



Planar Leaky-Wave Antenna with Tunability *Antennes planes à ondes de fuite ajustable*

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Abstract/Résumé

In this contribution a new leaky-wave antenna (LWA) with potential tunability is investigated. The leaky-wave antenna consists of a series of cells with series capacitance and shunt inductance. By modifying the capacitance by inserting RF MEMS switches, the radiation characteristics can be changed. In this contribution a leaky-wave antenna consisting of 20 cells with hard-wired RF MEMS is realized and investigated. 3 different configurations are possible, showing backward, forward and broadside radiation. Special emphasis is given to the design procedure, which is critical, as the design is very sensitive to any parasitics.

Dans cet article, une nouvelle antenne à ondes de fuite (Leaky-Wave Antenna) potentiellement ajustable est étudiée. L'antenne à ondes de fuite se compose d'une série de cellules avec capacité en série et inductance shunt. Afin de modifier cette capacité, des commutateurs RF MEMS sont utilisés, changeant ainsi les caractéristiques de rayonnement. Dans cet article, une antenne à ondes de fuite composée de 20 cellules avec des RF MEMS câblés est d'abord réalisée et puis étudiée. 3 configurations différentes sont possibles, montrant ainsi un rayonnement vers l'arrière, vers l'avant et de côté. Une attention particulière devait être accordée au procédé de conception à cause de la sensibilité de cette dernière aux parasites et aux changements infimes.

1 Introduction

Leaky-wave antennas (LWAs) are traveling-wave antennas with the wave propagating along the guiding structure. Coherent radiation is formed, when a small portion of the energy gradually leaks out along the structure. As a result, a radiated beam is created, while having a broad input match, as at the end of the relatively long device no reflection occurs, as most of the power has already been radiated [1]. Typical antennas consist of concatenated cells with inductive and capacitive elements. Introducing switching elements into the structure, these properties can be changed, resulting in a change of the beam direction [2].

As switching elements RF MEMS can be utilized, which can directly be integrated into the planar antenna structure. RF MEMS are tunable components based on mechanical movement, known now since 20 years. Unfortunately, problems in the technology and reliability problems of these complex multi-physical devices have delayed a rapid development and establishment as common RF components. Nowadays their multi-physical behaviour is better understood and mature technologies have been developed. Reliability issues are still investigated, however working devices with sufficient life time are on the market and in use within communication and measurement systems [3]. Electrostatic activated switches formed as cantilever series switches are small and introduce only low parasitics when in open state.

A transmission line with additional capacitances and inductances is called a CRLH (combined right/left handed) transmission line. The dispersion characteristics of one cell is shown in Figure 1. If not, a band gap between the right and left handed propagation modus is created. If the CRLH line is used to realize a leaky-wave antenna, the left handed behaviour will result in backward radiation, the right-handed behaviour produces the "normal" forward radiation. As it can be seen, a broadside radiation ($\beta=0$) can only be achieved, if the resonance frequencies of the two resonators are carefully adjusted.

One drawback of the tunable antenna is that the input impedance is changing significantly between the switching states. However, in this contribution it will be shown, that the input match can also be corrected by using stubs, made adjustable by RF MEMS.

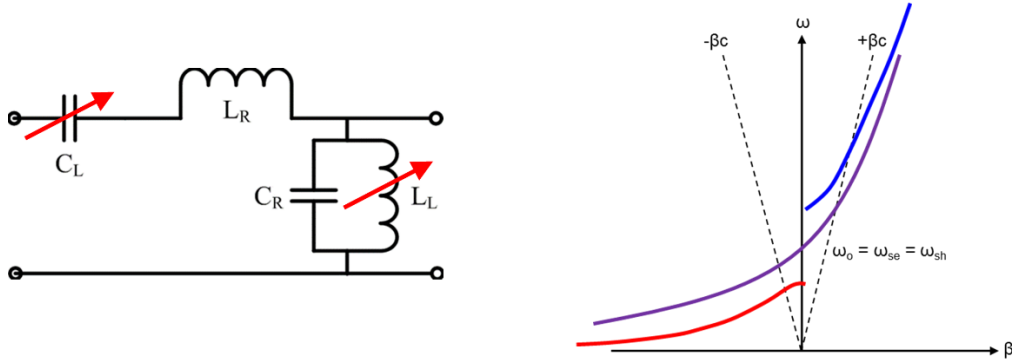


Figure 1 : a) Equivalent circuit and b) dispersion behaviour of one cell of a CRLH transmission line

2 Antenna design

In this contribution it will be investigated, whether a leaky-wave antenna with RF MEMS has a potential for beam-steering. Instead of implementing real RF MEMS switches the antenna is realized in 3 different fixed switching states, where the on-state of the switch is replaced by a direct connection, the off-state by a corresponding small capacitance.

In Figure 2 one cell in two switching states is shown. A similar design as in [5] will be used.

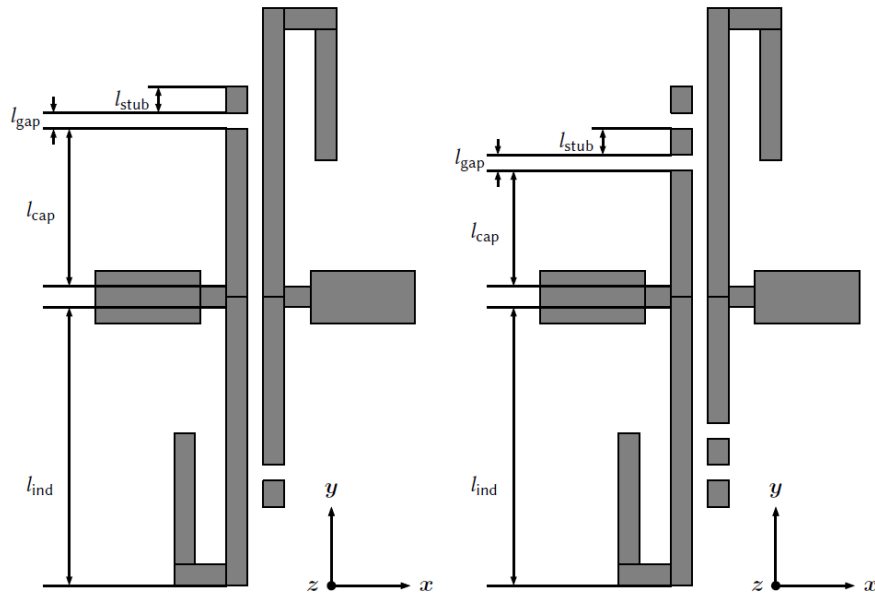


Figure 2 : Cell layout for a) broadside radiation b) backside radiation

The dimensioning of the cell and the leaky-wave antenna (LWA) is done according to [3]. First one cell is adjusted and optimized, then the concatenation of all cells is investigated, in order to include coupling effects between the cells. The flow-chart of the whole procedure is shown in Figure 3. The targeted design frequency is 8 GHz.

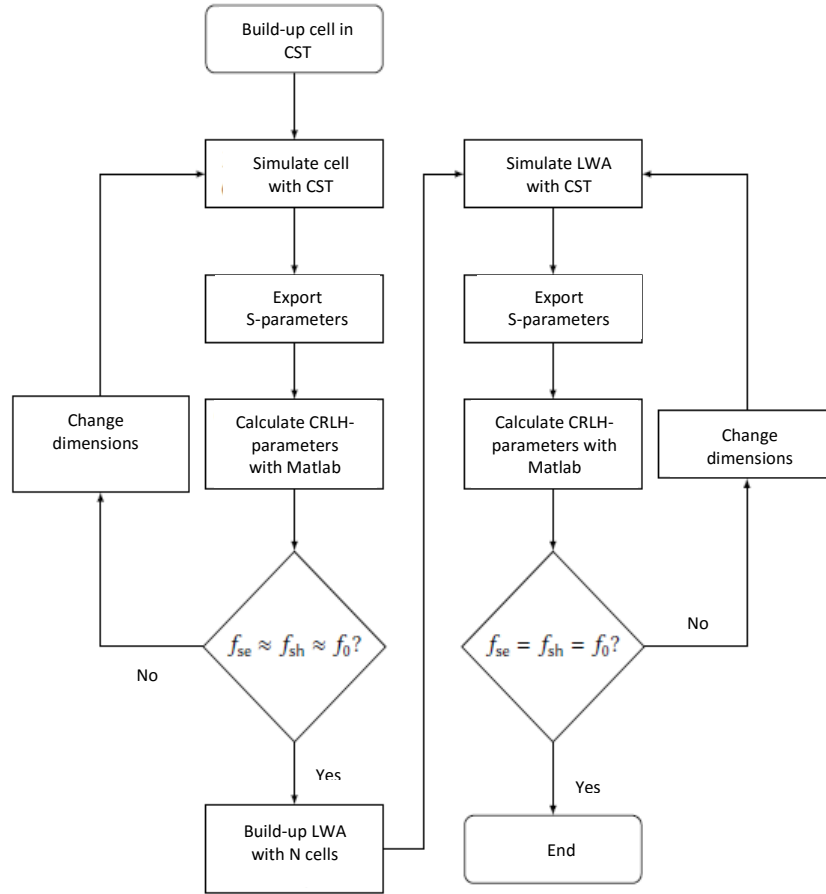


Figure 3 : Flow chart of the design procedure

As it can be seen in Figure 4, the input impedance for the different states quite different. Real and imaginary part for the two states “BW” backwards and “FW” forward are shown.

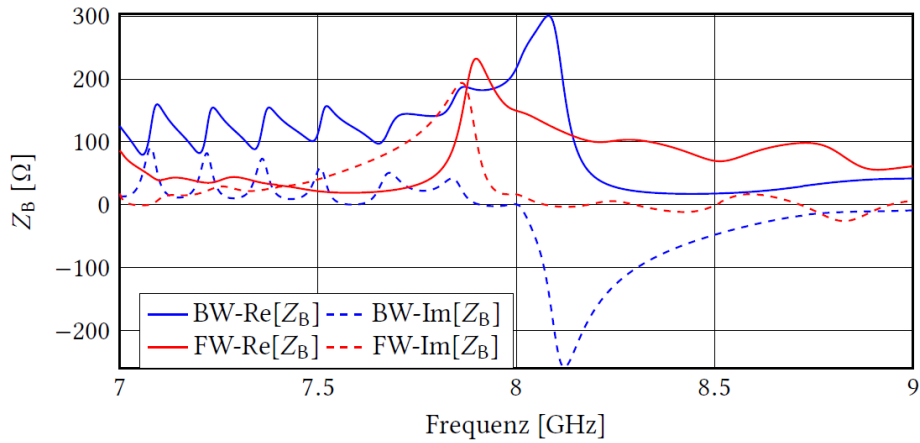


Figure 4 : Input impedance of the antenna for the states backward (BW) and forward (FW)

Therefore, after the adjustment of the antenna, the input matching is done by inserting 3 adjustable stubs, which can be connected to the line with RF MEMS. In Figure 4 the matching part is shown, when one stub is connected and the others disconnected. At the output a $\lambda/4$ -transformer but no matching network is foreseen, as at the output most of the inserted power should be radiated. As reference the impedance in the case broadside radiation is used.

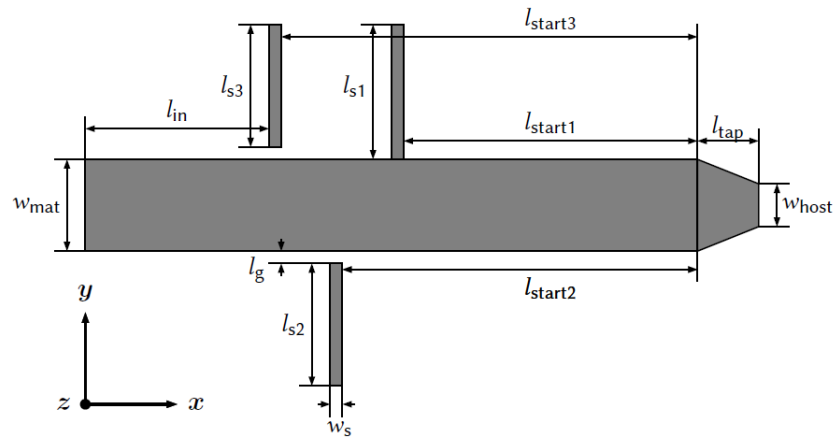


Figure 5 : Input matching network with 3 adjustable stubs

3 Technological realization

The antennas have been realized and fabricated on Rogers with a laser cutter. The Optimum number of cells due to the leakage factor should be 24, however, due to technological constraints (the uniformity of the laser cutter over the whole area) the number of cells was restricted to 20. Structures in 3 different states are shown in Figure 6.

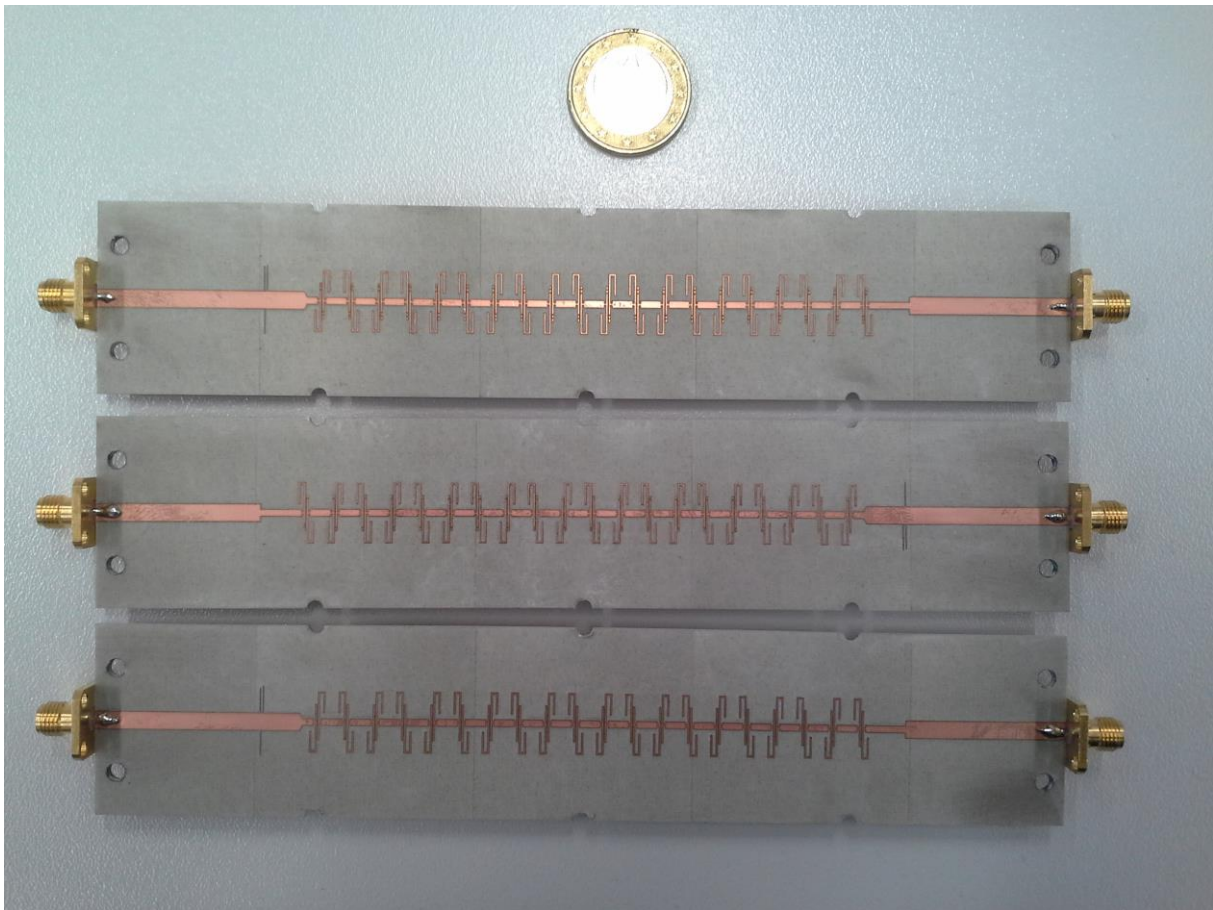


Figure 6 : Realized antennas for 3 switching states

A comparison of the simulated and measured S-parameters are shown in Fig.7. A small deviation from the target frequency of 8 GHz towards a lower frequency of 7.9 GHz can be observed.

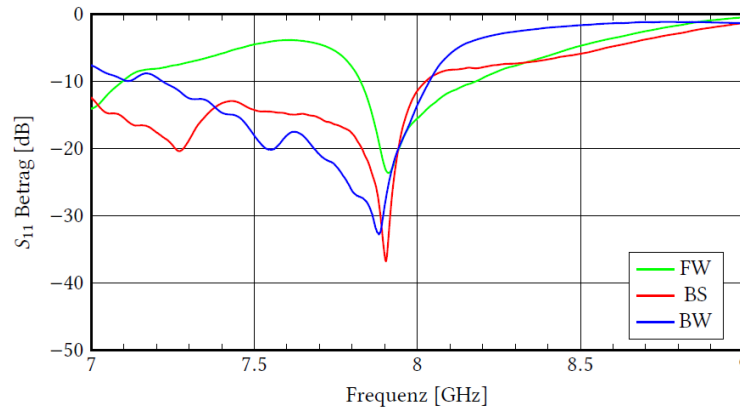


Figure 7: Measured and simulated scattering parameters of the LWA for broadside radiation, forward radiation and backward radiation

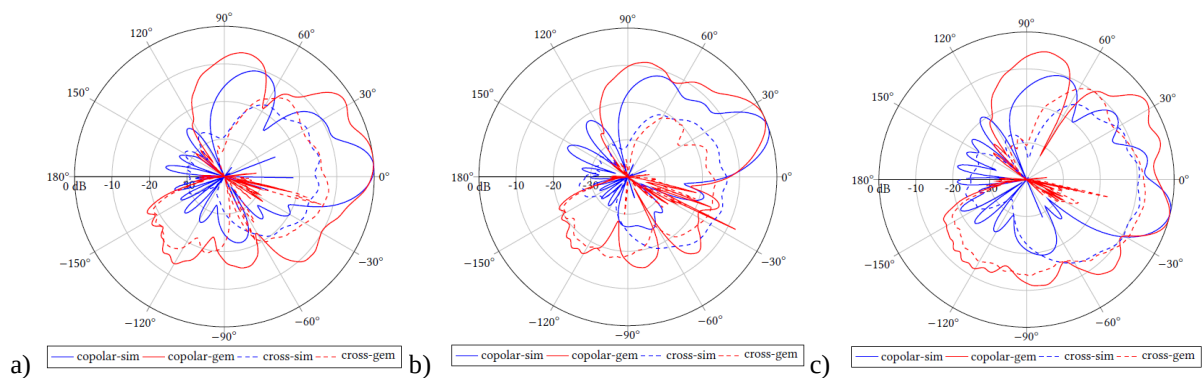


Figure 8: E-plane pattern, measured and simulated for a) broadside radiation, b) forward radiation and c) backward radiation

4 Conclusion

It has been shown, that a switchable leaky-wave antenna can be created by changing physical dimensions by RF MEMS. In this case 3 different switching states realizing backward, broadside and forward radiation. However, the design procedure is complex, as not only one switching cell but the structure has to be optimized to include coupling effects. The simulations have been done with CST, resulting in long simulation times for a structure with 20 or more cells. The measured radiation frequency is slightly lower than simulated, probably due to material parameters. The beamforming has to be improved. The deviation between simulated and measured far-field patterns has to be further investigated.

References

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