A 900 MHZ SAW MICROSTRIP ANTENNA–DUPLEXER FOR MOBILE RADIO

K. Anemogiannis[+], C. Beck[*], A. Roth[*], P. Russer[*], R. Weigel[*]

[+] Siemens Corporate Research and Development München
Otto–Hahn–Ring 6, D–8000 München 83, FRG

[*] Lehrstuhl für Hochfrequenztechnik, Technische Universität München
Arcisstrasse 21, D–8000 München 2, FRG

ABSTRACT

A novel SAW microstrip antenna–duplexer at 900 MHz which has been designed for the use in European mobile radio systems is presented. The duplexer consists of a transmitter SAW filter, two receiver SAW filters, a low noise receiver amplifier, and a duplexing microstrip circuit. A dual–track filter design using interdigital transducers for track coupling provides low insertion loss (5 dB), small passband ripple (± 0.5 dB), high stopband rejection (50 dB), and small chip–size (TO–39 package). The filters were fabricated on 36^0 rotated YX–$LiTaO_3$ substrates with a photolithographic technique. Due to the new design of the microstrip duplexer, the selectivity of the front–end is enhanced by 15 dB.

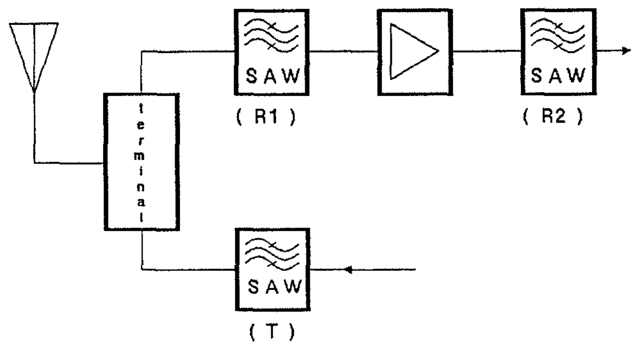

Figure 1 Blockdiagram of SAW Antenna–Duplexer

INTRODUCTION

Recently, with the increased role of cellular radio systems, much attention has been given to the use of surface–acoustic–wave (SAW) filters as front–end filters in UHF communication transceivers (1,2). One of the major goals of modern radio communication systems is to provide high–quality radio performance with low–power, small–size, small–weight data terminals and radio telephones. Due to the fact that the SAW wavelength is about 10^{-5} shorter than that of electromagnetic waves, SAW filters seem to offer the most promise for reduction of size of transceiver units. In a two–way transceiver consisting of a transmitter and a receiver connected in parallel via an appropriate RF circuit, filters have to be inserted for noise suppression in the transmitter path and preselection in the receiver path. The filter insertion loss has to be low in order to avoid deterioration of the signal–to–noise ratio. The fractional bandwidth varies between 1.0 % (NMT–Scandinavia and C–net–West Germany; 450 MHz) and 2.8 % (NMT and European D–net; 900 MHz).

The present work arose from a requirement of a miniature antenna–duplexer for 900 MHz European mobile radio systems. The block diagram of the SAW microstrip antenna–duplexer presented in this paper is schematically drawn in Figure 1. The duplexer consists of a transmitter final stage filter (T), a two–way antenna terminal, a receiver top filter (R1), a receiver low–noise amplifier, and a receiver second filter (R2). The duplexer simultaneously provides both filtering and diverging. It ensures that transmitter power does not flow into the receiver and receiver signals do not suffer attenuation by flowing into the transmitter.

MINIATURE LOW–LOSS SAW FILTERS

1. Basic Structure

Classical transversal SAW filters satisfy the requirements of flat passband, sharp cutoff frequency response, good reproducibility and high reliability (3). However, the bidirectional nature of interdigital transducers (IDT's) precludes low–loss operation. Typical values of the insertion loss vary in the range 15 dB to 25 dB. The main problem arises from spurious echoes due to reflected signals causing a high ripple in the passband. There exist some technical approaches to overcome these shortcomings, but most of them require either a complicated production technology or an additional external phasing network (4,5). In (6) *Hikita et al.* presented a sophisticated configuration which provides a low–loss, low–ripple characteristic by separating the parts of the structure affecting the filter selection and the low–ripple operation. We improved this configuration by using self–suppression mechanisms for echo signals and optimizing the structure pattern by means of accurate simulation models. The filter configuration is schematically shown in Figure 2. It consists of two parallel acoustic tracks with a transducer track–coupling. The coupling mechanism is based on the electrical matching condition between the coupling–transducers. For an appropriate dimension of the transducer pattern a tight coupling occurs within the passband. In the stopband however, the contribution of the electrostatic capacitance of the transducer leads to electrical mismatching and hence to decoupling of the tracks. In order to overcome the bidirectional IDT nature, a four–repetition

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structure has been chosen providing a theoretical loss of 1 dB. SAW reflectors with a small number of finger pairs are also inserted at both ends of the filter. These reflectors are adopted to obtain further reduction of IDT bidirectionality loss. In this configuration, SAW's propagating in both directions from the input IDT's are received and regenerated by image–impedance connected IDT's, and return to the output IDT's from both sides. Thus, a sharp cutoff and low–loss frequency response are obtained by the coupling transducers and the lateral repetition structure. The filter bandwidth is determined by the track–coupling. Remaining spurious echo signals are suppressed by using different separation distances between the transducers in the two tracks. This configuration provides low insertion loss, small passband ripple, high selectivity, and small size. Furthermore, the use of two acoustic tracks instead of one in conventional SAW filters enhances the out–of–band rejection. The filter configuration shown in Figure 2 has been developed for broadband applications (7).

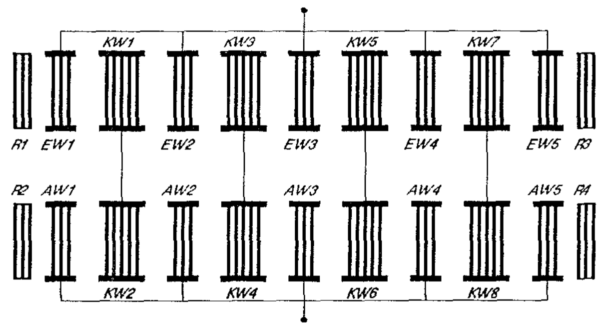

Figure 2 Dual–Track Low–Loss SAW Filter

2. Substrate and Modelling

As a substrate material, 36^0 rotated YX–$LiTaO_3$ has been used because of its high electromechanical coupling coefficient and its fairly good temperature behavior (–30 ppm/K). The acoustic wave mode is a surface skimming bulk wave (SSBW). Energy trapping by metallized propagation paths guides the wave at the surface and enables an efficient use of this mode with low propagation loss (8). CAD tools have been worked out for modelling and filter–synthesis (9,10). The models include the most important first and second order effects such as the charge distribution on the IDT electrodes for an accurate calculation of the frequency dependence of acoustic wave excitation and electrostatic capacitance, the mechanical and electrical reflections at the electrode edges and wave propagation effects.

3. Fabrication and Experimental Results

A basic requirement for high reliability and reproducibility of SAW filters is the optimized technology of the fabrication process. The technology developed for the fabrication of integrated circuits has been refined to meet the stringent requirements on dimensional precision for SAW components. The filters are fabricated by single layer technology and standard photolithography with 10:1 reduction projection printing and lift–off technique (11). The position accuracy is 0.01 μm.

Figure 3 shows the simulated and the measured filter response of a transmitter low–loss filter structure with an uplink center frequency of 902.5 MHz and a bandwidth of 28 MHz. The insertion loss is 5 dB, and the passband ripple is better than ± 0.5 dB. The receiver filters have been designed with the same procedure by scaling the geometry data for the downlink center frequency of 947.5 MHz.Very similar experimental results have been obtained.

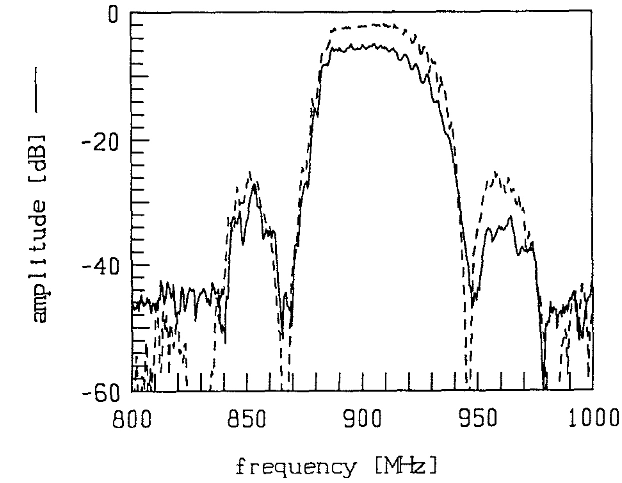

Figure 3 Simulation (– – –) and Measurement (——) of a 900 MHz Low–Loss Filter Using Four Coupling IDT Pairs

The layout of the structure which consists of four unweighted coupling–IDT pairs with only unsplit electrodes of quarter wavelength width is given in Figure 4.

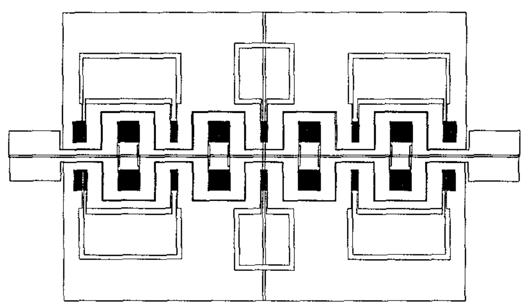

Figure 4 Layout of 900 MHz Low–Loss Filter

A metallization height of 200 nm has been chosen due to the tradeoff between ohmic losses and spurious acoustic bulk wave mode conversion. The finger electrodes had a minimum line width of 1.1 μm. The chipsize was 2.50 mm x 1.75 mm and the filters were mounted into TO–39 packages. The comparison between simulation and measurement shows good agreement. The model describes exactly the filter behavior in the stopband region and the passband skirts. The deviations in the passband and the frequency range above the center frequency occur primarily due to ohmic losses and spurious bulk wave excitation which are not precisely included in our models. The bulk wave radiation losses are typical for the 36^0 rotated

YX–$LiTaO_3$ substrates which show only a small difference between the velocities of the used leaky surface wave and the corresponding bulk wave. The out–of–band rejection is 50 dB, limited by direct electromagnetic feedthrough between input and output ports. The filter withstands 30 dBm output power.

FRONT–END

Both the receiver and the antenna terminal have been fabricated on low–cost epoxy ($\epsilon = 4.5$). The layout of the antenna terminal is shown in Figure 5. Transmission line t1 and stub t2 and transmission line r1 und stub r2 are approximately of length $\lambda/4$ at the transmitter frequency ($\lambda/4 \cong 39.1$ mm) and the receiver frequency ($\lambda/4 \cong 37.2$ mm), respectively. The physical length of the microstrip stubs is somewhat smaller that $\lambda/4$. That is due to the fact that commercial network analysis programs cannot exactly analyze such printed coils. A shunt inductance at node n1 and a shunt capacitance at node n2 provide final tuning. Whereas the inductance is realized as a distributed element, the capacitance is lumped due to the limited size of the substrate which is 1 x 1 inch² in dimension. Figure 6 gives the measured frequency response of the microstrip circuit. As can be seen, the selectivity of the front–end is improved by 15 dB due to the chosen design. The attenuation in the passbands is 3 dB and 4.5 dB, respectively, and the stopband rejection is better than 18 dB. Flat frequency characteristics within the transmitter and receiver bandwidth are obtained.

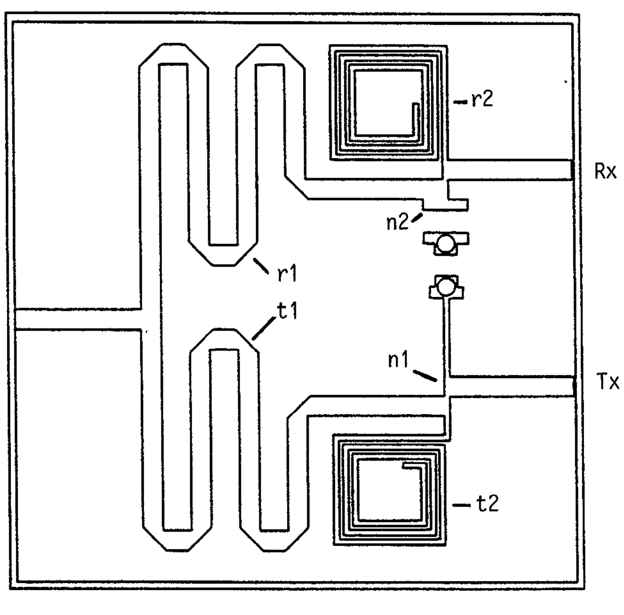

Figure 5 Layout of Microstrip Antenna Terminal

The receiver has been designed with conventional design techniques using two low–loss SAW filters and a low noise npn–silicon bipolar transistor. The dimension of the substrate in this case is 1 x 2 inch². Frequency responses for the complete SAW microstrip antenna–duplexer are shown in Figure 7a. The left trace corresponds to the transmitter–antenna path (Tx–Ant.) and the right trace to the antenna–

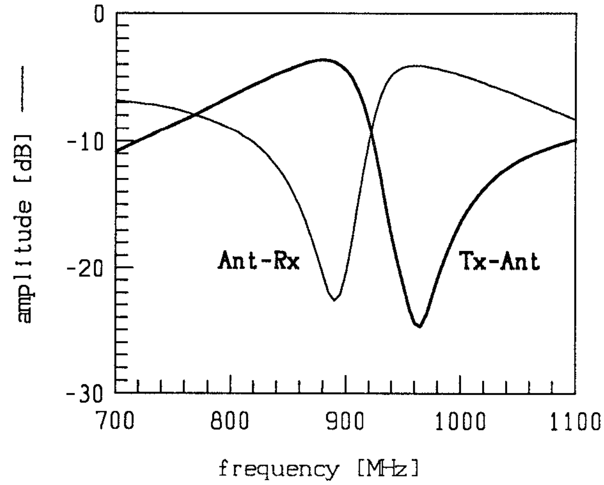

Figure 6 Frequency Response of Antenna Terminal

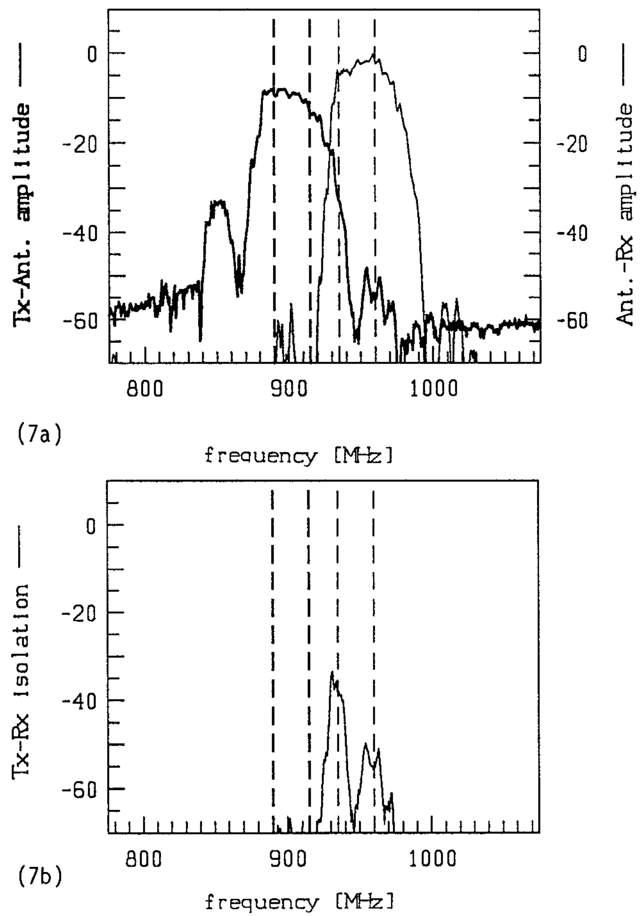

Figure 7 a) Frequency Characteristic of SAW Microstrip Antenna–Duplexer
b) Transmitter–Receiver Isolation of SAW Microstrip Antenna–Duplexer

–receiver path (Ant.–Rx). Attenuation and stopband rejection are 2 dB and 55 dB in the receiver band and 8 dB and 30 dB in the transmitter band, respectively. The isolation of the transmitter–receiver path (Tx–Rx) is shown in Figure 7b. Thus, the frequency characteristics almost satisfy the specifications for a portable telephone. However, the level of the receiver band should be somewhat higher which is expected to be achieved by improving the SAW filter insertion loss.

CONCLUSION

The work demostrates the feasibility of the combination of SAW and microstrip technologies for the development of low–cost mobile radio transceiver units. A planar acoustic dual–track filter configuration using interdigital transducers for the track coupling provides low insertion loss, sharp passband skirts, high out–of–band rejection, and small size. Due to the sophisticated design of the microstrip duplexer, the selectivity of the front–end is further enhanced. The presented work arose from a requirement of high–quality, low–power, small transceivers for European mobile radio systems at 900 MHz. Our fundamental experiments for a SAW microstrip antenna–duplexer show possibilities of new miniature functional devices, especially when designing front–ends to be used in future cellular radio systems operating at frequencies above 1 GHz.

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