed by multiple filterings that consume energy and volume in the equipment, and are moreover expensive.

Moreover, the power amplification stages, which deliver the signal to be transmitted, generate significant noise at carrier bottom when the amplifier is working close to its saturation, and therefore to its best efficiency. This
30 additional noise may be considerable, much greater than the small-signal noise.

Finally, the noise of the last power stage may not be able to be filtered since the feasibility of very selective filters is not acquired at high power. Even if these filters can be produced, the overall efficiency of the transmitter may be
35 considerably reduced due to the losses in these filters.

An aim of the invention is notably to alleviate the aforementioned drawbacks. For this purpose, the subject of the invention is an RF power amplifier comprising at least one transistor, the said transistor comprising a feedback circuit determining its amplification gain, the amplifier furthermore comprising
5 a feedback circuit effective in a base frequency band in which noise is produced at the output of the said transistor, so that a part of the output noise is injected at the input of the said transistor.

In a possible embodiment, the said feedback circuit is active in a frequency band corresponding to a frequency band in which one wishes to decrease
10 the noise transmitted and which lies around the carrier of the signal transmitted by the said amplifier, the said band being a transposition of the said base frequency band.

The said feedback circuit is for example linked between the output and the input of the said transistors via inductors, the said inductors being passing in
15 the said base frequency band and isolating for the other frequencies.

The said transistor being a field-effect transistor, the said feedback circuit, low frequency, is for example connected to the drain of the said transistor via a first inductor and to the gate of the said transistor via a second inductor.

20 The invention also relates to a radio-frequency transmission and reception system comprising a power amplifier such as described above.

Other advantages and characteristics of the invention will become apparent with the aid of the description which follows, given in relation to appended
25 drawings which represent:

- Figure 1, an exemplary power amplifier according to the prior art;
- Figure 2, an illustration of the generation of the noise of an RF power amplifier transposed to carrier bottom;
- Figure 3, an exemplary embodiment of a power amplifier according to
30 the invention;
- Figure 4, an illustration of the noise correction afforded by a the invention;

- Figure 5, a comparison of the generated noise between an amplifier according to the prior art and an amplifier according to the invention.

Figure 1 presents in a schematic manner a power amplifier according to the prior art. It comprises at least one transistor Q1 intended to amplify a low-level input signal E. A field-effect transistor is considered subsequently by way of example. If need be, several transistors can be interconnected in parallel to provide the necessary power. A typical power in the field of UHF or VHF telecommunications is 50 Watts. The transistor is linked to two bias voltages V_D and V_G . The first, V_D , linked to the drain of the transistor via an inductor L1, provides the electrical power necessary for the amplification. The second, V_G , biases the gate voltage of the transistor via a resistor R2. Conventionally, a feedback loop 10, active at UHF and VHF, is connected between the drain and the gate. This feedback loop 10 determines notably the RF gain of the amplification stage formed by the transistor. The radiofrequency signals present on the input E of the amplifier are coupled to the gate of the transistor via a capacitor C.

The amplifier generates noise which is present at the level of the antenna. More precisely, the resulting noise at the level of the antenna is the output noise of the amplifier and more particularly of the transistor Q1.

As was indicated above, filtering of the noise at the output of the power stage is not always possible. In particular, at VHF it is known how to filter at the output of the transistor Q1 but not at UHF.

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The noise at the output of the transistor Q1 is composed of two types of noise:

- Conventional noise, termed thermal noise, which is a function of temperature and is of nearly uniform frequency distribution;
- Non-conventional noise, termed electronic noise, due to the operation of the semi-conductors.

In particular, the noise level at the output of a transistorized power amplifier increases considerably in the vicinity of saturation. This phenomenon is particularly visible in class AB transistor layouts. The equivalent noise factor,

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close to the carrier, may be degraded by 20 dB with respect to small-level operation. The two phenomena presented hereinbelow may explain this non-conventional second type of noise:

- 5 - On the one hand, for class AB amplifiers, the current increases considerably when the transistor begins to self-bias. The carrier recombination noise (shot noise, $1/f$ noise, f being the frequency, notably) generated in baseband gets transposed to carrier bottom by the non-linearities. The $1/f$ noise at carrier bottom is proportional to the
10 current consumed and therefore to the average power transmitted for a class AB amplifier;
- On the other hand, an amplifier close to its saturation becomes non-linear, and therefore folds, detects and transposes the whole of its thermal noise band to baseband, and then transpose this noise again
15 to carrier bottom.

Trials and tests carried out by the Applicant have shown that this noise is essentially generated at the output of the transistor, on the drain-source pathway in the case of a field-effect transistor. This noise is not correlated
20 with the thermal noise at the input of the transistor. The conventional model of the noise source at the input of a power amplifier cannot therefore be taken into account to solve the problem posed.

Before setting forth the solution afforded by the invention, the creation of this noise generated at the output of the transistor is illustrated hereinafter.

25 Figure 2 illustrates the effects of the non-linearities such as described above, occurring when the amplifier is close to saturation, at its best efficiency.

A first part 1 shows, in the frequency domain, the carrier 21 of the signal transmitted, which is distinguished from the thermal noise floor 22.

A second part 2 shows the noise of recombination of the generated carriers
30 in baseband 23, at the low frequencies, this noise being of $1/f$ type. The non-linearities give rise to the folding of the noise spectrum, to baseband, as illustrated by this second part 2.

A third part 3 illustrates the transposition of the noise generated to baseband, at $1/f$ at the bottom 24 of the carrier. This noise thus transposed by the non-
35 linearities causes noise 25 added at the bottom of the carrier 21 and

transmitted by the amplifier. This $1/f$ noise is proportional to the current consumed and therefore to the average power transmitted for a class AB amplifier.

5 As indicated previously, the Applicant has evinced the fact that this noise is essentially generated at the output of the transistor Q1. More precisely, the gate of the transistor remains non-noisy whilst the source comprises the noise.

The conventional noise model of a power amplifier assuming a noisy input is therefore not suitable for countering this noise.

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Figure 3 illustrates an exemplary embodiment of an amplifier according to the invention. To remove the noise 25 at carrier bottom, or at least strongly attenuate it, according to the invention, a baseband analogue feedback loop 30 is added. This amounts, at low frequency, to slaving the output S of the amplifier to the input E, which is less noisy. Stated otherwise, this amounts to injecting a part of the output noise as input to the transistor so as to cancel this noise. The noise loop is active in the baseband 23, for example between a few hundred kilohertz and a few megahertz.

15 Returning to the exemplary embodiment of Figure 1, the feedback loop 30, which will subsequently be called a noise loop, is connected in parallel to the conventional feedback loop 10, by adding a few adaptation circuits or components.

In particular, this noise loop 30 is linked between the output and the input of the amplifier via decoupling inductors 31, 32. More precisely, a first inductor 25 31 is connected between the noise loop 30 and the drain of the transistor Q1 and a second inductor 32 is connected between the noise loop 30 and the gate of the transistor. These inductors are passing at low frequencies, in the baseband corresponding to the frequencies to be filtered, and isolate the noise loop at high frequencies.

30 As regards the connection to the bias voltages V_G , V_D , the noise loop is connected on one side to the drain voltage V_D by a low-frequency and radiofrequency filter, for example an inductor 34. It is connected on the other side to the gate voltage V_G via the bias resistor R2, already present in the layout of Figure 3.

The noise loop 30 consists for example of a capacitor whose capacitance value is suitable for the base frequencies. More precisely, the capacitance is calculated in such a way that the noise loop is active in the bands of interest, in the low frequencies, corresponding to the frequency band around the carrier in which one wishes to decrease the noise transmitted.

The feedback loop 30 is at low frequency, almost in baseband and therefore below the useful amplification band of the amplifier. The useful band is the band of use of the amplifier or radiofrequency band, between a frequency F_{min} and a frequency F_{max} . For example, $F_{min} = 20$ MHz and $F_{max} = 500$ MHz. The baseband is the modulation band, here the band situated below the useful band, i.e. between 0 and F_{min} . An effect of the invention is to obtain a maximum of feedback below the useful band, below F_{min} of the amplifier, while not modifying the feedback and therefore the gain of the amplifier in its useful band, F_{min} to F_{max} .

Figure 4 illustrates the effects of the noise loop on the attenuation of the noise at carrier bottom.

The first part 1 returns, in the frequency domain, to the case of Figure 2 with the carrier 21, the thermal noise floor 22 and the base frequency band.

The other two parts 2', 3' return to the baseband noise spectrum 25 of Figure 2 and the spectrum of the noise 45 corrected by the noise loop 30.

The second part 2' therefore presents the corrected noise 45 before transposition, with a strong attenuation with respect to the uncorrected $1/f$ noise.

The third part 3' illustrates the transposition of the corrected noise 45 to baseband, at the bottom 24 of the carrier. The corrected noise being strongly attenuated, this attenuation is found at the bottom of the carrier.

Figure 5 presents, in one form, the attenuation obtained on the noise generated at the output of the transistor Q1, seen from the output of the amplifier. A first curve 51 represents the gain of the noise as a function of frequency with no noise loop. A second curve 52 represents the gain of the noise for a power amplifier according to the invention, equipped with the noise loop 30. This second curve 52 shows a large decrease in the noise in

the baseband 23, which decrease is found at the bottom of the carrier 21 as illustrated by Figure 4.

Figures 4 and 5 show clearly that the invention makes it possible to
5 considerably limit the noise seen from the output of the power amplifier. In practice, this reduction in the noise in baseband translates into a significant decrease in the degradation of the noise at carrier bottom afforded by the non-linearities and the carrier recombination noise. Figure 4 shows notably that the resulting noise transposed to carrier bottom approaches the
10 conventional thermal noise. The trials performed by the Applicant have shown that these 10 to 100 times more significant noise powers are measured in the absence of the noise loop 30.

Advantageously, the present invention can be implemented in a very simple and economical manner. It is indeed easy and inexpensive to place a low-
15 frequency feedback loop in parallel with the conventional gain feedback loop. In a simple version, such as illustrated by Figure 3, the low-frequency feedback 30 is inserted at the level of the decouplings R2, 34 of the bias of the transistor.

The advantage of the invention is also that it is compact, that is to say that it
20 does not increase the bulkiness or the area occupied by the power amplifier, or in a very limited manner. Finally, it does not degrade the efficiency of the amplifier. Trials carried out by the Applicant have shown in particular that with an amplifier according to the invention it is possible to achieve a noise reduction of the order of 15 dB of the noise at carrier bottom added and
25 transmitted by the amplifier, with no filtering, with no losses, and therefore with no loss of efficiency. Advantageously, in certain cases of application it is possible to remove the output filter customarily used for co-site applications.

CLAIMS

1. RF power amplifier comprising at least one transistor (Q1), the said transistor comprising a feedback circuit (10) determining its amplification gain, characterized in that it furthermore comprises a feedback circuit (30) operating in a base frequency band (23) in which noise is produced at the output of the said transistor, so that a part of the output noise is injected at the input of the said transistor.
2. Power amplifier according to Claim 1, characterized in that the said feedback circuit (30) operates in a frequency band in which one wishes to decrease the noise transmitted (25) and corresponding to a frequency band around the carrier (21) of the signal transmitted by the said amplifier, the said band being a transposition of the said base frequency band (23).
3. Power amplifier according to any one of the preceding claims, characterized in that the said feedback circuit (30) is linked between the output and the input of the said transistors (Q1) via inductors (31, 32), the said inductors being passing in the said base frequency band (23) and isolating for the other frequencies.
4. Power amplifier according to Claim 3, characterized in that the said transistor (Q1) being a field-effect transistor, the said feedback circuit (30) is connected to the drain of the said transistor via a first inductor (31) and to the gate of the said transistor via a second inductor (32).
5. Radio-frequency transmission and reception system, characterized in that it comprises a power amplifier according to any one of the preceding claims.