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Receiver with a tunable parallel resonant circuit.

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**FIELD OF THE INVENTION**

The invention relates to a receiver comprising a tunable parallel resonant circuit which is coupled to an input of a transistor circuit via a coupling network which includes a coupling capacitor.

**BACKGROUND ART**

Philips television (TV) tuners of the type UV816 include a tunable bandpass filter which can be tuned throughout the VHF-low band ranging, say, from 48 to 168 MHz. The tunable bandpass filter is coupled between a radio-frequency (RF) input amplifier and a mixer circuit which forms part of an integrated circuit. It comprises two parallel resonant circuits which are mutually coupled. One of the two parallel resonant circuits is coupled to the RF input amplifier. The other of the two resonant circuits is coupled to an input transistor of the mixer circuit via coupling network which includes a coupling capacitor and a varicap diode of the type BB131. A tuning voltage is applied to the varicap diode so as to vary its capacitance throughout the VHF-low band.

**SUMMARY OF THE INVENTION**

The invention seeks, inter alia, to provide a receiver of the subject type which, with respect to the background art, allows more cost-efficient implementations. Claim 1 defines a receiver in accordance with the invention. Additional features, which may optionally be used to implement the invention to advantage, are defined in the dependent Claims.

The invention takes the following aspects into consideration. The transistor

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circuit should preferably see, as it were, a source impedance which remains substantially constant while the tunable parallel resonant circuit is tuned. However, tunable parallel resonant circuits generally have a resonance-frequency impedance which substantially varies while they are tuned. The coupling network should therefore compensate, as best  
5 as possible, tuning-dependency of the resonance-frequency impedance of the tunable parallel resonant circuits. If the coupling network fails to do so, the signal-handling will suffer from this in terms of noise, gain and frequency characteristics.

In the background art, it is essential that the coupling network includes the varicap diode to which the tuning voltage is applied. If the varicap had not been present,  
10 the background-art tuner would have suffered from relatively poor signal-handling in terms of noise and gain. Moreover, the tunable parallel resonant circuit would not have been sufficiently correctly tuned throughout the relevant frequency band, which is the VHF-low band, as a result of a tracking-error with an oscillator resonant circuit in the background-art tuner.

In accordance with the invention, the coupling network lacks a varicap  
15 diode but includes a coupling resistor which is coupled in series with the coupling capacitor. The coupling resistor and the coupling capacitor, which are coupled in series, provide an equivalent bridging capacitance between the tunable parallel resonant circuit and the transistor circuit. This equivalent bridging capacitance varies as a function of  
20 frequency in the same sense as how the varicap diode capacitance is made to vary by means of the tuning voltage in the background art. Consequently, the invention allows compensation of the tuning-dependency of the resonance-frequency impedance of the tunable parallel resonant circuit, without the use a varicap diode. Varicap diodes are relatively expensive, in particular the varicap diode used in the background-art coupling  
25 network. Thus, the invention allows more cost-efficient implementations than the background art.

Moreover, the invention also allows implementations which, with respect to the background art, have a comparable performance. At first sight, this may seem strange because, in the invention, the coupling resistor is a potential source of noise which is  
30 placed right in a signal path. Therefore, one might expect a penalty in terms of noise performance. In most practical cases, the penalty will be relatively mild, because the resonance-frequency impedance of the tunable parallel resonant circuit will generally be

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sufficiently high with respect to the impedance the coupling resistor, so as to prevent the coupling resistor from being a dominating noise source.

The invention and additional features, which may optionally be used to implement the invention to advantage, will be apparent from and elucidated with reference to the drawings described hereinafter.

## BRIEF DESCRIPTION OF THE DRAWINGS

- 10 Fig. 1a is a diagram showing the basic principles of the invention;  
Fig. 1b is an equivalent circuit diagram for further explaining the basic principles of the invention;  
Fig. 2 is a diagram illustrating an additional feature which may optionally be used to implement the invention to advantage;  
15 Fig. 3 is a circuit diagram of an example of a receiver in accordance with the invention.

## DETAILED DESCRIPTION OF THE DRAWINGS

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First, some remarks are made on the use of reference signs. Similar entities will be denoted with an identical lettercode throughout the drawings. In a single drawing, various similar entities may be shown. In that case, a numeral will be added to the lettercode, to distinguish similar entities from each other.

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Fig. 1a illustrates the basic principles of the invention. In Fig. 1a, a tunable parallel resonant circuit PRC is coupled to an input IN of a transistor circuit TRC via a coupling network CNW. The coupling network CNW includes a coupling capacitor  $C_c$  and a coupling resistor  $R_c$  which are coupled in series. The coupling network CNW lacks, however, a varicap diode.

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Fig. 1b is a circuit diagram which is equivalent to Fig. 1a. Fig. 1b shows, a resonant-frequency impedance  $R_p$  of the tunable parallel resonant circuit PRC, an input capacitance  $C_i$  of the transistor circuit TRC and, in broken lines, a source impedance  $R_g$

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seen, as it were, by the transistor circuit TRC at the input IN. Furthermore, Fig. 1b shows a bridging resistance  $R_b$  and a bridging capacitance  $C_b$ . They are both coupled in parallel between the tunable parallel resonant circuit PRC and the input IN of the transistor circuit TRC. The parallel-coupled bridging resistance  $R_b$  and bridging capacitance  $C_b$  are the equivalence of the series-coupled coupling resistor  $R_c$  and coupling capacitor  $C_c$  shown in Fig. 1a.

The resonant-frequency impedance  $R_p$  is transformed to the source impedance  $R_g$  by means of the bridging capacitance  $C_b$ , the bridging resistance  $R_b$ , and the input capacitance  $C_i$  of the transistor circuit TRC. If the tunable parallel resonant circuit PRC is tuned to higher frequencies, the resonant-frequency impedance  $R_p$  will increase to a certain extent. However, the source impedance  $R_g$  will not increase to the same extent, or will even not even increase at all. The reason for this is that the bridging capacitance  $C_b$  decreases with frequency. This decrease compensates to a certain extent the increase of the resonant-frequency impedance  $R_p$ . Of course, the foregoing will inversely apply, if the tunable parallel resonant circuit PRC is tuned to lower frequencies. Thus, if the tunable parallel resonant circuit PRC is tuned, any variation in the source impedance  $R_g$  will less than the variation in the resonant-frequency impedance  $R_p$ .

Fig. 2 illustrates the following additional feature. The coupling capacitor  $C_c$  has an impedance  $Z(C_c)$  which is lower than the impedance  $Z(R_c)$  of the coupling resistor  $R_c$  in at least a portion of a frequency range FR throughout which the tunable parallel resonant circuit can be tuned. Fig. 2 is an impedance ( $Z$ ) versus frequency ( $F$ ) graph having two curves denoted  $C_c$  and  $R_c$ . The curve denoted  $C_c$  shows the impedance  $Z(C_c)$  of the coupling capacitor  $C_c$ . The curve denoted  $R_c$  shows the impedance  $Z(R_c)$  of the coupling resistor  $R_c$ . In the graph, a formula has been placed which expresses the bridging capacitance  $C_b$  as a function of the impedances  $Z(C_c)$  and  $Z(R_c)$  of the coupling capacitor  $C_c$  and the coupling resistor  $R_c$ , respectively.

The Fig. 2 feature is based on the following considerations. If the impedance  $Z(C_c)$  of the coupling capacitor  $C_c$  is lower than the impedance  $Z(R_c)$  of the coupling resistor  $R_c$  by at least an order of magnitude, the bridging capacitance  $C_b$  will vary substantially inversely proportional to the square root with frequency. That is, if the frequency increases by a factor of 2, the bridging capacitance  $C_b$  will decrease by a factor of 2 to the square root, which is 4. In contradistinction, if the impedance  $Z(C_c)$  of

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the coupling capacitor  $C_c$  is higher than the impedance  $Z(R_c)$  of the coupling resistor  $R_c$  by at least an order of magnitude, the bridging capacitance  $C_b$  will vary as a function of frequency to a relatively little extent only. As a result, any variation in the resonant-frequency impedance  $R_p$  will be compensated to a relatively little extent too.

5 If the Fig. 2 feature is applied, the bridging capacitance  $C_b$  will vary as a function of frequency to an appreciable extent within the frequency range  $FR$  of interest. This allows the coupling network  $CNW$  to substantially compensate any variation in the resonant-frequency impedance  $R_p$ , so as to maintain the source impedance  $R_g$  at a relatively constant level throughout the frequency range  $FR$  of interest. If the latter is the  
10 case, a relatively good signal-handling in terms of noise, gain and frequency characteristics will be achieved. Thus, the Fig. 2 feature contributes to good signal-handling.

Fig. 3 shows an example of a receiver in accordance with the invention. The Fig. 3 receiver receives a signal  $S(RF)$  at a radio frequency  $RF$  within the VHF-low  
15 band and converts it to a signal  $S(IF)$  at an intermediate frequency  $IF$  of, say, 40 MHz. The receiver comprises an input amplifier  $RFA$ , a tunable filter  $TUF$  and a mixer-oscillator integrated circuit  $MOIC$ . Details of the input amplifier  $RFA$ , which may comprise a further tunable filter at its input, are not shown. External components of the integrated mixer-oscillator circuit  $MOIC$  are also not shown for reason of conciseness.

20 The tunable filter  $TUF$  includes two tunable parallel resonant circuits  $PRC1$  and  $PRC2$ . Tunable parallel resonant circuit  $PRC1$  receives an amplified signal from the input amplifier  $RFA$ . Tunable parallel resonant circuit  $PRC2$  transfers an amplified and filtered signal to an input  $IN$  of the mixer-oscillator integrated circuit  $MOIC$  via a coupling network  $CNW$ . The coupling network  $CNW$  has a coupling resistor  $R_c$  having a  
25 resistance of 1 kiloOhm and a coupling capacitor  $C_c$  having a capacitance of 3.3 picoFarad. The input  $IN$  of the mixer-oscillator integrated circuit  $MOIC$  has an input capacitance  $C_i$  of, say, 2,5 picoFarad.

The two tunable parallel resonant circuits  $PRC1$  and  $PRC2$  are mutually coupled by means of two top-coupling capacitors  $C_{t1}$  and  $C_{t2}$  and a foot-inductance  $L_f$ .  
30 The two tunable parallel resonant circuits  $PRC1$  and  $PRC2$  are tuned by means of varicap diodes to which a tuning voltage  $V_t$  is applied. The varicaps, which have no reference sign, may be of the type BB133 for example. The function of other elements which have

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no reference signs will be understood by those skilled in the art. For that reason, it is not necessary to further discuss these elements.

The Fig. 3 receiver includes the following additional features. The coupling capacitance of the coupling capacitor  $C_c$  is within an order of magnitude of the input capacitance  $C_i$  at the input IN of the mixer-oscillator integrated circuit MOIC.

Furthermore, the coupling capacitor  $C_c$  and the coupling resistor  $R_c$  have substantially equal impedances at a lower end of the VHF-low band throughout which the tunable parallel resonant circuit PRC2 can be tuned. These additional features have contributed to a satisfactory performance of the Fig. 3 receiver, despite the fact that the coupling network CNW lacks a varicap diode.

The table below illustrates the operation of the coupling network CNW in the Fig. 3 receiver. In the table,  $F_{tun}$  represents a frequency to which the tunable filter TUF is tuned,  $R_p$  represents the resonance-impedance of the tunable filter TUF,  $C_b$  represents the bridging capacitance between the tunable parallel resonant circuit PRC2 and the input IN of the mixer-oscillator circuit MOIC as provided by the coupling network CNW, and  $R_g$  represents a source impedance seen, as it were, by the mixer-oscillator integrated circuit MOIC at its input IN.

| $F_{tun}$ (MHz) | $R_p$ (kiloOhm) | $C_b$ (picoFarad) | $R_g$ (Ohm) |
|-----------------|-----------------|-------------------|-------------|
| 50              | 1               | 1.59              | 151         |
| 100             | 4               | 0.622             | 159         |
| 150             | 9               | 0.308             | 108         |

The table clearly shows that, although the resonance-impedance  $R_p$  of the tunable filter TUF changes drastically with frequency, it is transformed down to an almost constant source impedance  $R_g$  by the coupling network CNW. As a result, a satisfactory signal-handling is obtained. In particular, it allows the Fig. 3 receiver to have an gain which is substantially constant throughout the VHF-low band over which it can be tuned.

The drawings and the above description thereof, illustrate rather than limit the invention. Evidently, there are numerous alternatives which fall within the scope of the appended Claims. To that respect, the following closing remarks are made.

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There are numerous ways of physically spreading functions or functional elements over various units. In this respect, the drawings are very diagrammatic and respectively represent only one possible embodiment of the invention.

5 The coupling network CNW may comprise elements in addition to the coupling capacitor  $C_c$  and the coupling resistor  $R_c$  shown in the drawings. To give an example, it may comprise an additional coupling capacitor coupled in parallel with the coupling capacitor  $C_c$  and the coupling resistor  $R_c$ . All that matters, is that the bridging capacitance  $C_b$ , shown in Fig. 1b, has a capacitance which varies as a function of frequency. To that respect, additional elements may improve the manner in which the  
10 capacitance varies as a function of frequency and, as a result, they may improve the signal-handling.

Whilst the invention can be used to great advantage in television receivers, in particular in VHF-low band circuitry thereof, applications in other types of receivers are by no means excluded.

15 Any reference signs between parentheses shall not be construed as limiting the Claim concerned.

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Claims.

1. A receiver comprising a tunable parallel resonant circuit (PRC) which is coupled to an input (IN) of a transistor circuit (TRC) via a coupling network (CNW) which includes a coupling capacitor (Cc), characterized in that the coupling network (CNW) lacks a varicap diode but includes a coupling resistor (Rc) which is coupled in series with the coupling capacitor (Cc).
2. A receiver as claimed in Claim 1, characterized in that the coupling capacitor (Cc) has an impedance ( $Z(Cc)$ ) which is lower than the impedance ( $Z(Rc)$ ) of the coupling resistor (Rc) throughout at least a portion of a frequency range (FR) throughout which the tunable parallel resonant circuit (PRC) can be tuned.
3. A receiver as claimed in Claim 1, characterized in that the coupling capacitor (Cc) has coupling capacitance which is within an order of magnitude of an input capacitance (Ci) at the input (IN) of the transistor circuit (TRC), and in that coupling capacitor (Cc) and the coupling resistor (Rc) have substantially equal impedances at a lower end of a frequency range (VHF-low) throughout which the tunable parallel resonant circuit (PRC2) can be tuned.

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