NEGATIVE RESISTANCE ANTENNA AMPLIFIER ARRANGEMENT

ABSTRACT: An oscillator circuit is kept at a predetermined stable-operating point below the onset of oscillations by high-resistance feedback in the emitter circuit. The tuned circuit of the oscillator has one winding of a transformer whose second winding is connected either in series between the antenna and the receiver, or in parallel with the receiver. The impedance seen looking into the second winding is a negative resistance.
Fig. 3

Fig. 4

\[ G = \frac{1}{1 - \frac{R_T}{R_S + R_V + R_E}} \]
NEGATIVE RESISTANCE ANTENNA AMPLIFIER ARRANGEMENT

BACKGROUND OF THE INVENTION

This invention relates to antenna amplifiers. In particular, it relates to antenna amplifiers wherein an equivalent negative resistance is connected in series with said antenna by coupling an amplifier element in an oscillator-type circuit to said antenna.

The basic advantage of an antenna amplifier which presents an equivalent negative resistance and is connected in a two terminal configuration between the antenna and the receiver as compared to the conventional antenna amplifiers connected in a four-terminal connection is, that the antenna current and therefore the equivalent antenna absorption surface are increased, thus greatly increasing the signal-to-noise ratio. The negative resistance increases the figure of merit (Q) of the circuit and thus decreases the bandwidth of the antenna. The only limitation on the advantage to be gained by the arrangement set forth in the present invention is that a minimum bandwidth is prescribed for each transmission channel. However, it will be demonstrated below that an increase in gain of 29 db, for a frequency of 480 MHz and a high Q in the UHF region may be obtained even considering the regulations for minimum bandwidth mentioned above. Thus the increase in antenna gain by an antenna amplifier in accordance with the present invention is of great value when the fact is considered that an additional gain of 20 db. is sufficient to solve the reception problem in most fringe areas.

Antenna amplifiers using a tunnel diode as a negative resistance are known. However, the stability problems associated with these circuits are such that they cannot be used in a series or two terminal connection as is the amplifier of the present invention.

SUMMARY OF THE INVENTION

It is an object of this invention to furnish a negative resistance antenna amplifier which is sufficiently stable for use in a series connection. This invention comprises an antenna receiving arrangement comprising antenna means and receiver means and circuit means in series connected between said antenna means and said receiver means. Said circuit means are designed to provide an equivalent negative resistance between said antenna means and said receiver means, thus increasing the gain of the arrangement.

The circuit means for creating said above-mentioned equivalent negative resistance comprise an amplifier element and feedback means interconnected with said amplifier element in such a manner that the operating point of said amplifier element is kept just below onset of oscillations. These negative feedback means may for example comprise a very high resistance in the emitter circuit of the amplifier element. The circuit means also comprise coupling means, which may for example be a tank circuit, for coupling the interconnected amplifier element and its feedback means serially between the antenna means and the receiver means.

The circuit of the amplifier element may be further stabilized by providing high-frequency feedback by means of a voltage divider, said high-frequency feedback being designed to keep the operating point of the amplifier element in a region of relatively small variation in amplification.

Phase shift in the feedback circuit, and thus a lack of symmetry relative to the center frequency of the receiving arrangement is avoided by causing the voltage divider used for the high-frequency feedback to have a low leakage resistance compared to the input resistance of the control electrode of the amplifier element which is in parallel with said leadage resistance.

Capacitive diodes may be used as tuning elements. In a particularly advantageous embodiment of the present invention, the tuning elements and the operating point of the amplifier element are chosen in such a combination that the feedback remains the same over the whole tuning range.

A further improvement in stability of the receiving arrangement may be achieved by inserting a conventional antenna amplifier in a four pole arrangement between the antenna with the series connected antenna amplifier with negative resistance on the one hand, the the receiver means on the other hand. The distance between the antenna and said second, four-pole amplifier should be small relative to the wavelength of the receiving channel or alternatively a multiple of half of said wave length, so that a definite terminal resistance is formed at the input of this four-terminal network for the antenna circuit.

The output of the second antenna amplifier is matched to the wave impedance of the high-frequency cable leading to the receiver input in the conventional fashion. This matching eliminates reflections between the second amplifier and the receiver input. Furthermore, the second amplifier serves as a decoupling element and thus prevents the high-frequency cable and the impedance of the receiver from being reflected into the antenna circuit. Thus any receiver may be connected to the output of the second amplifier without requiring a change in the feedback arrangement of the series connected antenna amplifier.

The high stability achieved by the above means permit the series connection of the new antenna amplifier. The coupling elements coupling the amplifier element with its associated feedback means to the antenna and the receiver means may for example comprise tank circuits.

Conventional high-pass filters may be used for protecting the amplifier elements against overvoltages caused by lightning.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a first embodiment of a circuit in accordance with the present invention;
FIG. 2 is a second embodiment of a circuit in accordance with the present invention;
FIG. 3 is an equivalent circuit for the circuits shown in FIGS. 1 and 2; and
FIG. 4 is a plot of antenna gain as a function of the resistance elements in said circuits.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A preferred embodiment of the present invention will now be discussed with reference to FIG. 1. The circuit of FIG. 1 has an antenna means denoted by A, receiver means denoted by reference numerals 11 and 12, where 12 denotes the high-frequency cable leading into the receiver proper which is denoted by 11, a four-terminal amplifier circuit denoted by reference numeral 9, and two-terminal circuit means which comprise the remainder of the circuitry shown in FIG. 1 and will be discussed in detail below.

The transistor denoted by reference numeral 1 serves as an amplifier element. This transistor 1 together with the primary winding of transformer 2 which furnishes an inductivity and the tuning capacitor 3, in addition to the capacitive voltage divider comprising capacitors 4 and 5, form an oscillator circuit which is maintained below the onset of oscillation. The high-stability requirements of the arrangement are satisfied by the high-resistance value of the emitter resistors 6 and 7, as well as by the value chosen for the voltage-divider means comprising capacitors 4 and 5. The resonant frequency of the oscillator circuit corresponds to the carrier frequency of the complete receiving channel, thus causing the circuit means embodied in this so-called oscillator circuit to present an equivalent negative resistance value of R, at the secondary winding of transformer 2. As shown in FIG. 1, this negative resistance is con-
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Z = \frac{e}{C} \left( \frac{L}{2\pi} \ln \frac{2H}{r_o} \right) \Rightarrow \frac{Z_0}{e_0} = \sqrt{\frac{377 \Omega}{2\pi}}

Z = 60 \ln (2H/r_o) \Omega

d. the equivalent inductivity \( L^* \):
\[ L^* = L/(2\pi) \quad \text{H} \quad H = 0.04 \]
e. the equivalent capacitance \( C^* \):
\[ C^* = C/(2\pi) \quad \text{F} \quad \text{H} = 0.04 \]
f. the figure of merit of Q of the antenna then is:
\[ Q = \frac{Z_0}{R_a + R_v + R_e - R_T} = \frac{Z_0}{R_a + R_v + R_e - R_T} \]
g. If the value \( Q_0 \) for the figure of merit without an antenna negative resistance amplifier \( (R_T = 0) \) and the gain \( G \) as defined above are introduced into this expression for the figure of merit \( Q \), the following results are obtained:
\[ Q = \frac{60\ln \frac{2H}{r_o}}{R_a + R_v + R_e} \]
h. For a \( \lambda/2 \) dipole having a reflector \( R_T + R_a \) may be assumed to be 60\( \Omega \). Furthermore \( R_e \) is also 60\( \Omega \).

For these values:
\[ Q = \frac{60\ln \frac{2H}{r_o}}{120 - R_T} \]
i. For \( R_T = 0 \), that is without the two terminal negative resistance amplifier of the present invention:
\[ Q_0 = 0.5 \ln(2H/r_o) \]
j. If now \( f = 480 \text{ MHz}, \quad 2H = 0.9 \text{ in.} = 2.3 \text{ cm} \), and \( r_o = 0.5 \text{ cm} \):
\[ Q_0 = 0.5 \ln(2H/r_o) = 0.5 \times 2.3 = 2.35 \]
k. For \( f = 90 \text{ MHz}, \quad 2H = 0.95 \text{ in.} = 2.4 \text{ cm} \),
\[ r_o = 0.6 \text{ cm} \]
\[ Q_0 = 0.5 \ln(2H/r_o) = 0.5 \times 2.4 = 1.2 \]
l. For \( f = 480 \text{ MHz}, \quad \Delta f = 7 \text{ MHz} \) the required figure of merit:
\[ Q_{\text{req}} = 480\Delta f/68.6 \]
m. The maximum resulting gain then is:
\[ G_{\text{max}} = \frac{Q_0}{Q_{\text{req}}} = 68.6/2.36 = 29.1 \]
n. For \( f = 90 \text{ MHz}, \quad \Delta f = 0.3 \text{ MHz} \) the following figure of merit results:
\[ Q_{\text{req}} = 90/0.3 = 300 \]
o. This results in a maximum gain of:
\[ G_{\text{max}} = 300/3.1395 = 98.2 \]
p. The above-mentioned gains are theoretically obtainable if the optimal value of \( R_T \) is used. If these values are denoted \( -R_T(1) \) and \( -R_T(2) \), the respective values may be computed as follows:

\[ G_{\text{max}} = \frac{1}{R_T} - \frac{1}{R_T + R_v + R_e} \]

The curve denoting this equation is shown in FIG. 4.

For a \( \lambda/2 \) of dipole of length 2\( H \) and radius \( r_o \), the following equations result:

a. the inductivity \( L \):
\[ L = (\mu_0/2\pi) \ln(2H/r_o) \text{ per kilometer} \]
b. the capacitance \( C \):
\[ C = \frac{\epsilon_0}{2\pi} \ln(2H/r_o) \text{ per kilometer} \]
c. the wave impedance \( Z \):

\[ Z = \frac{e}{C} \left( \frac{L}{2\pi} \ln \frac{2H}{r_o} \right) \Rightarrow \frac{Z_0}{e_0} = \sqrt{\frac{377 \Omega}{2\pi}} \]
Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims. What is claimed as new and desired to be protected by Letters Patent is set forth in the appended.

1. Receiving arrangement, comprising, in combination, antenna means; a negative-resistance circuit means connected to said antenna means, said negative-resistance circuit means comprising oscillator circuit means having an amplifier element, said amplifier element having a first and second output electrode and a control electrode; high-resistance passive feedback means connected to said first output electrode for maintaining the operating point of said amplifier element at a predetermined stable point below onset of oscillations; and high-frequency voltage divider means connected to said amplifier element for furnishing additional feedback in such a manner that the operating point of said amplifier element lies in a region of relatively small changes in amplification; and receiver means connected to said negative-resistance circuit means. 2. An antenna arrangement as set forth in claim 1, further comprising four-terminal amplifier circuit means having a pair of input terminals connected to said interconnected antenna and negative-resistance circuit means, said four-terminal amplifier circuit means further having a pair of output terminals; and receiver means connected to said pair of output terminals of said four-terminal amplifier circuit means. 3. An antenna arrangement as set forth in claim 1, further comprising receiver means connected to said interconnected antenna means and negative-resistance circuit means. 4. An antenna arrangement as set forth in claim 3 wherein said circuit means comprises a series of said antenna means and said receiver means. 5. An antenna arrangement as set forth in claim 3 wherein said antenna means, said negative-resistance circuit means and said receiver means are connected in parallel to each other. 6. An antenna arrangement as set forth in claim 1 wherein said voltage-divider means comprise a first and second resistor connected in the circuit, each of said resistor having a leakage resistance, the value of said leakage resistance in parallel to said control electrode of said amplifier element being small compared to the input impedance of said control electrode. 7. An antenna arrangement as set forth in claim 1 wherein said amplifier element is a transistor and wherein said first output electrode is the emitter of said transistor. 8. Receiving arrangement, comprising, in combination, antenna means; a negative-resistance circuit means connected to said antenna means, said negative-resistance circuit means comprising oscillator circuit means having an amplifier element, said amplifier element having a first and second output electrode and a control electrode; high-resistance feedback means connected to said first output electrode for maintaining the operating point of said amplifier element at a predetermined stable point below onset of oscillations, said oscillator circuit further comprising tuning means for the resonating thereof and receiver means connected to said negative-resistance circuit means. 9. An antenna arrangement as set forth in claim 8, wherein said oscillator circuit further comprises transformer means having a first winding connected in parallel with said tuning means and a second winding, inductively coupled to said first winding, connected to said antenna means and said receiver means. 10. An antenna arrangement as set forth in claim 8 wherein said tuning means comprise capacitive tuning means. 11. An antenna arrangement as set forth in claim 10 wherein said capacitive tuning means comprise capacitive diodes.