

BANDSWITCHABLE DOUBLE TUNED RF CIRCUIT WITH BALANCED
SECONDARY

The present invention relates to television tuners, and more
5 particularly to double tuned circuits for converting a single ended RF
signal to a balanced RF signal.

Frequency selective tuned circuits are often used before
and after RF amplifying stages of a television tuner. Current practice
involves the use of a double tuned filter in the signal path before a
10 mixer to further improve frequency selection and to provide better
image rejection.

It is desirable to drive the mixer in an optimum manner in
order to maximize conversion efficiency, and reduce unwanted
harmonics and image frequencies. It is common to drive a mixer, e.g., a
15 doubly balanced mixer, with a transformer. However, a transformer is
a relatively expensive component and difficult to optimize. The mixer
of the present embodiment is a Gilbert cell mixer wherein the input
circuit is arranged in a common base configuration. Such an
arrangement provides a very consistent low input impedance with
20 optimum gain, wide bandwidth, good stability and low noise when the
signal input is driven from a balanced source.

To this end, it is desirable to drive the mixer from a
transformerless balanced source and to maintain this balanced drive
when bandswitching between frequency bands.

25 Briefly, the present invention concerns a band switchable
double tuned circuit having a balanced secondary. A primary tunable
tank circuit, having a plurality of series connected first inductances, is
tuned to a first frequency by a first capacitor. A secondary tank
circuit, having a plurality of series connected second inductances, is
30 tuned to the first frequency by a second capacitor. A DC reference
potential for the circuit is coupled to a nodal junction of the plurality of
second inductances with the secondary tank circuit providing a
balanced signal output. At least one of the plurality of both first
inductances and the second inductances are signal switchable for
35 bandswitching the tuning of the primary and secondary tank circuits to
a second frequency while maintaining a balanced signal output with
signal isolation of the DC reference potential coupled to the nodal
junction.

Reference can be had to the following drawings wherein
40 like members have been assigned like designations, and wherein:

Fig. 1 is a block diagram of a portion of a typical tuner of a television apparatus.

Fig. 2 is a schematic diagram of the double tuned circuit of Fig. 1 according to the prior art.

5 Fig. 3 is a schematic diagram of a double tuned circuit of an RF tuner according to aspects of the present invention.

FIG. 1 shows a typical arrangement of a television tuner. The RF signal path typically includes, in the order named, an antenna 10 or other television signal source, a tuned circuit 12, an RF amplifier 14, and a tuned circuit 16 which desirably is double tuned in order to provide sufficient adjacent channel signal rejection. The output signal from tuned circuit 16 is coupled to a mixer 22 where it is mixed with a signal from local oscillator 24 for converting the RF signal to an IF signal 25. Tuned circuit 12, double tuned circuit 16, and local oscillator 15 24 are tuned by a tuning voltage (VT) to a selected channel or frequency. Tuning voltage (VT) typically is applied to varactor diodes. Bandswitching often is also provided for tuned circuit 12, double tuned circuit 16, and local oscillator 24, i.e., bandswitching between the VHF low frequency band of channels 2-6 (United States) and the VHF high 20 frequency band of channels 7-13 (United States).

Referring now to FIG. 2, there is shown a schematic diagram of a typical prior art arrangement for the double tuned circuit 16. Circuit 16 receives a signal from single ended RF amplifier 14, and couples the double tuned signal to the balanced input of a mixer 22. RF 25 amplifier 14 typically is a MOSFET transistor 26 wherein the signal from tuned circuit 12 is coupled to gate electrode G1 with an RF AGC signal (not shown) being coupled to gate electrode G2. The source electrode S of transistor 26 is grounded and an amplified signal is available at the drain electrode D.

30 In the lower frequency band, the signal from drain electrode D is applied to a double tuned circuit 16 comprised of:

- 1) a primary circuit of series connected inductances 28, 30 coupled between drain electrode D to an AC reference point and DC reference potential 50, and
- 35 2) a secondary circuit of series connected inductances 32, 34 coupled between a nodal point N1, and AC reference point and DC reference potential 50.

There is a coefficient of mutual inductance "M" between inductances 28, 32 and between inductances 30, 34. The primary 40 circuit is tuned to the desired frequency by varactor diode 36 coupled

across inductances 28, 30 and the secondary circuit is tuned to about the same frequency by varactor diode 38 coupled across inductances 32, 34. The capacitance of varactor diodes 36, 38 is changed by application voltage V_t applied to their respective cathodes which are 5 coupled to signal ground through respective capacitors 40, 42.

The double tuned single ended output signal from secondary node N1 is coupled to mixer 22 through series connected inductors 44, 46 and balun transformer 48. the value of inductors 44, 46 are chosen to provide a constant bandwidth with frequency over 10 the appropriate frequency band, as disclosed in U.S. Patent No. 3,628,152 of Carlson. One side of the primary of balun transformer 48 is coupled to reference point 50 with the secondary winding providing a balanced signal to the input terminals of mixer 22, which can be a single or doubly balanced mixer.

15 Bandswitching is accomplished by PIN diodes 51, 52 coupled across respective inductances 30, 34. Diodes 51, 52 are switched by bandswitching control voltage BS1 applied to their respective anodes, which are signal grounded by respective capacitors 54, 56. In the switched "on" conductive state, diodes 51, 52 signal 20 bypass respective inductances 30, 34, thus lowering the total inductance in the respective primary and secondary circuits, and raising the tuned frequency.

When bandswitching, the inductive value of constant bandwidth inductances 44, 46 is accordingly changed by the series 25 connection of PIN diode 58 and capacitor 60 coupled across inductance 44, said diode 58 also being switched by bandswitching voltage BS1.

It should be noted that the tuning varactor diodes 36, 38 require a DC return path back to the DC reference potential 50 for their respective tuning voltage V_t and this DC return path is provided by 30 their respective tuned inductances 28,30 and 32,34. In a similar manner bandswitching diodes 51, 52, and 58 require a DC return path for their respective bandswitching voltage BS1, with the return path for diode 51 being inductance 30, inductance 34 being the return path for diode 52, and inductances 44, 32, 34 being the return path for 35 diode 58. An alternate DC return path for diode 58 is inductance 46 and the primary of balun transformer 48.

A balun transformer, for providing a balanced drive to the mixer, is a relatively expensive component and the transformer can be ill behaved making performance optimization difficult across the wide 40 tuning band. A better performance across the tuning band and more

consistent performance from unit to unit can be provided by avoiding use of transformer 48 and direct driving mixer 22. This is particularly desirable since the mixer of the present embodiment is a doubly balanced Gilbert cell mixer, i.e., an MTI 3001T integrated circuit
5 manufactured by the Philips Company of the Netherlands. This mixer is driven in a grounded base configuration at about a 50 ohm impedance across a wide band of frequencies. However, with the elimination of transformer 48, conversion is now provided by double tuned circuit 16.

10 Reference is now made to Fig. 3 wherein like members shown in Fig. 2 have given like numeral designations. In the lower frequency band, the signal from drain electrode D is applied to double tuned circuit 16 comprised of:

- 15 1) a primary circuit of series inductances 28, 30 coupled between drain electrode D to AC reference point and DC reference potential 50, and
- 2) a secondary circuit of inductances 32, 34 and 62 coupled between nodal points N1 and N2.

 There is a coefficient of mutual inductance "M" between
20 inductances 28, 32, and between inductance 30 and at least one of the secondary inductances 34 and 62. The inductance values of inductances 32 and 34 are the same as in the circuit arrangement shown in Fig. 2. However, the inductance of inductance 62 is equal to the sum of the inductance of series connected inductances 32 and 34.
25 The primary circuit is tuned to the desired frequency by varactor diode 36 coupled across series connected inductances 28, 30 and the secondary circuit is tuned to about the same frequency by varactor diode 38 coupled across series connected secondary inductances 32, 34 and 62. In this arrangement, a double tuned balanced signal is
30 provided between nodal points N1 and N2.

 The DC reference potential 50 is coupled to a nodal point N3, which is the junction of secondary inductances 34 and 62. Since the inductance of inductance 62 equals the sum of the inductance of inductances 32 and 34, connection of reference potential 50 is at the
35 AC reference point for the balanced system and the AC grounding of node N3 does not change the AC signal characteristics of the secondary of double tuned circuit 16.

 The tuning of double tuned circuit 16 is accomplished by changing the capacitance of varactor diodes 36, 38 by application of
40 tuning voltage V_t applied to their respective cathodes, which are AC

coupled across their respective primary and secondary inductances by respective capacitors 40, 42. The balanced double tuned output signal from nodes N1, N2 is coupled to mixer 22 through respective series connected constant bandwidth inductors 44a, 46a, and 44b and 46b.

5 The sum of the inductance of series inductances 44a, 46a and 44b, 46b are chosen for providing a signal of constant bandwidth with frequency, over the appropriate frequency band, to mixer 22. Such a constant bandwidth arrangement is disclosed in U.S. Patent No. 3,628,152 of Carlson, which is incorporated by reference herein.

10 Bandswitching is accomplished by PIN diodes 51 and 52 coupled across respective inductances 30, and 34, 62. Switching diodes 51, 52 are switched by bandswitching voltage BS1 applied to their respective anodes, with the AC circuit being completed by respective capacitors 54, 56. In the switched "on" conductive state, diodes 51, 52
15 signal bypass respective inductances 30, 34 and 62, thus lowering the total inductance in the respective primary and secondary circuits, and raising the tuned frequency.

Since the signal from nodes N1, N2 is a balanced signal, changes made in one signal path must also be made in the other signal
20 path in order that the signal remain balanced. The values of the sum of inductances 44a, 46a, and of 44b, 46b are accordingly changed by the switching "on" of respective PIN diodes 58a, 58b by bandswitching voltage BS1. Respective capacitances 60a, 60b complete the diode circuit.

25 Tuning varactor diodes 36, 38 require a DC return path for tuning voltage V_t , and bandswitching diodes 51, 52, 58a and 58b require a DC return path for their respective bandswitching voltage BS1. This will now be discussed.

In the bandswitched mode, the balanced signal at node N2
30 is isolated from DC ground return 50 by inductances 34 and 62, which are in an AC parallel arrangement. This prevents the signal at node N2 from being short circuited to ground while still providing a DC return path for the diodes 38, 52, 58a and 58b. This AC isolation of DC ground return 50 by the parallel connection of inductances 34 and 62 is
35 effective even though inductance 30 of the primary circuit is signal short circuited by bandswitching diode 51. This is because the coefficient of mutual inductance "M" between inductance 30 and inductances 34, 62 goes to zero since there is no signal current flowing through inductance 30. Thus, an AC short circuit of inductance 30 is
40 not reflected from the primary to the secondary circuit. In this way.

the DC return path for diode 38 is through inductances 32 and 34, the DC return path for diode 52 is through inductance 34, the DC return path for diode 58a is through inductances 44a, 32, and 34, and the DC return path for diode 58b is through inductances 44b, and 62. As an
5 additional matter, for the bandswitched higher frequency mode, the AC reference point of the balanced secondary signal shifts to a virtual node within inductance 32.



CLAIMS:

1. In a television tuner, a band switchable double tuned circuit having a balanced secondary comprising:

5 a signal source for providing an RF signal at a signal terminal with respect to a signal reference potential and DC reference potential;

 a primary tank circuit comprising a first capacitor coupled in parallel with a first series circuit of a first and a second
10 primary inductances for resonating at a first predetermined frequency, the primary tank circuit being coupled to the signal terminal of the signal source in an unbalanced configuration;

 a secondary tank circuit comprising a second capacitor coupled in parallel with a second series circuit for resonating at the
15 first predetermined frequency, the second series circuit comprising in the order named a first, second and third secondary inductances, said first primary inductance and said first secondary inductance having a first coefficient of mutual inductance therebetween, said
20 second primary inductance and at least one of said second and third secondary inductances having a second coefficient of mutual inductance therebetween, the DC reference potential being coupled to a junction of the second and third secondary inductances so that the first and second secondary inductances operate together in combination with the third secondary inductance for providing a
25 balanced signal at a pair of balanced secondary output terminals;

 a first bandswitch means responsive to a bandswitch control signal coupled across the second primary inductance, and a second bandswitch means responsive to the bandswitch control signal coupled across the second and third secondary inductances for
30 causing the tuning of the primary and secondary tuned circuits to be switched from the first predetermined frequency to a second predetermined frequency;



a first and second constant bandwidth means coupled in series with one of the balanced secondary output terminals for coupling the signal to one input terminal of a balanced load, and third and fourth constant bandwidth means coupled in series to the
5 other balanced secondary output terminal for coupling the signal to another input terminal of the balanced load, and

third and fourth bandswitch switch means responsive to the bandswitching control signal, each being coupled across one of a respective first and third constant bandwidth means, for changing
10 the value of respective constant bandwidth means for each of the balanced output signals when the primary and secondary tuned circuits are bandswitched between the first predetermined frequency and the second predetermined frequency.

15 2. The television tuner of claim 1 wherein the values of the first, second and third secondary inductances are selected so that the inductance of the sum of the first and second secondary inductances equals the value of the third secondary inductance.

20 3. In a television tuner, a band switchable double tuned circuit having a balanced secondary comprising:

a signal source for providing an RF signal at a signal terminal with respect to a signal reference potential and DC reference potential;

25 a primary tank circuit comprising a first capacitor coupled in parallel with a first series circuit of a first and a second primary inductances for resonating at a first predetermined frequency, the primary tank circuit being coupled to the signal terminal of the signal source in an unbalanced configuration;

30 a secondary tank circuit comprising a second capacitor coupled in parallel with a second series circuit for resonating at the first predetermined frequency, the second series circuit comprising in the order named a first, second and third secondary inductances,



said first primary inductance and said first secondary inductance having a first coefficient of mutual inductance therebetween, said second primary inductance and at least one of said second and third secondary inductances having a second coefficient of mutual
5 inductance means therebetween, the DC reference potential being coupled to a junction of the second and third secondary inductances so that the first and second secondary inductances together operate in combination with the third secondary inductance for providing a balanced signal at a pair of balanced secondary output terminals;
10 a first bandswitch means responsive to a bandswitch control signal coupled across the second primary inductance, and a second bandswitch means responsive to the bandswitch control signal coupled across the second and third secondary inductances for causing the tuning of the primary and secondary tuned circuits to be
15 switched from the first predetermined frequency to a second predetermined frequency;

4. The television tuner of claim 3 further comprising:
a first and second constant bandwidth means coupled in
20 series with one of the balanced secondary output terminals for coupling the signal to one input terminal of a balanced load, and third and fourth constant bandwidth means coupled in series to the other balanced secondary output terminal for coupling the signal to another input terminal of the balanced load, and
25 third and fourth bandswitch switch means responsive to the bandswitching control signal, each being coupled across one of a respective first and third constant bandwidth means, for changing the value of respective constant bandwidth means for each of the balanced output signals when the primary and secondary tuned
30 circuits are bandswitched between the first predetermined frequency and the second predetermined frequency.



5. The television tuner of claim 3 wherein the values of the first, second and third secondary inductances are selected so that the sum of the inductive value of the first and second secondary inductances equals the value of the third secondary inductance.

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6. In a television tuner, a band switchable double tuned circuit having a balanced secondary comprising:

10 a signal source for providing an RF signal at a signal terminal with respect to a signal reference potential and DC reference potential;

a primary tunable tank circuit having a plurality of first inductances and tuned to a first frequency by a first capacitor coupled in parallel with the first inductances;

15 a secondary tank circuit having a plurality of second inductances inductively coupled to ones of the first inductances and having a second capacitor coupled in parallel with the second inductances for tuning the secondary to the first frequency, the plurality of second inductances having a node therebetween with a DC reference potential coupled thereto and providing a balanced
20 signal output;

at least one of the plurality of first inductances and the second inductances being switchable for bandswitching the primary and secondary tank circuits to a second frequency.