DESIGN OF SAW EXPANDER AND COMPRESSOR ON $LiTaO_3$ FOR A TCDMA SPREAD SPECTRUM SYSTEM

L. Reindl[1], F. Kalabic[2], G. Ostermayer[2], A Pohl[2], F. Seifert[2], R. Weigel[3]

[1]Siemens AG München, Corporate Research and Development, Munich, Germany
[2]TU Wien, Institut für Allgemeine Elektrotechnik und Elektronik, Vienna, Austria
[3] Universität Linz, Institut für Nachrichtentechnik/Informationstechnik, Linz, Austria

ABSTRACT

We report on the design and performance of SAW minimum-shift-keying (MSK) tapped delay lines (TDL's) using pseudonoise (PN) code sequences of length 128 chips. As a substrate, $LiTaO_3$-X112°-rotY has been used due to the system requirements of a given CDMA/TDMA system (TCDMA). System IF frequency, bandwidth of the major lobe, and integration time were respectively 360 MHz, 63.5 MHz, and 3 μs. We used SAW TDL's employing non-weighted as well as cosine-apodized input transducers incorporating split-fingers. We designed both expander as well as compressor filters attaining very similar results. We found insertion loss values down to 16 dB and amplitude ripples of less than 2 dB. The close-in selectivity was 28 dB.

INTRODUCTION

Radio frequency (RF) consumer communications enjoy a tremendous growth due to the many upcoming wireless personal communicator applications. One of the key technologies of RF consumer communications is thought to be the spread spectrum (SS) technique which has been allowed on a number of ISM frequency bands in the USA and in Japan. Wireless SS communication, in which fast PN code sequences are used for channel separation is well-known to show excellent performance against multipath and jamming because of its inherent wideband transmission and the occuring processing gain. The ongoing trend towards RF SS communication is also due to the demand for user privacy, low-power, and unlicensed communication devices [1]. Among feasible encoding and decoding techniques necessary in any SS system is SAW code generation and SAW matched-filtering. Using SAW expander and compressor filters, the front-end hardware can be implemented simply and compactly. SAW devices easily can be designed and manufactured to exhibit moderate time-bandwidth products in the order of 20 to 23 dB which cannot be met by digital techniques. Both the programmable SAW convolver and the fixed-code SAW TDL approach are feasible. The TDL approach is in particular applicable to, e.g., the mobile stations of a mobile radio system because it is not neccessary for the mobile stations to know the spreading codes of other mobile users. In what follows, we describe MSK TDL's which are designed to operate in a special time code division multiple access (TCDMA) system [2].

PRINCIPLE OF TDL OPERATION

The SAW TDL is basically a transversal filter incorporating an input interdigital transducer (IDT) and an output IDT one of which being phase-coded. The chip defining phase reversal of the waveform cycles is simply achieved by an appropriate polarity reversal of the IDT fingers. We use MSK modulation, the SAW implementation of which can be achieved by

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two different ways either incorporating a non-weighted or a cosine-apodized input IDT. Both techniques, which are described in detail in [3], are inherently equivalent and show in principle the same result.

TDL DESIGN AND SIMULATION

The present work arose from a requirement of TDL's processing 128-chip Gold codes with an integration time of 3 μs and a bandwidth greater than 50 MHz. The IF frequency of the 2.45 GHz TCDMA indoor system under consideration was chosen to be 360 MHz. Broadband matching to a 50 Ω environment, temperature stability and insertion loss considerations led to the substrate material X112.2°rotY lithium tantalate ($LiTaO_3$). The required bit rate of 333 kbit/s yields a chip time of 23 ns, i.e. at f_c we have 16 cycles per chip. Transducers employing $\lambda/8$ split-fingers and dummy electrodes have been used which are fabricated using conventional optical lithography technology. The phase-coded transducer has 4064 split-fingers. Trade-offs based on spurious effects such as electromagnetic feedthrough, microacoustic diffraction and propagation losses, local reflections, Ohmic losses etc. have been compromised for by using IDT apertures and inter-IDT distances in the order of 80 microacoustic wavelenghts and an aluminum height of 150 nm.

The simulations have been carried out using signal-theory modeling (impulse response modeling), network-theory modeling (P-matrix modeling ([4]), and diffraction analysis ([5]). First, the principal geometrical data of the TDL's were computed based on signal theory guidelines and network-theory algorithms. Finally, angular spectrum of waves-analysis has been used to compensate for beam steering (beam steering angle: 1.11°) and losses due to diffraction and attenuation by tilting the axis and linearly weighting the finger overlap of the phase-coded IDT in a manner as is illustrated in Fig. 1. A simulation result is given in Figs. 2 and 3. The time-domain amplitude response shows a very flat and low-ripple behavior, and the time dependence of the relative instantaneous frequency Δf_i illustrates the implemented code.

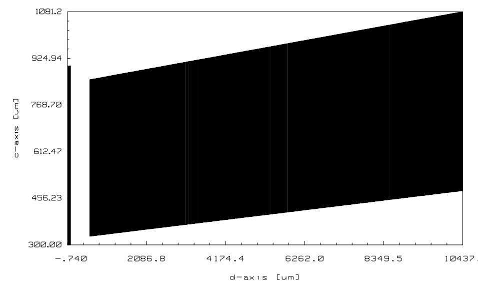

Fig. 1: TDL structure with tilted and overlap-weighted phase-coded output IDT.

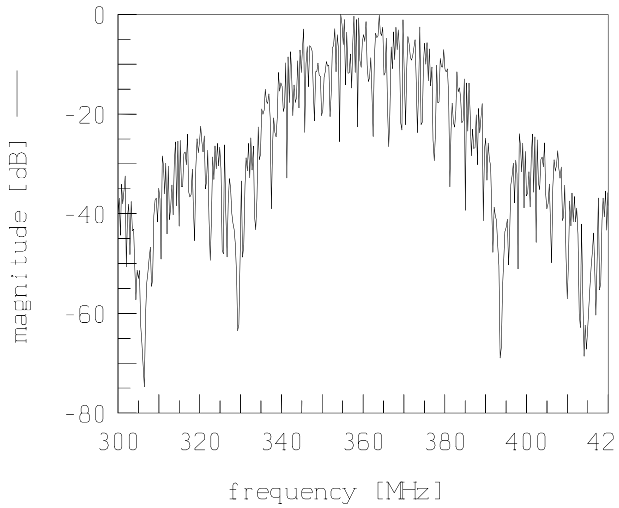

Fig. 2: Computed frequency response of a 360 MHz TDL using non-weighted input IDT.

EXPERIMENTAL RESULTS

Several TDL structures (encoding and decoding ones; with non-weighted and cosine-apodized input IDT's) were simulated before the masks were designed. Fig. 4 shows a test chip mounted in a DIP14 package. Three bond wires have been used for connecting the bus bars in order to reduce the Ohmic losses due to the bus bars.

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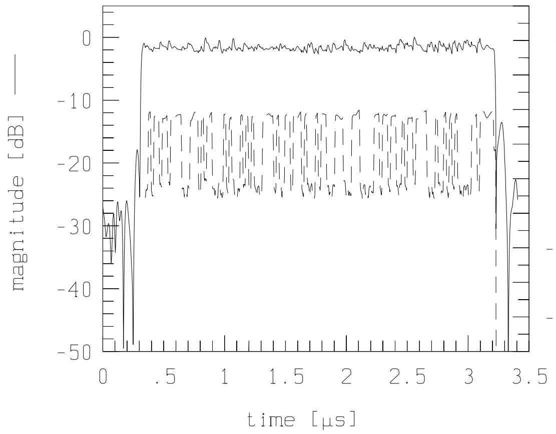


Fig. 3: Computed magnitude (—) and relative instantaneous frequency (- - -) of impulse response of a 360 MHz TDL using non-weighted input IDT.

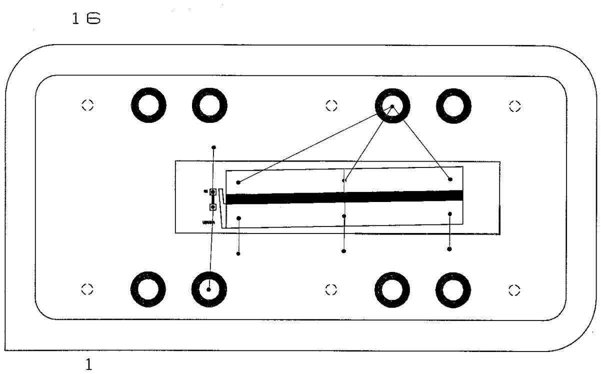
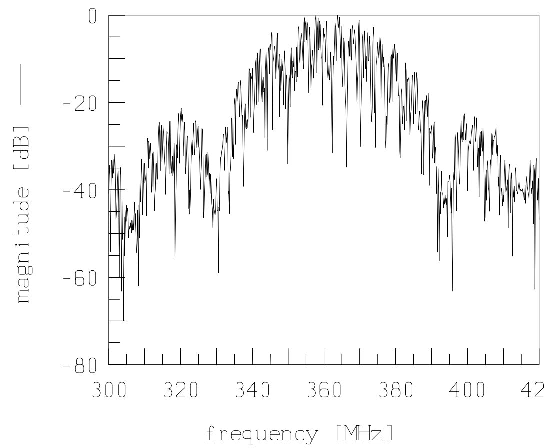
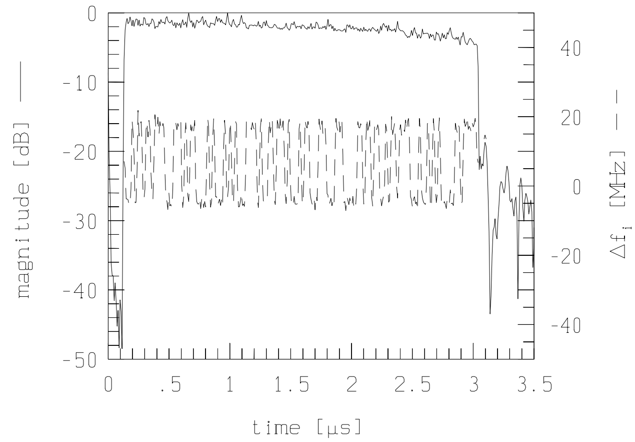


Fig. 4: Test chip employing triple bonding.



a)



b)

Fig. 5: Experimental behavior of an unmatched 360 MHz TDL using non-weighted input IDT; (a) frequency response; (b) magnitude (—) and relative instantaneous frequency (- - -) of impulse response.

Since our various design approaches yield very similar results, we will discuss only the performance of an encoding device employing a non-weighted input IDT. Fig. 5 gives the experimental results of such a TDL. The unmatched insertion loss in this case is 36 dB. The input IDT's have high impedances, whereas the output IDT's have low impedances. This is due to the fact that they have, respectively, few and many fingers. Therefore, in practice broadband matching is an issue to be addressed thoroughly. We matched the TDL's successfully over bandwidths greater than 60 MHz to insertion loss values as low as 15.5 dB which is seen in Fig. 6. Amplitude ripple and close-in selectivity are 1 dB and 28 dB, respectively.

Fig. 7 gives the experimental time-domain correlation result of a test system incorporating an expander cascaded with a compressor. As is shown, at a temperature of 20 °C we achieved a sidelobe suppression of the communication system of nearly 13 dB.

CONCLUSION

The present work demonstrates the feasibility of miniature low-cost SAW TDL's for consumer applications. The devices are designed for the use in a special TCDMA system demonstrator. We expect that in the decade

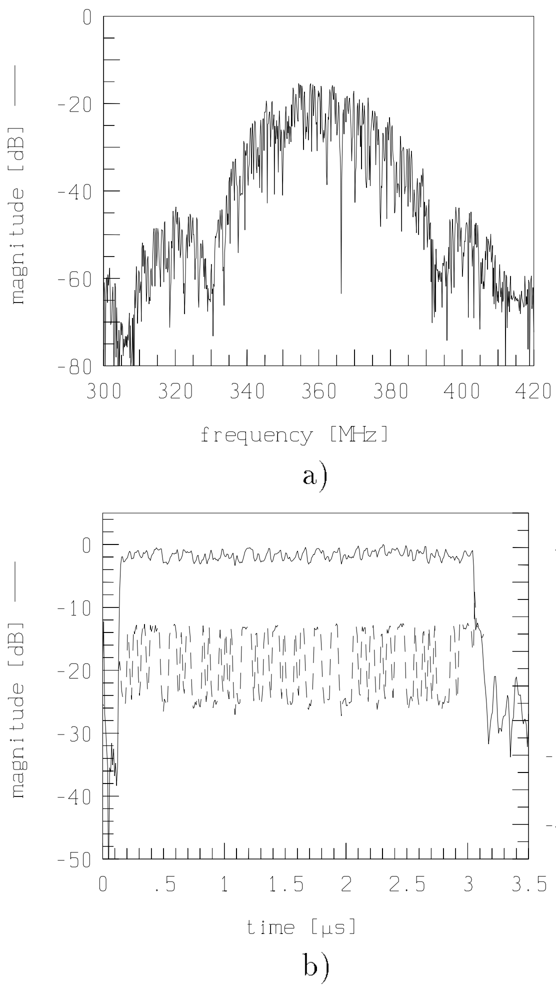


Fig. 6: Experimental behavior of a matched 360 MHz TDL using non-weighted input IDT; (a) frequency response; (b) magnitude (—) and relative instantaneous frequency (- - -) of impulse response.

ahead such moderate time-bandwidth product SAW devices will play an important role in radio-based RF SS communications.

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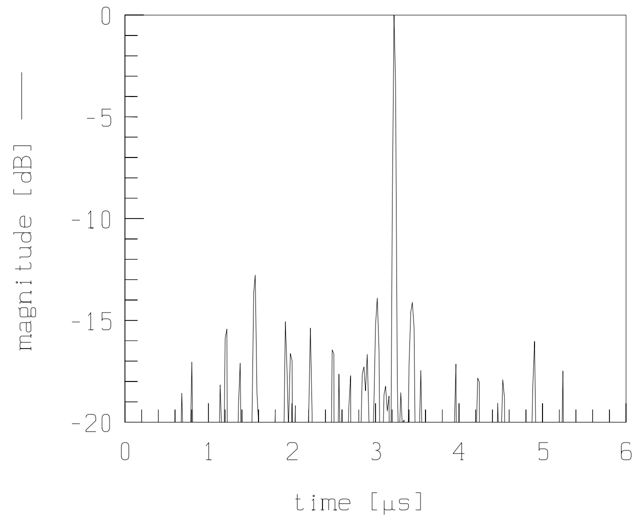

Fig. 7: Experimental correlation of SAW expander-compressor system at 20 °C.

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