TV Tuning Systems with SAW Comb Filter

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Abstract—We have successfully developed two TV tuning systems which apply a SAW comb filter device in a new way. One is an automatic channel indicating system and the other is a frequency synthesizer. The SAW comb filter has comb peaks at the frequencies where channels are allocated. A channel number is recognized by counting the number of comb peaks which the local oscillator signal of a tuner goes through. The SAW comb filter has a minimum electrode width of 1 μm. It has four sets of IDT's to cover all TV channels, fabricated on a single chip.

I. Introduction

TODAY surface acoustic wave (SAW) devices are used in various products in the field of consumer electronics, such as TV receivers, FM radio tuners, video games, etc., and it is recognized that they are very effective for both performance improvement and cost reduction, with the TV IF filter as a good example [1]–[3]. However, all the SAW devices mentioned above are bandpass filters, with operating frequencies limited to the range of 10 to 100 MHz.

This paper aims to adapt an SAW device to a TV tuning system which is a new field for SAW device applications. TV receivers have reached a stage where electronic tuners are widely used instead of mechanical ones. In an electronic tuner, the tuning frequency is controlled by a tuning voltage which is applied to variable capacitance diodes used in resonant circuits. Many kinds of digital tuning systems have been developed. They can be classified into two basic systems: voltage synthesizer utilizing a digital-to-analog converter and a semiconductor memory device, and frequency synthesizer utilizing a 1-GHz prescaler.

We have already successfully developed a tuning system based on the former type [4], which is constructed with a tuning LSI including a D/A converter and a nonvolatile memory. When a channel button is selected, the tuning LSI reads the tuning voltage data which were previously stored in the nonvolatile memory, and converts them into the tuning voltage by the D/A converter. This tuning system features "one-touch" tuning and "one-touch" automatic search preset, simplified operation, and improved reliability. However, this system cannot indicate channel numbers automatically. No two electronic tuners, to which the same tuning voltage is applied, can tune to the same channel, because each has its own characteristic of the tuning frequency with respect to the tuning voltage. Therefore, we cannot recognize a channel number in terms of a tuning voltage.

Frequency synthesizing directly controls the frequency, so a channel number indication is easily achieved. But it is expensive on account of a 1-GHz prescaler and a high-speed PLL (phase locked loop) digital LSI. Therefore, in order to feature voltage synthesizing with a channel indication, we have developed a new channel indicating system. Furthermore, we have developed a new cost-effective frequency synthesizer, which is an expanded system derived from the channel indicating system. The key device employed in these systems is a newly developed SAW comb filter [5], which is designed to have its comb peaks at the frequencies where channels are allocated. Operating frequency of this SAW comb filter approaches 1 GHz (consequently, the electrode width is about 1 μm) and the bandwidth is very wide covering all TV channels. We have already developed the SAW device with 1-μm geometry in 1978. We have been mass-producing the channel indicating system since January 1979, and the SAW frequency synthesizer since October 1980.

II. SAW Comb Filter

A. Principle of the SAW Comb Filter

Fig. 1 (a) shows a fundamental structure of the SAW comb filter. One input interdigital transducer (IDT) and two output IDT's are formed on a piezoelectric substrate. When the delay time between two output IDT's is τ, the signals V_1 and V_2 on the output IDT's 1 and 2, respectively, are expressed as

$$V_1 = A_1 \exp(-j2\pi ft) \tag{1}$$

$$V_2 = A_2 \exp(-j2\pi f(t-\tau)) \tag{2}$$

where A_1 and A_2 are amplitudes, f is frequency, and t is time. Assuming $A_1 = A_2 = A$ for convenience, the amplitude V of the added signal is given by

$$V = |V_1 + V_2| = 2A\cos(\pi f\tau). \tag{3}$$

Equation (3) shows that V is maximum when $f = n/\tau$ and minimum when $f = (n+1/2)/\tau$, where n is an integer. The frequency interval Δf between successive maxima or minima is given by

$$\Delta f = 1/\tau. \tag{4}$$

Fig. 1 (b) illustrates the frequency response of the amplitude V, which has peaks and bottoms with the constant frequency interval Δf.

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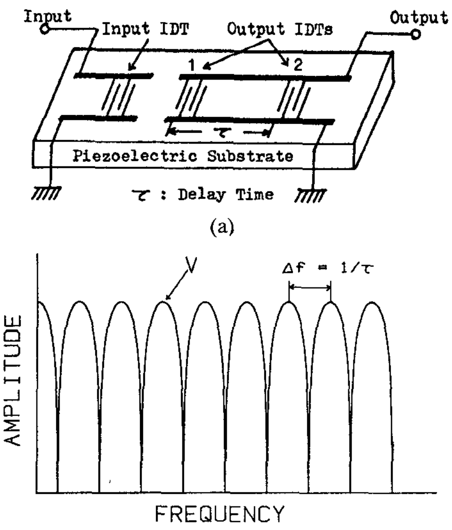


Fig. 1. SAW comb filter. (a) Fundamental structure. (b) Frequency response.

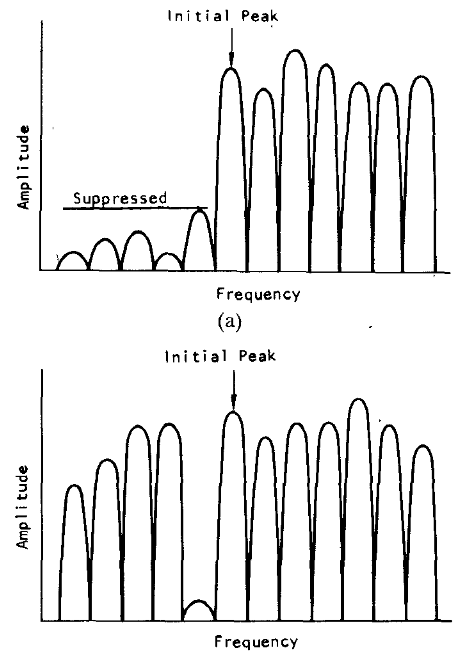


Fig. 2. Initial peak designation.

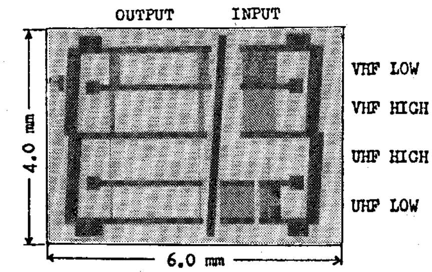
Since TV channels are basically allocated at an equal frequency interval, the SAW comb filter is designed so that it has comb peaks at the exact local oscillator frequencies where channels are located. Fig. 1 (b) illustrates V if A is independent of frequencies. The envelope of the comb filter characteristic can easily be modified by means of apodizing the input IDT.

B. Initial Peak Designation

When a swept local oscillator output of an electronic tuner is put into the SAW comb filter, the output amplitude V changes as shown in Fig. 1 (b). Therefore, the relative change in instantaneous frequency is approximately known by means of counting the number of peaks. But in order to get the absolute frequency value, it is necessary to designate the initial peak to start counting.

Fig. 2 shows the principles of initial peak designation. In Fig. 2 (a) the frequency response below the initial peak is sufficiently suppressed by using an apodized input IDT and an additional grating reflector. In this case the IDT is complicated and transmission loss increases. But it is easy to detect the initial peak without any additional logic circuit.

In Fig. 2 (b), at least one peak below the initial one is



		Input IDT	Grating Reflector	Output IDT
VHF Band	Low	Apodized Split N=30.5 pairs W=2.0 μm		Unapodized N=10 pairs x 2 W=5.4 μm
VHF Band	High	Apodized Split N=46.5 pairs W=1.2 μm		Unapodized N=8 pairs x 2 W=3.4 μm
UHF Band	Low	Apodized N=61.5 pairs W=1.2 μm	N=200 W=1.7 μm	Unapodized N=7 pairs x 2 W=1.4 μm
UHF Band	High	Unapodized N=4 pairs W=1.1 μm		Unapodized N=4 pairs x 2 W=1.1 μm

N: Number of electrodes
W: Minimum electrode width

Fig. 3. IDT layout and construction.

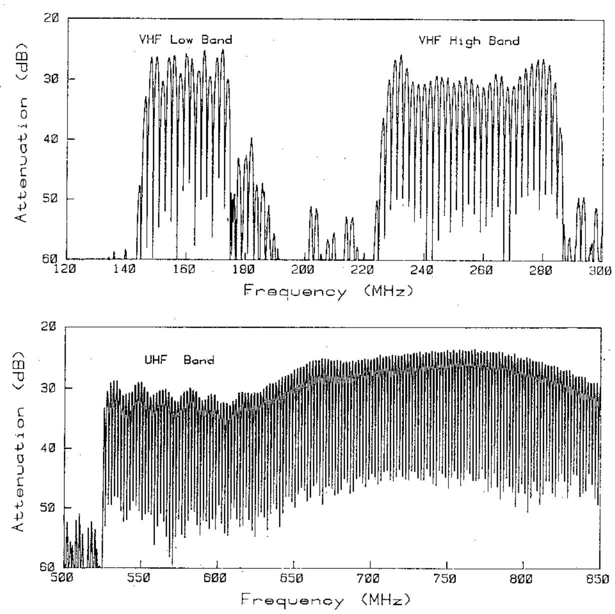


Fig. 4. Frequency characteristics of SAW comb filter.

suppressed by using the grating reflector. The initial peak is detected by means of measuring the time interval between peaks during the frequency sweep. In this case simple, unapodized IDT's are used so that the transmission loss is less than in Fig. 2 (a).

III. TV Channel Indicating System

A. Frequency Response of the SAW Comb Filter

In order to cover all the TV bands (VHF low band: 150–162 MHz, VHF high band: 230–276 MHz, UHF band: 530–824 MHz, in Japan), the SAW comb filter chip has four sets of input and output IDT's. Fig. 3 shows the IDT layout and the IDT construction of the filter. The frequency interval Δf is designed to be 2 MHz, because of the irregular channel separation of 4 MHz between channel 7 and channel 8 against the normal separation of 6 MHz in Japan. The frequency characteristics of the filter are shown in Fig. 4.

B. System Construction

Fig. 5 shows a block diagram of the developed channel indicating system, which is constructed with three major sections: the voltage synthesizing tuning section, the analog

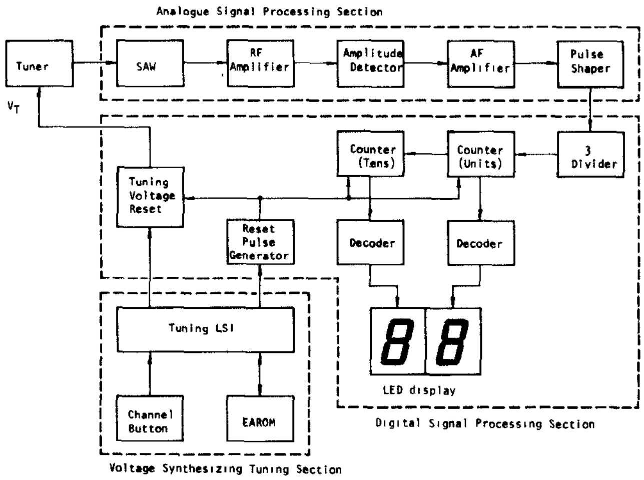


Fig. 5. Block diagram of channel indicating system.

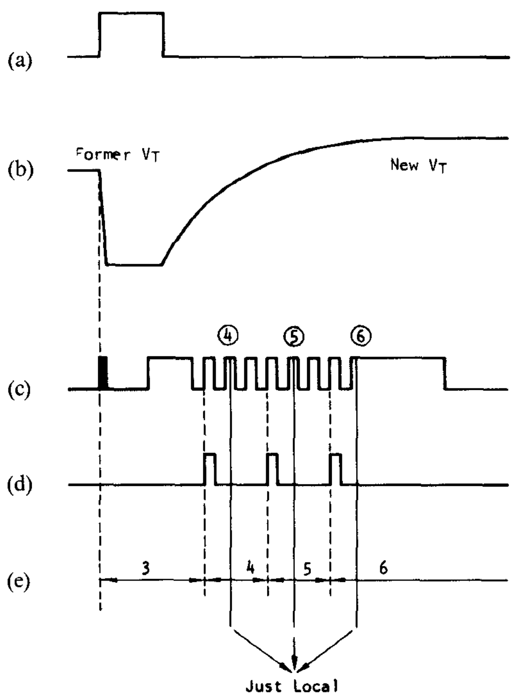


Fig. 6. Timing chart of channel indication system. (a) Reset pulse. (b) Tuning voltage. (c) Analog section output. (d) 3-divider output. (e) Counter data.

signal-processing section including the SAW comb filter, and the digital signal-processing section. Fig. 6 shows the timing chart in the case when channel 6 (in Japan) is selected. When a channel button is selected, the tuning LSI reads the tuning voltage data which were previously stored in the nonvolatile memory (EAROM: electric alternative read-only memory), and converts it into the tuning voltage by a PWM (pulsewidth modulation) type D/A converter included in an LSI chip. At the same time, the tuning voltage reset circuit makes the tuning voltage once fall down to zero (Fig. 6 (a), (b)). Then the tuning voltage starts going up to the predetermined value which makes the tuner tune to the addressed station. The output of the swept local oscillator is picked up and applied to the SAW comb filter. In the analog signal-processing section, the output of the filter is amplified and then detected by the amplitude detector. The output of the detector is amplified and reshaped to rectangular pulses (Fig. 6 (c)).

In the digital signal-processing section, reshaped pulses are divided by three and then applied to the BCD (binary-coded decimal) counter (Fig. 6 (d)). The BCD counter counts these pulses upward from the initial value 00, 03, or 12, respectively, when the VHF low band, the VHF high band, or the UHF band is addressed. The counter data increase step by step up to 6 as shown in Fig. 6 (e). The decoder decodes this number into the seven segment data

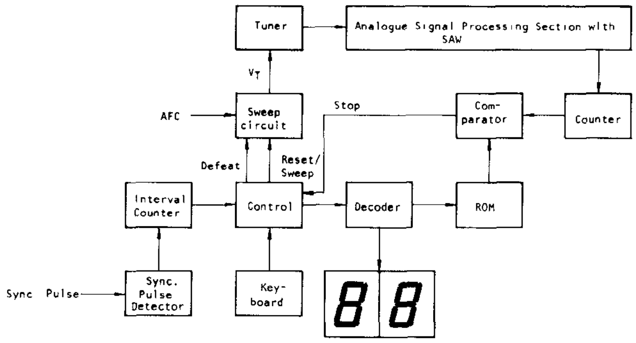


Fig. 7. Block diagram of SAW frequency synthesizer.

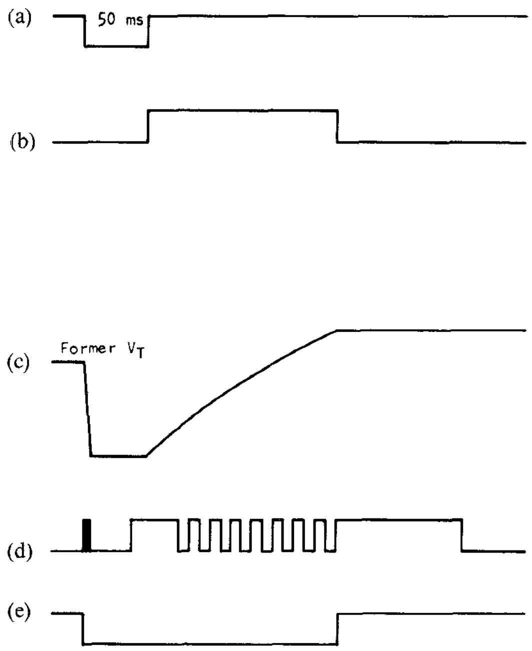


Fig. 8. Timing chart of SAW frequency synthesizer. (a) Reset pulse. (b) Sweep. (c) Tuning voltage. (d) Analog section output. (e) Comparator output.

and drives the LED display. The indication range is from 2 MHz below to 4 MHz above the exact tuning point as shown in Fig. 6 (e).

IV. SAW Frequency Synthesizer

A. *System Principle*

Fig. 7 shows a block diagram of the frequency synthesizer utilizing the SAW comb filter, and Fig. 8 shows the timing chart. When a station is selected through the keyboard, the decoder drives the LED display and at the same time the sweep circuit makes the tuning voltage go to zero, followed by a gradual increase. Consequently, the local oscillator frequency is swept, and periodic pulses corresponding to peaks of the SAW comb filter come out of the analog signal-processing section as mentioned above. The counter counts these pulses. The counter data are compared with the ROM data which were previously determined according to the channel number. When the coincidence is found among these data, the comparator produces the stop signal which is applied to the sweep circuit. If there is an available station near the stopped frequency, that station is received at the exact tuning point by means of an AFC.

If there is no station at the selected channel, the tuning voltage holds the stopped value. However, it is difficult to hold it for a long period. Therefore, the same channel is automatically selected at regular time intervals. The automatic refreshment is achieved by the sync pulse detector and the time interval counter.

B. *"One-Touch" Tuning System*

We described an SAW frequency synthesizer which selects a station by entering the channel number through the keyboard. In this system, a two-button operation is always required for each broadcast channel and it is, therefore, cumbersome. We propose a more progressive tuning system utilizing the SAW frequency synthesizing system, which has a "one-touch" tuning function, a "one-touch" automatic preset, and an automatic digital channel indication.

This system first begins a tuning search from the lowest channel on and memorizes the channel number of all available stations step by step in a nonvolatile EAROM, completely automatically. When a channel button is selected, it reads the channel number stored in the EAROM and tunes the selected station through the SAW frequency synthesizing operation.

V. Conclusion

We have successfully developed two TV tuning systems which apply an SAW device in a new way. One is the automatic channel indicating system which uses voltage synthesizing with a channel indication. The other is frequency synthesizing utilizing an SAW comb filter, which is an expanded system derived from the former one. In these systems, a newly developed SAW comb filter is introduced, which has comb peaks at the frequencies where channels are allocated. A channel number is recognized by counting the number of comb peaks which the local oscillator signal goes through. In the SAW frequency synthesizing, a channel is selected by sweeping the local oscillator frequency until the number of comb peaks coincides with the predetermined number according to the channel number.

These systems are also applicable to any system such as NTSC, PAL, and SECAM, and furthermore to CATV receivers.

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Implementation of Satellite Communication Systems Using Surface Acoustic Waves

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Abstract—**Current performance of surface-acoustic-wave (SAW) devices offers several advantages in the construction of digital communication networks. Experimental examples of delay lines, filters, oscillators, etc., used for the modulation, the frequency conversion, and the demodulation of *n*-phase-shift-keyed (PSK) digital signals are described and present results are reported. These devices, especially designed for satellite communication systems, operate in the range 70 MHz to 1 GHz where the surface-wave technology allows reduction in size and weight combined with ruggedness and reliability.**

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I. Introduction

This paper identifies and describes the subunits of equipment involved in a satellite digital communication link where applications of surface-acoustic-wave (SAW) devices can improve significantly their design.

After a brief review of the essential features of the 2- and 4-PSK modulation, the first section deals with the trans-

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