CASCADED RESONATOR WITH DIFFERENT REFLECTOR PITCH

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority under 35 U.S.C. § 119(e) to U.S. Provisional Patent Application Serial No. 62/940,075, titled "CASCADED RESONATOR WITH DIFFERENT REFLECTOR PITCH," filed November 25, 2019, incorporated herein by reference in its entirety for all purposes.

BACKGROUND

Technical Field

Embodiments of this disclosure relate to acoustic wave devices and electronic devices including same.

Description of Related Technology

Acoustic wave devices, for example, surface acoustic wave (SAW) and bulk acoustic wave (BAW) devices may be utilized as components of filters in radio frequency electronic systems. For instance, filters in a radio frequency front end of a mobile phone can include acoustic wave filters. Two acoustic wave filters can be arranged as a duplexer or a diplexer. Multiple acoustic wave filters can be connected to work as a multiplexer, which may be used for carrier aggregation (CA) in LTE Advanced.

SUMMARY

In accordance with one aspect, there is provided an acoustic wave device. The acoustic wave device comprises a piezoelectric substrate, interdigital transducer electrodes having an electrode pitch λ_0, and first and second reflector gratings disposed on opposite respective sides of the interdigital transducer electrodes in a propagation direction of a main acoustic wave through the acoustic wave device, the first reflector grating having a different electrode pitch λ_1 than an electrode pitch λ_2 of the second reflector grating to suppress ripples in a conductance curve of the acoustic wave device. Each of λ_1 and λ_2 being greater than λ_0 by between about 2% and about 5%.

In some examples, one of λ_1 or λ_2 is equal to λ_0.

In some examples, the acoustic wave device further comprises second interdigital transducer electrodes in series with the interdigital transducer electrodes, and third and fourth reflector gratings disposed on opposite respective sides of the second interdigital transducer electrodes in the propagation direction, the third reflector grating having a different electrode pitch λ_3 than an electrode pitch λ_4 of the fourth reflector grating.

In some examples, λ_1 is equal to one of λ_3 or λ_4.

In some examples, λ_2 is equal to one of λ_3 or λ_4.

In some examples, each of λ_1, λ_2, λ_3, and λ_4 is different.

In some examples, λ_1 and λ_2 may be the same throughout all electrode fingers in the first reflector grating and the second reflector grating, respectively

In accordance with another aspect, there is provided an electronic device including at least two filters coupled to an antenna node, a first of the at least two filters being a ladder filter having a series resonator closest to the antenna node. The series resonator comprises a piezoelectric substrate, interdigital transducer electrodes having an electrode pitch λ_0, and first and second reflector gratings disposed on opposite respective sides of the interdigital transducer electrodes in a propagation direction of a main acoustic wave through the series resonator, the first reflector grating having a different electrode pitch λ_1 than an electrode pitch λ_2 of the second reflector grating to suppress ripples in a conductance curve of the series resonator. Each of λ_1 and λ_2 being greater than λ_0 by between about 2% and about 5%.

In some examples, the electronic device further comprises second interdigital transducer electrodes in series with the interdigital transducer electrodes, and third and fourth reflector gratings disposed on opposite respective sides of the second interdigital transducer electrodes in the propagation direction, the third reflector grating having a different electrode pitch λ_3 than an electrode pitch λ_4 of the fourth reflector grating.

In some examples, each of λ_1, λ_2, λ_3, and λ_4 is different.

In some examples, each of λ_3, and λ_4 is greater than an electrode pitch of the second interdigital transducer electrodes.

In some examples, one of λ_1 or λ_2 is equal to one of λ_3 or λ_4.

In some examples, λ_1 and λ_2 may be the same throughout all electrode fingers in the first reflector grating and the second reflector grating, respectively

In accordance with another example, there is provided a radio frequency filter including an acoustic wave resonator. The acoustic wave resonator comprises a piezoelectric substrate, interdigital transducer electrodes having an electrode pitch λ_0, and first and second reflector gratings disposed on opposite respective sides of the interdigital transducer electrodes in a propagation direction of a main acoustic wave through the acoustic wave device, the first reflector grating having a different electrode pitch λ_1 than an electrode pitch λ_2 of the second reflector grating to suppress ripples in a conductance curve of the acoustic wave resonator.

In some examples, each of λ_1 and λ_2 is greater than λ_0. Each of λ_1 and λ_2 may be greater than λ_0 by between about 2% and about 5%.

In accordance with another example, there is provided an electronics module including a radio frequency filter including an acoustic wave resonator. The acoustic wave resonator comprises a piezoelectric substrate, interdigital transducer electrodes having an electrode pitch λ_0, and first and second reflector gratings disposed on opposite respective sides of the interdigital transducer electrodes in a propagation direction of a main acoustic wave through the acoustic wave device, the first reflector grating having a different electrode pitch λ_1 than an electrode pitch λ_2 of the second reflector grating to suppress ripples in a conductance curve of the acoustic wave resonator.

In accordance with another aspect, there is provided an electronic device. The electronics device comprises an electronics module including a radio frequency filter, the radio frequency filter including an acoustic wave resonator. The acoustic wave resonator includes a piezoelectric substrate, interdigital transducer electrodes having an electrode pitch λ_0, and first and second reflector gratings disposed on opposite respective sides of the interdigital transducer electrodes in a propagation direction of a main acoustic wave through the acoustic wave resonator, the first reflector grating having a different electrode pitch λ_1 than an electrode pitch λ_2 of the second reflector grating to suppress ripples in a conductance curve of the acoustic wave resonator. Each of λ_1 and λ_2 being greater than λ_0 by between about 2% and about 5%.

In some examples, one of λ_1 or λ_2 is equal to λ_0.

In some examples, each of λ_1 and λ_2 is different from λ_0.

In some examples, each of λ_1 and λ_2 is greater than λ_0.

In some examples, λ_1 and λ_2 are the same throughout all electrode fingers in the first reflector grating and the second reflector grating, respectively.

CLAIMS

1. An acoustic wave device comprising:

a piezoelectric substrate;

interdigital transducer electrodes having an electrode pitch λ_0; and

first and second reflector gratings disposed on opposite respective sides of the interdigital transducer electrodes in a propagation direction of a main acoustic wave through the acoustic wave device, the first reflector grating having a different electrode pitch λ_1 than an electrode pitch λ_2 of the second reflector grating to suppress ripples in a conductance curve of the acoustic wave device, each of λ_1 and λ_2 being greater than λ_0 by between 2% and 5%.

2. The acoustic wave device of claim 1 further comprising:

second interdigital transducer electrodes in series with the interdigital transducer electrodes; and

third and fourth reflector gratings disposed on opposite respective sides of the second interdigital transducer electrodes in the propagation direction, the third reflector grating having a different electrode pitch λ_3 than an electrode pitch λ_4 of the fourth reflector grating.

3. The acoustic wave device of claim 2 wherein λ_1 is equal to one of λ_3 or λ_4.

4. The acoustic wave device of claim 3 wherein λ_2 is equal to one of λ_3 or λ_4.

5. The acoustic wave device of claim 2 wherein each of λ_1, λ_2, λ_3, and λ_4 is different.

6. The acoustic wave device of any one of claims 1 to 5, wherein λ_1 and λ_2 are the same throughout all electrode fingers in the first reflector grating and the second reflector grating, respectively.

7. An electronic device including at least two filters coupled to an antenna node, a first of the at least two filters being a ladder filter having a series resonator closest to the antenna node, the series resonator comprising:

a piezoelectric substrate;

interdigital transducer electrodes having an electrode pitch λ_0; and

first and second reflector gratings disposed on opposite respective sides of the interdigital transducer electrodes in a propagation direction of a main acoustic wave through the series resonator, the first reflector grating having a different electrode pitch λ_1 than an electrode pitch λ_2 of the second reflector grating to suppress ripples in a conductance curve of the series resonator, each of λ_1 and λ_2 being greater than λ_0 by between 2% and 5%.

8. The electronic device of claim 7 further comprising:

second interdigital transducer electrodes in series with the interdigital transducer electrodes; and

third and fourth reflector gratings disposed on opposite respective sides of the second interdigital transducer electrodes in the propagation direction, the third reflector grating having a different electrode pitch λ_3 than an electrode pitch λ_4 of the fourth reflector grating.

9. The electronic device of claim 8 wherein each of λ_1, λ_2, λ_3, and λ_4 is different.

10. The electronic device of claim 8 wherein each of λ_3, and λ_4 is greater than an electrode pitch of the second interdigital transducer electrodes.

11. The electronic device of claim 8 wherein one of λ_1 or λ_2 is equal to one of λ_3 or λ_4.

12. The electronic device of any one of claims 7 to 11, wherein λ_1 and λ_2 are the same throughout all electrode fingers in the first reflector grating and the second reflector grating, respectively.

13. An electronic device comprising an electronics module including a radio frequency filter, the radio frequency filter including an acoustic wave resonator including a piezoelectric substrate, interdigital transducer electrodes having an electrode pitch λ_0, and first and second reflector gratings disposed on opposite respective sides of the interdigital transducer electrodes in a propagation direction of a main acoustic wave through the acoustic wave resonator, the first reflector grating having a different electrode pitch λ_1 than an electrode pitch λ_2 of the second reflector grating to suppress ripples in a conductance curve of the acoustic wave resonator, each of λ_1 and λ_2 being greater than λ_0 by between 2% and 5%.

14. The electronic device of claim 13, wherein λ_1 and λ_2 are the same throughout all electrode fingers in the first reflector grating and the second reflector grating, respectively.