

**TUNABLE INTERSTAGE FILTER****FIELD OF THE INVENTION**

The present invention concerns a tunable interstage filter
5 useful in a tuner.

BACKGROUND OF THE INVENTION

Present day tuners do not work sufficiently well for
processing digital signals received using various digital transmission
10 systems which are currently proposed. Both the RF and IF
characteristics of the receivers need improvement since a digital signal
occupies the entire spectrum of a channel, and delay and frequency
response errors have a much more severe effect on digital signals than
on analog signals. Moreover, since the transmitted power of digital
15 signals is less than the transmitted power for analog signals, acceptable
reception of the desired digital signal can be more difficult, especially
in the presence of strong adjacent channel signals.

Towards this end, it is desirable to improve the RF filtering
in the tuner prior to the mixer, especially to reduce the effect of strong
20 adjacent channel signals.

SUMMARY OF THE INVENTION

Briefly, a tunable bandpass filter processes the RF signal
prior to the mixer. This bandpass filter has a combined high side
25 coupling portion having an increasing coefficient of coupling with
increasing frequency and a low side coupling portion having a decreasing
coefficient of coupling with increasing frequency. The two coefficients
of coupling vary with frequency inversely with respect to each other as
the bandpass filter is tuned through the frequency band.

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BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing a tuner arrangement
including a interstage bandpass filter, according to the prior art.

Figs. 2a-2d are schematics of various bandpass filter
35 arrangements with Figs. 2a and 2b showing arrangements according to
the prior art and Figs. 2c and 2d showing filter arrangements according
to aspects of the present invention.

Fig. 3 shows a tuner arrangement of Fig. 1 with the schematic
of the filter arrangement of Fig. 2d used as the interstage bandpass
40 filter, according to aspects of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Fig.1 shows an RF tuner, according to the prior art, comprising a single tuned input bandpass filter 10, a first RF amplifier 12 which typically is a dual gate MOSFET amplifier having gain which is AGC controllable, a double tuned interstage filter 14 and a second RF amplifier 16, with the output signal from amplifier 16 being coupled to a mixer (not shown) for frequency conversion of the processed RF signal. In the usual arrangement, tuning bandpass filter 14 to higher frequencies often causes the pass band response to get wider and causes an impedance mismatch between the input and output terminals of filter 14 and the respective output and input terminals amplifiers 12, 16.

Figs 2a-2d shows a plurality of double tuned interstage bandpass filters wherein components having like functions are given like designations. Fig. 2a shows a doubly tuned bandpass filter with high-side coupling, i.e., input and output tuned circuits of adjustable capacitors C1 and inductances L are coupled together by a high-side capacitor Cx (The designation C1 is used for both of the capacitors since they have substantially the same value of capacitance). Fig. 2b shows a doubly tuned bandpass filter with low-side-coupling, i.e., input and output tuned circuits of adjustable capacitors C1 and inductances L are coupled together by a low-side coupling capacitor Cy.

For the high-side coupled bandpass filter of Fig. 2a, the coefficient of coupling between input and output is approximately the capacitance value of capacitor Cx divided by the square root of the product of the capacitance values of adjustable capacitors C1. Thus, the coefficient of coupling factor k of the bandpass filter shown in Fig. 2a is inversely proportional to the value of the square root of C1. The filter shown in Fig. 2a is tuned to higher frequencies by adjustment of the values of capacitors C1 to smaller values of capacitance. Thus, the coefficient of coupling K increases with the tuning of the filter to higher frequencies. For the low-side coupling bandpass filter of shown in Fig. 2b, the coefficient of coupling between input and output is approximately the square root of the product of the capacitance values of capacitors C1 divided by the capacitance value of capacitor Cy. Thus, the coefficient of coupling K of the bandpass filter shown in Fig. 2b is directly proportional to the value of the square root of C1 (see ITT Reference Data for Radio Engineers, 4th edition, copyright 1956, page 238, for the equations for both high side and low side coupling). The filter shown in Fig. 2b is tuned

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to higher frequencies by the adjustment of the values of capacitors C1 to smaller values of capacitance. Thus, the coefficient of coupling decreases with the tuning of the filter to higher frequencies. The present inventor has recognized that the coefficient of coupling of the high side coupling filter of Fig. 2a and the coefficient of coupling of the low side coupling filter of Fig. 2b, change in an inverse relationship to each other as the values of capacitors C1 are decreased to tune the respective bandpass filters from a lower frequency to a higher frequency. The present inventor has devised new and advantageous interstage filters based upon this recognition. These are shown in Figs. 2c and 2d.

Fig. 2c shows a double tuned bandpass filter which combines the high-side coupling and low-side coupling arrangements of Figs. 2a and 2b with capacitors C1 returning to ground through capacitor Cy and capacitor Cx being coupled between the high side of capacitors C1. This arrangement of the combination of highside and low-side coupling, according to aspects of the present invention, provides a variation of the coefficient of coupling as the filter is tuned from lower to higher frequencies somewhere between the extremes of the filters shown in Figs. 2a and 2b. For example, since the coupling effects of capacitors Cx (high side) and Cy (low side) have an inverse relationship with tuned frequency, by the proper choice of values for capacitors Cx and Cy, a reasonably constant coupling factor over the entire tuning range can be obtained, as well as a reasonably constant input and output termination impedance to reduce the impedance mismatch of the interstage filter with amplifiers 12 and 16, as the filter is tuned through the band by adjustment of the two C1s.

An alternative arrangement shown in Fig. 2d, is obtained by Y-delta conversion of the filter shown in Fig. 2c. The discussion above in connection with the double tuned interstage filter of Fig. 2c concerning the coefficient of coupling vs frequency and tuning also applies to the double tuned bandpass filter shown in Fig. 2d.

A tuner arrangement for the UHF range is shown in Fig. 3 using the filter according to Fig. 2d inserted in place of the interstage filter 14 of Fig. 1. The various capacitors Cx, Cy and C1 can include parasitic and stray capacitances associated with said capacitances shown in the schematic. Inductances L are provided by stripline elements which are coupled to ground and provide a DC return for tuning varactor diodes C1. Amplifiers 12 and 16 have 50 ohm input and output impedances and provide a gain of 25dB and 8dB, respectively. Tuning of

the filter 14 is accomplished by application of an appropriate tuning voltage at terminal V_t , through resistors R , to the anodes of the matched varactor diode capacitors $C1$. The tuning voltage V_t may be generated by a microprocessor (not shown) via a DAC (not shown) for tuning the 5 interstage filter and other tunable items (not shown) to the desired frequency according to tuning voltage values read from an EPROM, as is commonplace in modern tuners. The tuning voltage may also be generated by a phase locked loop, as is also well known in the art.

10 In the exemplary embodiment of Fig. 3, amplifiers 12 and 16 are respectively MAR-8 and MAR-4 amplifiers made by the Mini-Circuits Company of Brooklyn, New York, U.S.A. Tuning capacitors $C1$ are monolithic double varactor diodes BBY62, made by the Philips Co. of the Netherlands.



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CLAIMS

1. A bandpass filter having a signal input terminal and a signal output terminal, and which is tunable over a band of frequencies from a lower frequency to a higher frequency, comprising:

5 a high side coupling portion having an increasing coefficient of coupling with increasing frequency from the lower frequency to the higher frequency;

 a low side coupling portion having a decreasing coefficient of coupling with increasing frequency from the lower frequency to the
10 higher frequency;

 the coefficient of coupling for the high side coupling portion varying inversely with frequency to the change of the coefficient of coupling for the lower side coupling portion as the bandpass filter is tuned through the frequency band.

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2. The filter of claim 1 wherein the inverse changes of the coefficients of coupling of the high side and lower side coupling portions are complementary so that the coupling coefficient of the bandpass filter between the input and output terminals remain generally constant with
20 tuning across the frequency band.

3. A bandpass filter having a signal input terminal and a signal output terminal, and which is tunable over a band of frequencies, comprising:

25 a first inductance coupled between the input terminal and reference point;

 a first capacitor coupled between the input terminal and a node;

 a second capacitor coupled between the node and the
30 reference point;

 a third capacitor coupled between the output terminal and the node;

 a second inductance coupled between the output terminal and the reference point, and

35 a fourth capacitor coupled between the input terminal and the output terminal,

 the first and third capacitors being adjustable,

 the values of the second capacitor and the fourth capacitor being chosen so that the bandpass filter will have a generally constant





coefficient of coupling when the bandpass filter is tuned across the frequency band by adjustment of the first and third capacitors.

4. A bandpass filter having a signal input terminal and a
5 signal output terminal, and which is tunable over a band of frequencies, comprising:

a first inductance coupled between the input terminal and reference point;

a first capacitor coupled between the input terminal and a
10 first node;

a second capacitor coupled between the first node and the reference point;

a third capacitor coupled between the output terminal and a second node;

15 a fourth capacitor coupled between the second node and the reference point;

a second inductance coupled between the output terminal and the reference point;

a fifth capacitor coupled between the input terminal and the
20 output terminal, and

a sixth capacitor coupled between the first and second nodes, the first and third capacitors being adjustable,

the values of the fourth and fifth capacitors being chosen so that the bandpass filter will have a generally constant coefficient of
25 coupling when the bandpass filter is tuned across the frequency band by adjustment of the first and third capacitors.

5. A bandpass filter having a signal input terminal and a signal output terminal, and which is tunable over a band of frequencies,
30 comprising:

a first inductance coupled between the input terminal and reference point;

a first capacitor coupled between the input terminal and a node;

35 a second capacitor coupled between the node and the reference point;

a third capacitor coupled between the output terminal and the node;





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a second inductance coupled between the output terminal and the reference point, and

a fourth capacitor coupled between the input terminal and the output terminal.

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6. The bandpass filter of claim 5 wherein the first and third capacitors are adjustable.

7. The bandpass filter of claim 6 wherein the values of the
10 second capacitor and the fourth capacitor are chosen so that the bandpass filter will have a generally constant coefficient of coupling when the bandpass filter is tuned across the frequency band by adjustment of the first and third capacitors.

15 8. A bandpass filter having a signal input terminal and a signal output terminal, and which is tunable over a band of frequencies, comprising:

a first inductance coupled between the input terminal and reference point;

20 a first capacitor coupled between the input terminal and a first node;

a second capacitor coupled between the first node and the reference point;

25 a third capacitor coupled between the output terminal and a second node;

a fourth capacitor coupled between the second node and the reference point;

a second inductance coupled between the output terminal and the reference point;

30 a fifth capacitor coupled between the input terminal and the output terminal, and

a sixth capacitor coupled between the first and second nodes.

9. The bandpass filter of claim 8 wherein the first and third
35 capacitors are adjustable.



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10. The bandpass filter of claim 9 wherein the values of the fourth and fifth capacitors are chosen so that the bandpass filter will have a generally constant coefficient of coupling when the bandpass filter is tuned across the frequency band by adjustment of the first and third capacitors.