# INVESTIGATION OF MMIC INDUCTOR COUPLING EFFECTS

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**ABSTRACT**

The coupling effects of two closely placed coplanar spiral inductors are investigated using the FDTD method. Different configurations of two inductors are simulated and the simulation results are compared with measurements. The investigations show an unexpected high impact of the orientation of the coils to the coupling of the two inductors.

**INTRODUCTION**

One of the main goals in MMIC design is small chip size because this parameter directly effects the costs of the circuit. Therefore lumped elements are widely used e.g. in matching and bias networks. Reliable models of these lumped elements are the key to an efficient circuit design with a small number of technology cycles. To meet the goal of small chip size the distance between lumped elements may become very small, so the investigation and modelling of coupling effects must be added to the modelling of the single elements.

**COUPLED INDUCTORS**

These aspects are investigated for different configurations of two coupled coplanar inductors. One of the examined configurations is depicted in figure 1. The two spiral inductors are placed on a GaAs-substrate with a distance of $d = 60\mu$m. The width of the center conductor and the slot of the coplanar lines is 20 and 15 $\mu$m, respectively. Details of the investigated inductors are shown in figure 2. To reduce the parasitic capacitance of the inductor, the spiral itself is elevated above the substrate using air bridges. The feedlines are also connected to the inductor by air bridges to suppress the coplanar odd mode on the feedlines. Alltogether four different structures shown in figure 3 were investigated. For the single inductor (case A) an equivalent circuit model was constructed shown in figure 4. Two coplanar lines $CPL_1$ and $CPL_2$ account for the feedlines. The rest of the single inductor is modeled using a standard $\pi$-circuit with additional in-

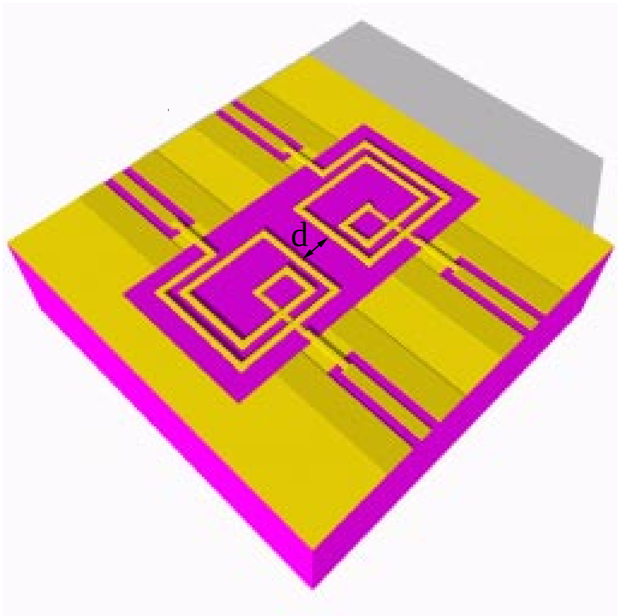


Fig. 1.: Coupled coplanar inductors on a GaAs-substrate.

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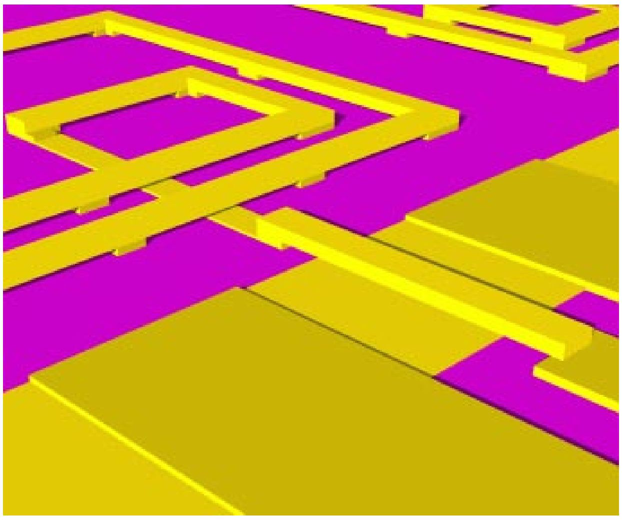

Fig. 2.: Details of the coupled coplanar inductors on a GaAs-substrate.

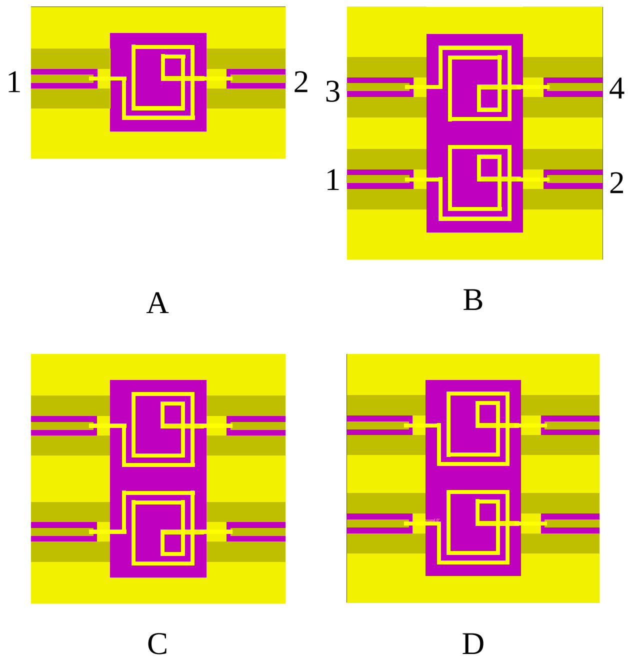


Fig. 3.: Different configurations of coupled coplanar inductors on a GaAs-substrate with port numbering.

ductors $L_1$ and $L_2$ and two 50 ohms transmission lines $TRL_1$ and $TRL_2$. The values of the equivalent circuit model elements were extracted from measurements given in the result section using microwave harmonica.

In addition to the single inductor three different cases

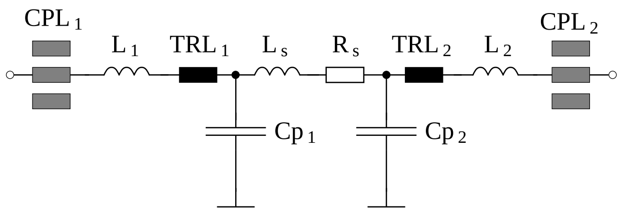


Fig. 4.: Equivalent ciruit model of the single inductor.

of coupled inductors with different orientations of the turns were analysed.

Because of multiple coupling between bends and lines of the inductors a CAD like simulation approach [1], [2] using segmentation of the structure was not applicable. Instead the FDTD-method [3]–[5] was employed. In the simulation the finite conductor thickness of 3 $\mu$m was discretized with one cell. For the conductor width of the spiral (10 $\mu$m) four FDTD-cells were used. The rest of the structure was discretized non equidistantly leading to an overall number of 214, 136 and 34 cells for the length, width and heigth of a single inductor, respectively.

For the measurements of the coupled inductors three test structures with two matched terminations for each structure at different ports were fabricated. These test-structures enable the characterisation of the coupled inductors with several two port measurements.

## RESULTS

A comparison of simulation results and measurements of the reflection coefficient at port one and the transmission coefficient $s_{21}$ of a single inductor and two coupled inductors (configuration B) is shown in figure 5. The comparision indicates that the coupling with the second inductor does not influence these scattering parameters. For the simulation the finite conductivity of the metallisation was assumed to be infinite which causes the small deviation between measured and simulated results.

The scattering parameters $|s_{31}|$ and $|s_{41}|$ that characterize the coupling of the inductors are depicted in figure 6. The simulation results and the measurements of the configuration B compare very well. The simulations of the other structures C and D show an unex-

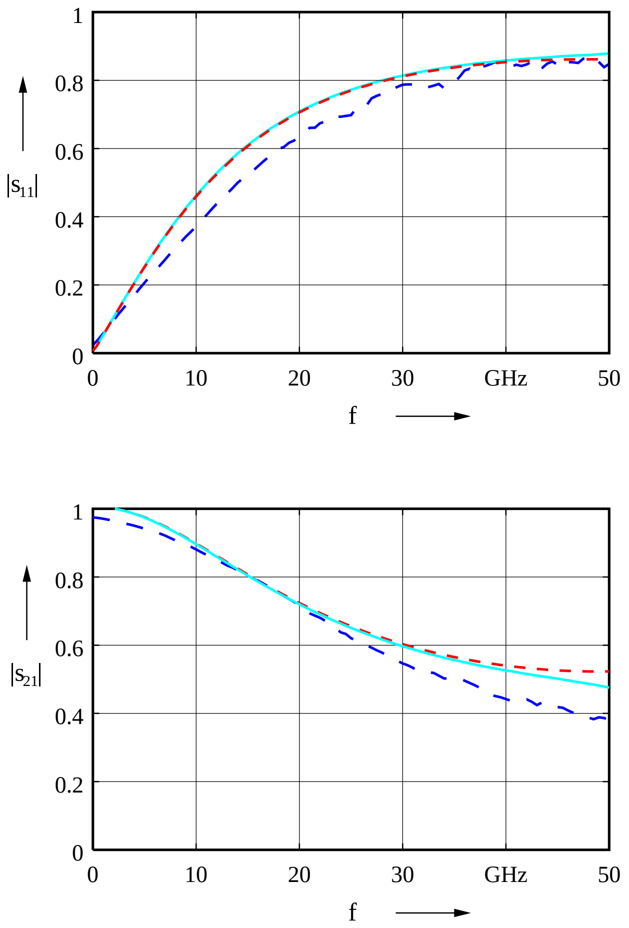


Fig. 5.: Comparison of scattering parameters $|s_{11}|$ and $|s_{21}|$ of a single inductor and two coupled inductors (configuration B), —— coupled inductors (simulations), - - - single inductor (simulations), – – coupled inductors (measurements).

pected high impact of the orientation of the turns to the coupling of the two inductors. Especially structure C has a very strong coupling that is nearly one order of magnitude higher than the coupling of configuration B. In this case the coupling effects can not be neglected [6] so precautions like increasing the distance of the inductors must be considered to prevent parasitic coupling.

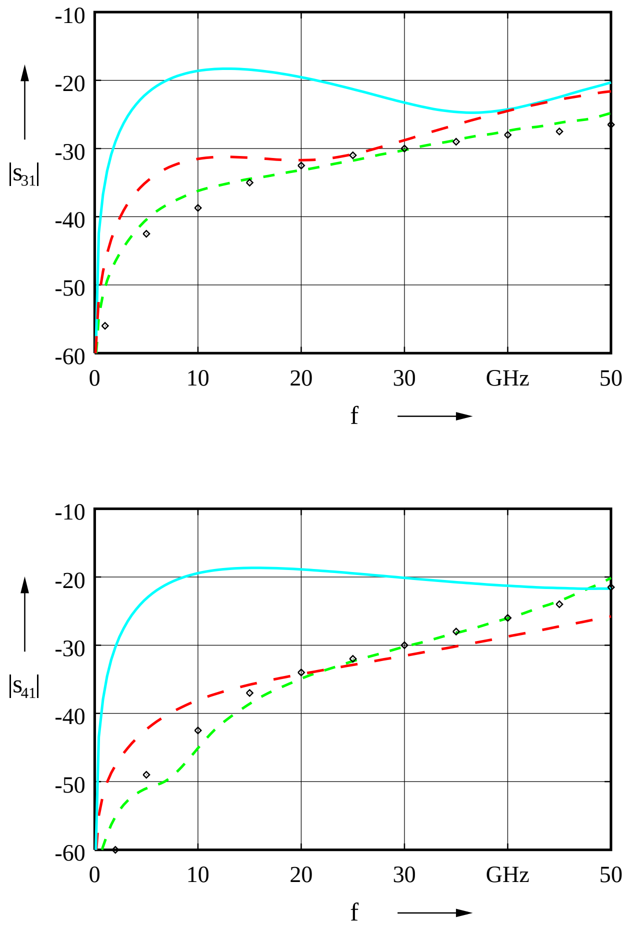


Fig. 6.: Transmission $|s_{31}|$ and $|s_{41}|$ of two coupled inductors for different configurations, ♢ measurements (B), - - - simulations (B), —— simulations (C), – – simulations (D).

## CONCLUSIONS

The investigation of coupling effects of two closely placed coplanar spiral inductors using the FDTD method has been presented. The simulation results of different configurations of two coupled inductors compare well with measurements. The results clearly indicate that the coupling of spiral inductors strongly depends on the orientation of the coils.

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