

AN INTERSTAGE COUPLING NETWORK

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This invention relates to an interstage coupling network including switched reactive elements so as to pass signals in two different frequency bands.

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Interstage coupling networks couple signals from the output of one stage to the input of another stage and usually include frequency selective tunable circuits for selecting the passband of the coupled signal. Interstage coupling networks are typically included in the tuner portion of a television receiver for selecting the signals which are passed from an RF signal amplifying stage to a heterodyning mixer stage. The interstage coupling network includes tunable elements which are adjusted in response to the selected television channel for passing the proper frequency range of the received RF signals to the mixer so that the selected television signals can be processed for ultimately presenting a video and audio program to a viewer. In general, television receivers must be able to select a particular RF signal for a specified channel out of several different frequency ranges, or bands, of broadcast television signals. By way of example, in the United States, the television tuner must be capable of selecting channels for which the RF picture carrier frequency may be in the low-VHF, high-VHF or the UHF tuning band.

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Continuous tuning of an interstage coupling network from the low-VHF through to the UHF frequency band is generally not possible because of the great frequency range which must be covered. Therefore, television tuner interstage coupling networks typically include switching provisions for selecting different reactive elements for inclusion therein, depending on the frequency band of the

selected channel. Figure 1a illustrates a prior art tunable interstage coupling network suitable for use in a multiband television tuner. A tunable interstage coupling network 10 couples RF signals from a signal source 12 to a load circuit 14. Source 12 may comprise the output of an FET RF amplifying stage, represented by a current source i_s coupled in parallel with an impedance R_p , which receives television RF signals from an antenna (not shown) and supplies the full range of received RF signals to an input terminal 16 of network 10. Load circuit 14 may comprise the input impedance of a heterodyning mixer circuit and is represented by a resistor R_L which receives the selected RF signals from output terminal 18 of network 10. Network 10 includes a primary inductor 20 having one end coupled to input terminal 16 and a secondary inductor 22 having one end coupled to output terminal 18. The other ends of inductors 20 and 22, respectively, are coupled to the anodes of series-connected, oppositely-poled diodes 24 and 26. The junction of diodes 24 and 26 is coupled to a point of reference potential, such as signal ground, via a series connection of a mutual inductor 28 and a first source of switching signal V_{s1} . A series connection of two further inductors 30 and 32 is coupled in parallel with series-connected diodes 24 and 26. The junction between inductors 30 and 32 is also coupled to signal ground, via a mutual inductor 34 and a second source of switching signal V_{s2} . Variable capacitance tuning elements 36 and 38 are coupled to terminals 16 and 18, respectively, and concurrently controlled (as indicated by the dashed lines) for tuning the RF signal passband of coupling network 10 within the frequency band selected by the polarity of switching signals V_{s1} and V_{s2} .

For receiving RF signals in a first tuning band, switching signal source V_{s1} provides a high positive voltage to the cathodes of diodes 24 and 26 while source V_{s2} provides signal ground to their anodes. This biases diodes 24 and 26 into conduction and results in a

configuration for interstage coupling network 10 as illustrated in Figure 1(b). In that Figure, the forward resistance of the diodes and the equivalent inductance of their signal leads are small enough to be insignificant and therefore are not shown. A coupling network of this type is generally said to have "low-side L" inductive mutual coupling, due to the fact that the coupling between inductors 20 and 22 is substantially determined by an inductor 28, which is coupled from the junction of inductors 20 and 22 to the low side of network 10, i.e., signal ground. As is readily apparent, as the frequency of interest is increased, the impedance of inductor 28 increases, allowing for a greater coupling of signals from the primary side (input) to the secondary side (output) of network 10.

Tracking tunable elements 36 and 38 can tune a passband of e.g., 10 MHz, from the low end to the high end of the selected frequency band. The desired tuning is shown in Figure 2 for passbands tuned at the low (f_1), middle (f_2) and high (f_3) portions of the selected frequency band. Note that it is desirable that the bandwidth of the RF signal passband be relatively constant across the selected frequency band and that frequencies above the f_3 passband be sharply attenuated. In a television receiver, frequencies just above the selected tuning band may include image frequencies, which, if not substantially attenuated, can undesirably effect the quality of the reproduced picture and/or sound. Coupling network 10 exhibits a passband bandwidth variation which varies across the selected band in accordance with the cube of the frequency (f^3). It is herein recognized as desirable to compensate for this bandwidth variation by using what is generally referred to as "top-side C" capacitive coupling which comprises adding a coupling capacitor C_c such as shown in FIGURE 1(b), between terminals 16 and 18. As generally known to those skilled in the design of interstage coupling networks, capacitor C_c reduces passband bandwidth variations to approximately

2:1 across the selected frequency band and additionally forms a resonant trap circuit with the "low-side L" inductor 28 of network 10 for attenuating the image frequency signals which are just above the upper end of the selected frequency band. This effect can intuitively be understood once it is realized that low side L coupling has a positive coefficient of coupling and top side C coupling has a negative coefficient of coupling.

Therefore the top side C coupling tends to cancel the low side inductive coupling, thereby substantially compensating for the passband bandwidth variations caused by the low side inductive coupling and forms a trap circuit at the frequency wherein their coupling is equal but opposite. For the sake of simplicity, the resultant 2:1 passband variation is not shown in Figure 2, however, the effect of the image trap is clearly indicated for signal frequencies equal to or greater than the upper end of the f_3 passband.

For receiving RF signals in a second tuning band of, e.g., a lower frequency range than the first tuning band, switch signal source V_{s1} provides a low voltage to the anodes of diodes 24 and 26 while switch source V_{s2} provides a high positive potential to their cathodes. This biases diodes 24 and 26 out of conduction and results in a configuration for network 10 as illustrated in Figure 1(c). Thus, inductors 30 and 32 become part of the series connection of inductors between input and output terminals 16 and 18. Low side L inductive coupling is provided in this configuration by an inductor 34 coupled from the junction of inductors 30 and 32 to signal ground via the second source of switching signal V_{s2} . It is herein recognized as desirable to also include top side C coupling in this configuration of network 10. Due to the lower frequency of the second tuning band, the capacitance value of a top-side C coupling capacitor C'_C must be greater than the capacitance value of C_C of Figure 1(b), in order to provide an image trap for frequencies just above the high end of the second tuning band. If C_C were

used in the Figure 1(c) configuration, its capacitance value would be too low for the lower frequency tuning band of the second configuration, and the image trap would undesirably occur at a higher frequency.

5 In order to provide both C_c and C'_c in coupling network 10 of FIGURE 1(a), it would seem appropriate to simply include them in a passband shaping network connected between terminals 16 and 18 which includes a series connection of a second capacitor and a switching
10 diode in parallel with C_c such that when the diode is conductive, the parallel combination of the second capacitor with C_c would equal C'_c . However, it is undesirable to include a switching diode in the top-side C coupling circuit of FIGURE 1(a) due to its increased cost
15 and added circuit complexity. Perhaps more importantly, the signal frequency of the first and second bands may be relatively high and the parasitic reactance of the switching diode may adversely effect the equivalent top-side C coupling circuit and a proper value for C_c may
20 not be attainable. Thus, it would be desirable to connect a coupling capacitor to network 10 such that the passband bandwidth variation is minimized and the location of the image frequency trap remains at a useful position just above the upper end of each selectable frequency band.

25 In accordance with one aspect of the invention there is provided a tunable interstage coupling network comprising: an input terminal for receiving signal and an output terminal for supplying signal; first and second variable capacitance elements coupled to said input and
30 output terminals, respectively, for causing said network to tune within a selected frequency range; a series connection of more than two inductors coupled between said input and output terminals, a junction between two of said inductors being coupled to a signal reference
35 potential via a shunt inductor; switching means coupled in series with two of the inductors of said series connection and in parallel with the other(s) of the

series connected inductors, selective conduction of said switching means causing said network to assume a first configuration which effectively eliminates said remaining ones of said inductors from said network such that it is
5 tunable by said variable capacitance elements in a first selected frequency range, and selective nonconduction of said switching means causing said network to assume a second configuration which is tunable in a second
selected frequency range; and a capacitor coupled across
10 some but less than all of said inductors, said capacitor having one end coupled to one of said input and output terminals.

According to a second aspect, there is provided a tunable interstage coupling network comprising: an
15 input terminal for receiving signal and an output terminal for supplying signal; first and second variable capacitance tuning elements, one end of said first and second tuning elements being coupled to said input
terminal and said output terminal, respectively, and the
20 other ends being coupled to a signal reference potential; first and second inductors, one end of said first and second inductors being coupled to said input and said output terminals, respectively; series-coupled,
oppositely-poled switching diodes coupled between the
25 other ends of said first and second inductors, the junction of said switching diodes being coupled to a first source of switch potential via a third inductor; fourth and fifth series-coupled inductors also coupled
between the other ends of said first and second
30 inductors, the junction between said fourth and fifth inductors being coupled to a second source of switch

potential via a sixth inductor; and a capacitor coupled between said input and output terminals, such that it is coupled in series with said first inductor and in parallel with said second inductor.

- 5 According to a third aspect, there is provided an interstage coupling network comprising: an input terminal for receiving signal and an output terminal for supplying signal; a series connection of an even number greater than two of reactive elements coupled between
- 10 said input terminal and said output terminal, the midpoint junction of said series connection of reactive elements being coupled to a first signal reference potential via a first reactive shunt element; a series
- 15 connection of oppositely-poled switching diodes coupled in parallel with a portion of said series connection of reactive elements which are centered about said midpoint junction, the junction of said series-connected diodes being coupled to a second signal reference potential via a second reactive shunt element; and a third reactive
- 20 element coupled between said output terminal and a point on said series connection of reactive elements which is between said input terminal and a junction of said switching diodes with said series connection of reactive elements.

The invention will now be described by way of example with reference to the accompanying drawings in which:

FIGURES 1(a), 1(b) and 1(c) previously described, illustrate in schematic diagram form prior art tunable interstage coupling networks;

5 FIGURE 2 illustrates the desired tunable passband response for the interstage coupling network of FIGURES 1(a)-1(c);

10 FIGURES 3(a), 3(b) and 3(c) illustrate in schematic diagram form an interstage coupling network in accordance with the present invention; and

 FIGURE 4 illustrates in schematic diagram form a preferred embodiment of a tunable interstage coupling network in accordance with the present invention suitable for use in a television receiver.

15 FIGURE 3(a) illustrates a tunable interstage coupling network 310 substantially similar to network 10 of FIGURE 1(a) except for the connection of a top-side C coupling capacitor 40. In FIGURE 3(a) elements having the same function as those described with respect to FIGURES 1a to c are similarly numbered and their connection and operation will not be further described. In network 310 a single top-side coupling capacitor 40 is coupled between the junction of inductor 20 and bandswitching diode 24 and the
20 output terminal 18. The manner in which capacitor 40 can be effective in two different frequency selective bands will be described with respect to FIGURES 3b and 3c, which correspond to the configuration of network 310 for a first and a second, lower, frequency band, such as previously
25 described with respect to FIGURES 1(b) and 1(c) except that in FIGURE 3(b), L_{eq} and R represent the equivalent inductance and resistance of each of bandswitching diodes 24 and 26.

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Illustratively, the first tuning band may comprise television RF signal frequencies between 271 MHz and 463 MHz (corresponding to United States of America TV channels in what is called the superband and hyperband cable television bands), and the second tuning band may comprise television RF signal frequencies between 157 MHz and 265 MHz (corresponding to USA TV channels in the upper portion of the midband cable television band and in the high VHF broadcast band).

As previously noted, when the interstage coupling network is configured to tune the higher frequency range band, if the value of the top-side C is not changed from what it was for the lower frequency range band, it would be of a value which is too large. This would result in too much coupling of signal from input terminal 16 to output terminal 18 and would therefore not effectively control bandwidth variations, and could result in an image trap which has a resonant frequency which would fall within the passband of the higher frequency range configuration of the interstage coupling network. However, connection of capacitor 40 in accordance with the present invention prevents these undesirable results. As shown in FIGURE 3(b), capacitor 40 receives signal from the junction of inductor 20 and the equivalent inductance L_{eq} of diode 24. In a preferred embodiment of a television tuner coupling network to be described with respect to FIGURE 4, inductor 20 has a value of about 20 nH while L_{eq} has a value of about 4 nH. Thus, capacitor 40 receives signal which is substantially attenuated due to the inductive voltage divider action caused by the conduction of diode 24. This action advantageously reduces the amount of signal which is coupled by capacitor 40 to output terminal 18 (which amount of coupled signal would otherwise be too great, since the value of capacitor 40 is too high for the first frequency band) thereby delaying until a greater frequency the point at which the top side coupling cancels the low side coupling, and

consequently shifting the resonant frequency to a point just above the first tuning band.

Referring to FIGURE 3(c), in a preferred television tuner embodiment, the value of the total inductance for the series string of inductors between input and output terminals 16 and 18 may be selected such that the value of inductors 30 and 32 is at least twice as large as the value of inductors 20 and 22, respectively. In the preferred embodiment, the values of inductors 20 and 22 are approximately 20 nanohenries (nH) and inductors 30 and 32 are approximately 60 nH. Inductor 34 is approximately 10 nH. A value of 0.56 pico Farads (pF) for capacitor 40 has been found to be effective in a bandswitched television tuner interstage coupling network for controlling the passband bandwidth variation to within approximately a 2:1 variation over the entire frequency range of the second tuning band and which established an image frequency trap just above the highest frequency in the band. Since inductor 20 is of a value significantly less than the value of inductor 30, the coupling of one end of capacitor 40 to the junction between inductors 20 and 30 has relatively little effect on the proper operation of capacitor 40 with respect to passband shaping.

Thus what has been shown is the advantageous use of coupling one end of the top side C capacitor to a point common to both circuit configurations, yet near the connection point of the switching diode 24 to inductor 20 which effectively forms a voltage divider when diode 24 conducts, thereby reducing the coupling provided by the top side C capacitor and raising the resonant frequency of the image signal trap.

FIGURE 4 illustrates in schematic diagram form a preferred embodiment 410 of the interstage coupling network 310 of FIGURE 3(a). In network 410 tunable capacitors 36 and 38 are illustrated as comprising variable capacitance diodes which receive the television tuning voltage V_t for controlling their capacitance value.

V_t typically can vary from 2-25V for causing diodes 36 and 38 to have a capacitance variation from approximately 1-20 pF so as to tune from one end of the selected frequency band to the other end. DC voltage blocking capacitors 42 and 44 prevent the tuning voltage from interfering with the operation of bandswitching diodes 24 and 26. Furthermore, in accordance with a further embodiment of the invention, inductor 28 of FIGURE 3(a) is replaced by a " π " network comprising inductors 28' and 28", having first ends which are coupled to signal ground by coupling capacitors 46 and 48, respectively, and second ends which are coupled together by a printed circuit board foil strip 29. A coupling capacitor 50 couples one end of inductor 34 to signal ground. The π network is advantageous in that it allows a greater freedom in picking component values for the inductors of the interstage coupling network which are (1) of a convenient value with respect to the selected tuning band and (2) which enable a relatively good impedance match to the adjoining input and output stages. For example, suppose network 410 was required to match different impedances at input terminal 16 and output terminal 18. In this case, the ratio of the inductance of inductor 20 to that of inductor 28' can be selected independently of the ratio of inductances for inductor 22 to that of inductor 28", since foil 29, which corresponds to about 3 nH, adds a finite impedance between inductors 28' and 28".

Although the interstage coupling network has been described for use in a television receiver tuner, it is apparent that interstage coupling networks are equally effective in any application wherein multiband signals must be handled. Furthermore, although in the preferred embodiment, a specific arrangement of inductive and capacitive reactive elements is illustrated, it is apparent that a different arrangement and/or additional reactive components can also be used without departing from the scope of the invention.

CLAIMS:

1. A tunable interstage coupling network comprising:

an input terminal for receiving signal and an
5 output terminal for supplying signal;

first and second variable capacitance elements
coupled to said input and output terminals, respectively,
for causing said network to tune within a selected
frequency range;

10 a series connection of more than two inductors
coupled between said input and output terminals, a
junction between two of said inductors being coupled to a
signal reference potential via a shunt inductor;

switching means coupled in series with two of
15 the inductors of said series connection and in parallel
with the other(s) of the series connected inductors,
selective conduction of said switching means causing said
network to assume a first configuration which effectively
eliminates said remaining ones of said inductors from
20 said network such that it is tunable by said variable
capacitance elements in a first selected frequency range,
and selective nonconduction of said switching means
causing said network to assume a second configuration
which is tunable in a second selected frequency range;
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a capacitor coupled across some but less than
all of said inductors, said capacitor having one end
coupled to one of said input and output terminals.

30 2. A network according to Claim 1, wherein
said series connection of inductors includes first,
second, third and fourth inductors coupled in the named
order between the said input and output terminals and
said shunt inductor is coupled between the junction of
35 said second and third inductors and said signal reference
potential.



3. A network according to Claim 2, wherein the inductance value of said second and third inductors is at least twice the inductance value of said first and second inductors.

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4. A network according to Claim 2 or 3, wherein said switching means comprises series-coupled, oppositely-poled, switching diodes connected in series with said first and fourth inductors and in parallel with said second and third inductors.

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5. A network according to Claim 4, wherein the equivalent inductance of said switching diodes when conductive is less than the inductance of said first and fourth inductors.

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6. A network according to Claim 2, 3, 4 or 5, wherein said capacitor is coupled between the junction of said first and second inductors and said output terminal.

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7. A network according to any preceding claim, wherein said first configuration is for passing signals in a first RF television signal band and said second configuration is for passing RF television signals in a second RF television signal band having a frequency range lower than the frequency range of said first television signal band.

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8. A tunable interstage coupling network comprising:

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an input terminal for receiving signal and an output terminal for supplying signal;

first and second variable capacitance tuning elements, one end of said first and second tuning elements being coupled to said input terminal and said

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output terminal, respectively, and the other ends being coupled to a signal reference potential;

first and second inductors, one end of said first and second inductors being coupled to said input and said output terminals, respectively;

series-coupled, oppositely-poled switching diodes coupled between the other ends of said first and second inductors, the junction of said switching diodes being coupled to a first source of switch potential via a third inductor;

fourth and fifth series-coupled inductors also coupled between the other ends of said first and second inductors, the junction between said fourth and fifth inductors being coupled to a second source of switch potential via a sixth inductor; and

a capacitor coupled between said input and output terminals, such that it is coupled in series with said first inductor and in parallel with said second inductor.

9. A network according to Claim 8, wherein said capacitor has one end coupled to the junction of said first inductor to said series coupled switching diodes and the other end coupled to the network output terminal.

10. A network according to Claim 8 or 9, wherein the inductance of said fourth and fifth inductors is at least twice as large as the inductance of said first and second inductors.

11. A network according to Claim 8, 9 or 10, wherein said series-coupled, oppositely-poled switching diodes have an equivalent inductance when conductive which is equal to or less than the inductance of said first and second inductors.



12. An interstage coupling network comprising:
an input terminal for receiving signal and an
output terminal for supplying signal;

5 a series connection of an even number greater
than two of reactive elements coupled between said input
terminal and said output terminal, the midpoint junction
of said series connection of reactive elements being
coupled to a first signal reference potential via a first
reactive shunt element;

10 a series connection of oppositely-poled
switching diodes coupled in parallel with a portion of
said series connection of reactive elements which are
centered about said midpoint junction, the junction of
said series-connected diodes being coupled to a second
15 signal reference potential via a second reactive shunt
element; and

a third reactive element coupled between said
output terminal and a point on said series connection of
reactive elements which is between said input terminal
20 and a junction of said switching diodes with said series
connection of reactive elements.

13. A network according to Claim 12, wherein
said series and shunt reactive elements each comprise
25 reactive inductors and said third reactive element
comprises a capacitor.

14. A network according to Claim 13, wherein
said series connection of reactive elements comprises
30 first, second, third and fourth inductors coupled in
series in the named order between said input terminal and
said output terminal and said midpoint junction is
situated between said second and third inductors.



15. A network according to Claim 14, wherein
said series-coupled switching diodes are coupled in
parallel with said second and third inductors so as to
bypass these inductors when conductive, such that said
5 network is operable to tune within a frequency range
which is of a higher frequency than when said
oppositely-poled switching diodes are not conductive.

16. A network according to Claim 14 or 15,
10 wherein said third reactive element is coupled in series
with said first inductor and in parallel with said fourth
inductor.

17. A network according to Claim 14, 15 or 16
15 wherein, said third reactive element is coupled between
the junction of said first and second inductors and said
output terminal.

18. An interstage coupling network
20 substantially as hereinbefore described with reference to
Figures 3a, 3b and 3c or with reference to Figure 4 of
the accompanying drawings.

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