COMMERCIAL APPLICATION OF A SURFACE WAVE TELEVISION IF FILTER

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ABSTRACT

An acoustic surface wave filter is ideally suited to form the selectivity block in a color T.V. IF. The paper discusses, in some detail, the requirements for the frequency response of a T.V. IF and compares those to the results obtained by means of a surface wave filter. The configuration of the surface wave filter is shown and the fabrication method, very similar to that of integrated circuits, is described. The electrical properties are compared to properties of standard IF's. The initial reaction of television engineers is favorable; the filter described is a first generation commercial device and further improvements can be expected.

Introduction

Soon after the development of the interdigital (ID) surface acoustic wave transducer, it was realized that such devices could be made to provide the main selectivity for a color television set. In addition to the general similarities between the frequency response of a simple surface wave device and the required response of a color television IF amplifier, several other contributing factors are worthy of note:

1) The center frequency of a color T.V. IF is an almost ideal range for surface wave devices, requiring only a modest amount of piezoelectric material, while not requiring very critical photofabrication processes.

2) The filter response requirements are fairly complex. Surface wave filters can meet such requirements at modest cost, while complex conventional filters need many elements.

3) Color television sets are mass-produced. Surface wave devices offer significant advantages in reproducibility and ease of IF adjustment.

Considerable effort has been expended, at Zenith and elsewhere, in the development of surface wave filters for color T.V. It is the purpose of this paper to describe such a filter: the requirements placed on it by its surrounding circuitry, the design and fabrication of the filter itself, and the performance results obtained from limited quantity production of such a device.

General Requirements of the IF Amplifier

The filter must have a relatively large bandwidth, of about 10 percent, to pass a 6 MHz T.V. channel. To eliminate interference from adjacent channels, however, it must have steep slopes and high out-of-band rejection; particularly large attenuation is required at a few specific frequencies which correspond to sound or picture carriers of adjacent channels that might be much stronger than the desired signal.

Figure 1-a shows a conventional IF design.[1] The circuit block marked A_1 provides most of the required IF gain, controlled by the automatic gain control AGC, and essentially all of the selectivity. It consists of single stage transistor amplifiers coupled by tuned circuits which provide the selectivity and increase the gain of each stage by tuning out the transistor capacitances. The circuit block marked B includes a driver amplifier stage, a sound detector which heterodynes the 41.25 MHz sound carrier against the 45.75 MHz picture carrier of the desired channel, thus obtaining a 4.5 MHz secondary sound carrier, a video detector preceded by a 41.25 MHz sound trap (an LC circuit) which prevents a 920 kHz beat between the sound carrier and the 42.12 MHz color carrier, and finally circuits required for automatic frequency control (AFC).

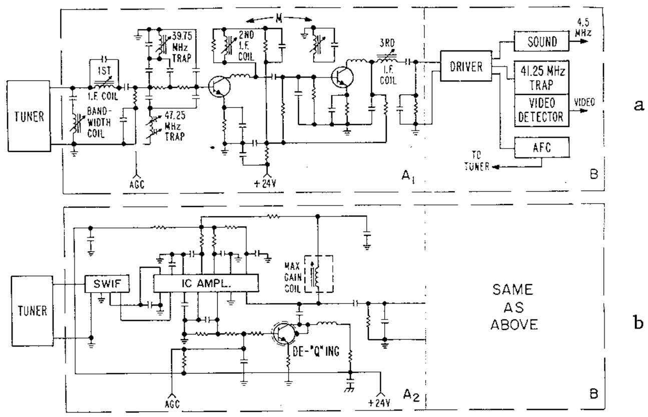

Figure 1. Block diagrams, including some detailed circuit diagrams, comparing the SWIF IF (A_2B) to a conventional IF (A_1B).

Figure 1-b shows a SWIF (Surface Wave Integrated Filter) IF. Following a conservative design approach for the initial introduction of a brand-new component, this version is intended to be interchangeable with the standard IF, requiring that circuit block B be left unchanged. The circuits in block A_2 now mainly consist of the surface wave integrated filter, which provides essentially all of the selectivity, and a wideband I.C. amplifier which supplies all the gain and gain control. The circuit is greatly simplified, as most of the coils and all critical capacitors in block A have been eliminated. It should be stressed that this initial approach does not take full advantage of the design possibilities opened by the SWIF; by allowing changes in circuit block B or by using different detector schemes, further simplifications and improvements are possible.

The frequency response of a SWIF IF, as measured just ahead of the video detector, is compared with that of the standard IF in Figure 2. Generally, the SWIF IF compares favorably with the standard IF.

Filter Design and Fabrication

The filter itself consists of a small (.140" x .455") polished piece of $LiNbO_3$ with aluminum thin-film transducer patterns photoetched on the polished surface (see Fig. 3). One of the transducers (T_1) is apodized: the finger lengths and widths are not constant throughout the transducer. This transducer provides most of

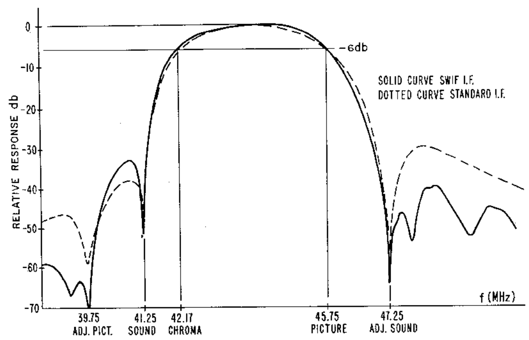

Figure 2. Comparison of the response at the luminance detector of the SWIF IF with that of a conventional production IF.

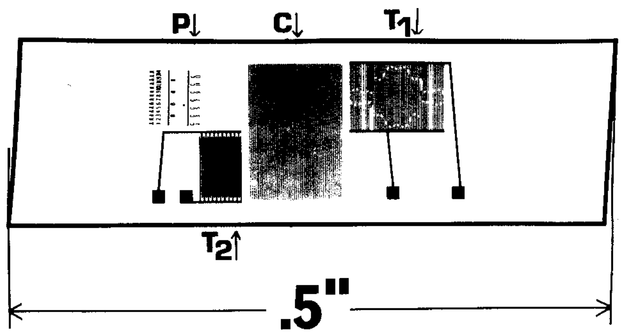

Figure 3. Surface wave filter element fabricated on a $LiNbO_3$ substrate. The two transducers (T_1 and T_2) are coupled by means of a multistrip coupler C. The pattern P serves to identify the position of the filter element on the wafer.

of the selectivity of the device, including zeroes in the response at 39.75 MHz and 47.25 MHz. A description of the synthesis of this apodized transducer is found elsewhere.[2,3]

The other transducer (T_2) has uniform finger lengths and widths. Its sin x/x frequency response adds about 15dB attenuation at the two traps, as well as additional out-of-band rejection beyond the traps.

The two transducers are acoustically coupled by means of a multistrip coupler (C) which diverts surface waves from the upper track where they were generated by transducer T_1, to the lower track, where they can be intercepted by receiver transducer T_2. This is necessary because surface wave transducers also generate spurious waves which travel through the bulk of the material and are reflected from the bottom surface. If both transducers were located directly opposite each other, interference between the surface waves and bulk waves would degrade the upper trap and out-of-band rejection. The multistrip coupler diverts only the surface waves to the lower track; bulk waves stay in the upper track region and are thus ignored.

Pattern P is an identification pattern used to determine the position of a particular chip on a wafer, shown in Figure 4. Thirty-six devices are made on a single wafer of $LiNbO_3$ using standard photolithographic techniques, as used in integrated circuit technology. A disc is coated with 5000Å aluminum, then with a layer of photoresist. The coated disc is placed in contact with a photographic mask and exposed to ultraviolet light. The photoresist is developed, the exposed aluminum is etched away, and the remaining photoresist is cleaned off, resulting in a disc with

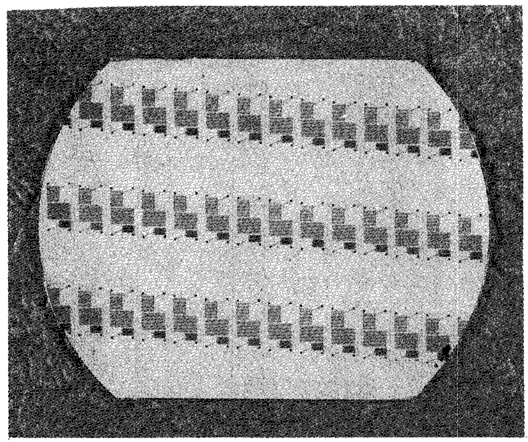

Figure 4. Lithium Niobate wafer (0.020 in. thick), containing 36 filter elements.

thirty-six devices shown in Figure 4.

After photoetching, the disc is deepscribed with a standard semiconductor saw. Breaking the discs apart then provides individual filter elements which are ready for packaging and electrical test.

Originally, these devices were packaged in a ceramic single-in-line package, which was sealed with an epoxy pre-formed gasket. Since such a package will not pass accelerated humidity tests, a modified TO-8 package has been selected. This hermetic TO-8 package configuration is shown in Figure 5.

The $LiNbO_3$ chip is attached to the header by means of a conductive epoxy preform, which also provides a good ground plane at the bottom of the crystal to minimize electromagnetic feedthrough. After microbonding gold wire connections between the package leads and the transducer bonding pads, an acoustically lossy material is applied to the ends of the crystal to absorb surface wave reflections. The cap is then welded on, and the device is electrically tested.

Experience to Date with Surface Wave Filters

In general, the reaction of television engineers to surface wave filters has been quite favorable. Since a new device must perform at least as well as, if not better than, the parts it replaces, it is worthwhile to note that the positive reaction of television engineers to SWIFs is due to advantages in the following areas:

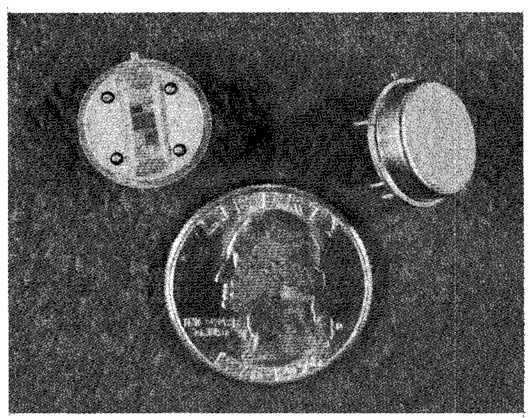

Figure 5. SWIF TO-8 package.

1. Frequency Response We have already shown in Figure 2 that the first-generation SWIF IF compares quite favorably with the standard IF. In general, complex filter responses can be realized using SWIFs.

2. Phase Response Unlike conventional LC filters, a surface wave filter is not a minimum phase network. Phase response can be specified independently of amplitude response. A linear phase system reproduces most faithfully the envelope of an input waveform. In standard IF's the phase response usually deviates strongly from linearity, specifically at frequencies where the amplitude response varies rapidly. In surface wave filters the phase response can be made linear, even in regions of deep traps with steep slopes.

3. Transient Response The transient response is completely determined by the amplitude and phase response. In surface wave devices, more than in regular filters, spurious effects have to be carefully controlled. The time delay of spurious responses caused by triple-transit, reflections of surface waves against edges, or by undesired electromagnetic feedthrough usually differs by a few microseconds from the delay of the desired signal. The amplitude of such spurious pulses, shown in Figure 6, should be at least 40dB below the desired response, otherwise ghosts may be detected in the picture.

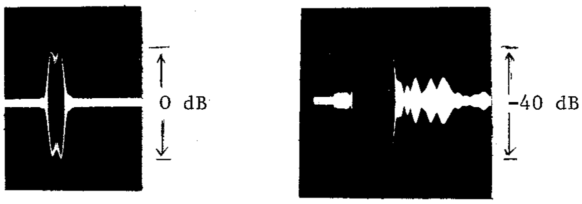

Figure 6. Measured burst response of T.V. IF filter. The burst frequency is 45.75 MHz and the duration is 0.5 μs. The pulse response at the output of the filter is shown at two levels of amplification. The response following the main burst is caused by a combination of spurious modes and triple-transit signals.

4. Regeneration Regeneration, caused by slight electromagnetic coupling between the output of an IF and the input or any other point in the IF will affect the frequency response. This is found to be much less troublesome in the SWIF IF than in a conventional one. As a result, circuit layout is much easier.

5. Ease of IF Adjustment Although the SWIF itself is fixed and needs no adjustment, the circuits used in this first generation SWIF IF still have some adjustments. However, the number of factory alignments is reduced from 16 to 8 steps in the subassembly stage, and from 6 to 1 in the final assembly.

6. Reproducibility and Stability The reproducibility of the filter is excellent. The attenuation at any specific frequency in the passband varies no more than a few tenths of a dB. The frequency accuracy of the filter is presently specified to be better than $\pm$ 0.2 percent; about half of that tolerance is due to velocity variations inherent in the material, one third is due to allowable misalignment of the filter with the crystal axes, and the rest to miscellaneous causes. An improvement in frequency accuracy to $\pm$ 0.1 percent should be feasible in the future.

7. Reliability It is expected that the reliability of an hermetically packaged SWIF will be high. No failure modes have been found.

8. Temperature Stability The temperature coefficient of a SWIF is completely determined by the variation of surface wave velocity on the $LiNbO_3$ substrate: -90 ppm /°C. Although a lower temperature coefficient would be desirable, the variations caused by this temperature drift can be tolerated.

9. Insertion Loss Surface wave filters are usually lossy. Tuning the transducer capacitances with coils can reduce the losses but makes the response more prone to variations, and in general increases the triple-transit echos. In this first generation SWIF IF, the filter has an insertion loss of 19.7 dB.[1]

10. Cost The cost of a mass-produced surface wave filter for a color television set is presently estimated at between $1 and $2, making a SWIF IF somewhat more expensive than a standard IF. In such a cost comparison, it is difficult to estimate the savings obtained by some of the advantages stated above, such as better reproducibility, fewer factory and service adjustments, etc. Greater economies can probably be realized as the technology develops.

Conclusion

Surface wave filters can profitably take over the function of providing the main selectivity of a color television set. Experience gained through small quantity production has demonstrated numerous advantages of surface wave technology for this application. Still more improvements can undoubtedly be realized in the near future.

References

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3. J. Rypkema, A. DeVries and F. Banach, "Engineering Aspects of the Application of Surface Wave Filters in Television IF's", IEEE Transactions on Consumer Electronics, Vol. CE-21, No. 2, May 1975, p. 105.