SAW BASED DIRECT FREQUENCY SYNTHESIZERS

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ABSTRACT

Many new electronic systems, including spread spectrum links, require frequency synthesizers capable of providing accurate signals of high spectral purity, yet hopping in fractions of a microsecond. Three such synthesizers, based on comb generators, SAW filterbanks, and fast switches, are described. Each of these synthesizers has an output of one of over 200 frequencies of integral MHz value, at approximately 1.3 GHz.

Introduction

Surface acoustic wave(SAW) components offer a compact, cost-effective way to make a variety of components, including filters, delay lines, and correlaots. Although any of the standard approaches to frequency synthesis, i.e., phase-locked-loop oscillators, digital synthesis, and direct synthesis, may benefit from SAW components to reduce size and cost, the direct synthesizer is most appropriate for fast frequency-hopping. A now-proven approach to achieving a combination of sub-microsecond hopping, frequency precision(as good as that of the reference clock), high spectral purity, and moderate cost, is the use of a comb generator and a switchable SAW filterbank. We have previously published[1] and patented[2] such an approach, which is useful for rapid hopping among a small number(less than 50) of frequencies, as a filter is required for each output frequency available. Where more output frequencies are required, mixing the output of such synthesizers allows obtaining a much larger number of frequencies per filter. In a design which allows use to be made of all combinations of frequencies obtained by mixing, the number of tones which may be obtained is the product of the number of filters in each bank. I. e., if there are two elementary SAW synthesizers, one producing 4 tones and the other 8, the mixing of these outputs will allow any of 32 tones to be generated, while requiring only 12 filters. If the synthesizer can be designed so that the 4 tones are a subset of the 8, then the 32 tones can be obtained while only using 8 filters.

Approach

In this paper we present three different approaches to the set of specifications given in Table 1.

Table 1
Synthesizer specifications

Frequency range	1369–1609 MHz
Frequency spacing	1 MHz
Spurious tones	63dB down
Noise (dB/Hz)	120dB down
Switching speed	0.5 microseconds

Technical Problems

These specifications for the overall performance of the synthesizer in turn place requirements on each component. Efficient generation of comb spectra, while achieving high spectral purity and locking to the reference frequency of each tone, high isolation in SAWs, switches, and packaging, and high signal-to-noise ratios, were some of the major problems encountered.

Comb Source

All of the signals which appear in the synthesizer output arise from combining tones which originate from the comb source. The purpose of the filtering and switching which follows each comb source is to select the required tones-they do not change the character of the tones, which must have low close-in noise and spurious within specifications. Two approaches to comb generation have proven satisfactory. A CW signal of frequency equal to the required tone separation of the comb can be passed through a snap diode to generate the desired sequence of harmonics which is the required comb. Although conceptually simple, this technique is inefficient, as it yields a great deal of energy in the harmonics far lower in frequency than the ones desired for the comb. By generating the comb at a relatively low level, then passing it through a bandpass filter and amplifying, most of the energy can be placed in the desired portion of the spectrum.

A more efficient approach is to generate a CW signal at the center of the desired band, then coherently gate this tone at the required channel spacing. This yields a comb spectrum with its energy concentrated in the required band.

In each case, the time domain structure of the comb reveals a high peak-to-average power ratio, which increases power handling requirements and therefore costs of the amplifiers, as well as power consumption. In one of the synthesizers, this limitation was overcome by putting a SAW chirped filter immediately after the gated source, thereby leveling out the time domain signal while retaining the desired comb structure in the frequency domain.

Still another approach is the mode-locked SAW oscillator[3]. It has the unusual property of being a comb oscillator. It consists of a loop consisting of a SAW filter designed to pass the required comb, an amplifier, and a non-linear element which maintains the full bandwidth of the comb rather than allowing it to oscillate only at the single lowest insertion loss frequency which satisfies the phase conditions for oscillation. Although a mode-locked SAW oscillator was used as one of the sources for our in-house synthesizer, it needs additional work to achieve satisfactory performance over a wide temperature range.

SAW Design

The specifications present two major difficulties. In order to achieve an architecture which maintains the inherent efficiency of this concept, it is necessary to keep the filtering at least as high in frequency as 250 MHz. I. e., one of the main advantages of the SAW synthesizer is that it avoids the multiplying up from a crystal oscillator frequency, with the inherent signal degradation and the high multiplier power consumption. The high

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performance dictated by the low allowable spurious level implies that double electrode transducers are necessary. This, in combination with the relatively high operating frequencies, requires line widths in the vicinity of 1 micrometer.

The other difficulty, also associated with the spurious specification, is that second-order effects, such as other acoustic modes and electromagnetic leakage, become highly significant.

With very careful and pragmatic design, including control of the above phenomena plus diffraction, it was possible to satisfy the requirements.

An alternative approach, used for two of the synthesizers, was to cascade two SAW filters to accomplish each of the required filtering functions.

Interconnection of the filters within each filterbank presented another set of problems. The goals of any interconnection or multiplexing technique are as follows: 1) insertion loss minimization, 2) insertion loss uniformity among channels, and 3) small size and low cost. Use of an optimized series-parallel interconnection scheme[4] or a constant-k ladder[5] achieved these requirements.

Switches

Even if perfect comb spectra and SAW filters could be attained, the performance of a synthesizer would still be limited by the switches. Two of the synthesizers used commercially available switches, which proved to be marginal in performance. I. e., specified isolation was achieved in most, but not all, channels. On the other hand, the third synthesizer developed a custom hybrid circuit, which included the development of 1x4 switches. These switches not only were satisfactory, but their incorporation into the custom circuit allowed a great savings in space.

Conclusion

All three synthesizers demonstrated that the SAW synthesizer approach can yield a compact, high performance synthesizer. The version developed by TRW, in particular, which incorporated a special mix-and-divide custom circuit, appropriate to the iterative synthesizer approach used, shows potential for being reduced to 50 cu. in.

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