A 30 GHz highly integrated LTCC antenna element for digital beam forming arrays

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Abstract

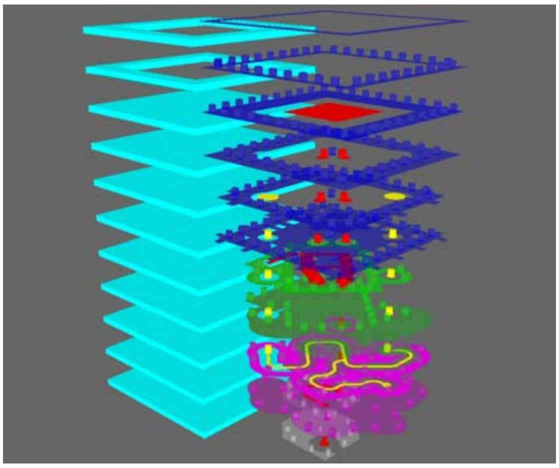
The increasing demand for mobile access to fast data services is one of the drivers for future broadband satellite systems. In-flight data exchange between aircrafts and satellites for real-time internet access is a prominent example for this kind of satellite link. Antennas employing Digital Beam-Forming provide the fast and flexible reconfigurability required in such a system without the necessity for moving mechanical parts.[1], [2] The antenna presented in this paper is a circularly polarised, 4×4 element array building block. This module can be used for a digital beam forming terminal transmitting system operating at 29.75 GHz.[3] The array features a calibration network as well as transmitting circuitry for each single element. This high density integration task is achieved by the vertical integration of antenna and circuitries in an LTCC multilayer module.

Introduction

LTCC multilayer modules are appreciated for their flexibility in realising an arbitrary number of layers with easy-to-integrate circuit components like via-holes, cavities, thickfilm resistors, SMT components and chip devices. For the frequency range of the Ka-Band, manufacturing tolerances become more critical with respect to the wavelength. Yet, the demand for high integration is especially increasing for these frequency bands.

For the antenna presented in this paper, the circular polarisation of the antenna elements is achieved by a hybrid ring coupler.[4] The area for this circuitry is limited to the grid defined by the cell size of one element. In addition, the array features a calibration network to enable an automatic array calibration. Via holes are used to connect circuits on different layers, to shield striplines and to form metallic cavities.

Overview



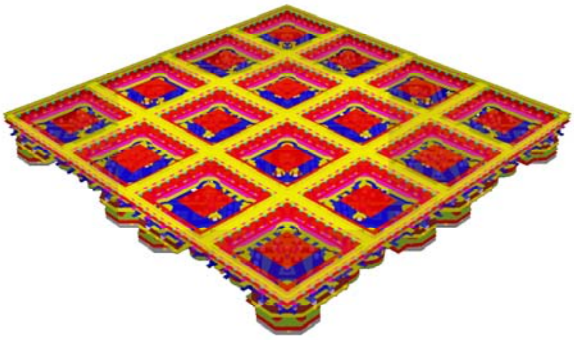


Fig. 1: Eleven layer structure integrated in a FERRO A6 LTCC substrate.

Fig. 2 4x4 array.

Fig. 1 shows the complete architecture of one multiplayer antenna element. The structure consists of eleven layers. Four different functional blocks can be identified: The antenna block is depicted in blue, the green block marks the hybrid ring coupler, the velvet parts forms a part of the calibration network and the RF-to-antenna interface is shown in grey. The transmitting signal path is marked in red, while the yellow path shows the calibration signal. In Fig. 2, the 4×4 array, consisting of 16 of such antenna cells, is visualised.
In the following, the different functional blocks are described in more detail.

The antenna element

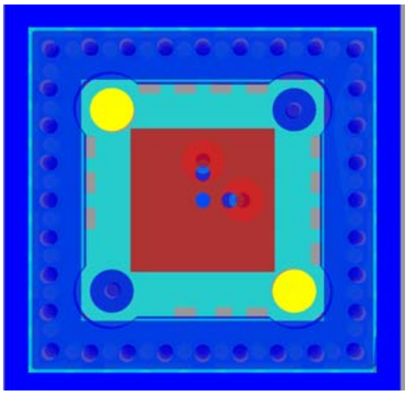


Fig. 3: Patch antenna top view.

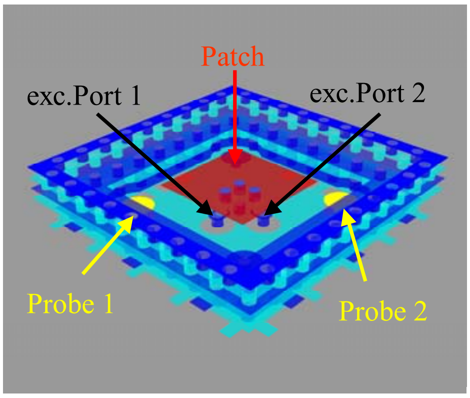


Fig. 4: Patch antenna iso view.

One of the special features of the antenna patch element is that it is counter sunken in a cavity , as depicted in Fig. 1 and, in more detail, in Fig. 4. The patch element is operated in a frequency range from 29.5 to 30 GHz. It has two excitation ports. The phase shift between these ports is 90° to ensure circular polarisation. In close proximity to the antenna element are two via near field probes. These probes are receiving a small part of the antenna signal for the calibration network without disturbing the antenna mode significantly.

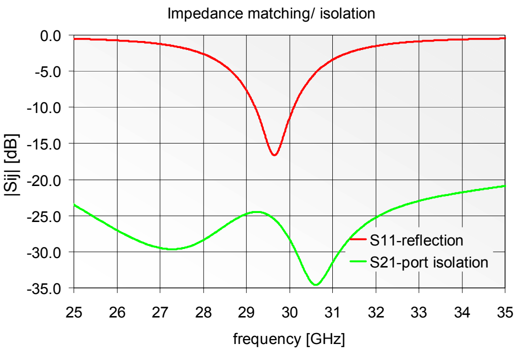


Fig. 5:Scattering matrix results of the antenna simulated with FDTD simulator Empire^{TM} [5] .

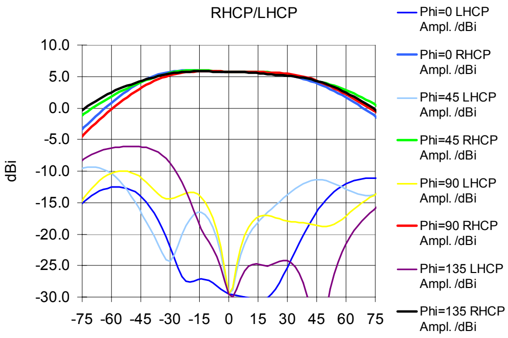


Fig. 6: Polarisation behaviour and far field patterns of the antenna simulated with FDTD simulator Empire^{TM} [5].

The diagrams of Fig. 5 and Fig. 6 show the simulation results of the FDTD antenna model. It can be observed that the design is successfully suppressing the mutual coupling between both excitation ports while maintaining a good reflection coefficient. Due to this high port isolation, the far field patterns indicate a very good polarisation behaviour.

The hybrid coupler

The hybrid ring coupler is used to excite the circular polarisation of the patch, while absorbing the cross polar components of the antenna. This is an important feature, especially for antenna arrays with higher element numbers.

The simulation model of the hybrid ring coupler is shown in Fig. 8. Located beneath the antenna block, the hybrid ring is a stripline circuit layout. The simulation results are shown in Fig. 7. A good reflection coefficient can be stated in combination with an equal transmission to the two antenna feeding ports. Only a neglectable amount of power has to be absorbed by port 4, which is matched by a buried thickfilm resistor.

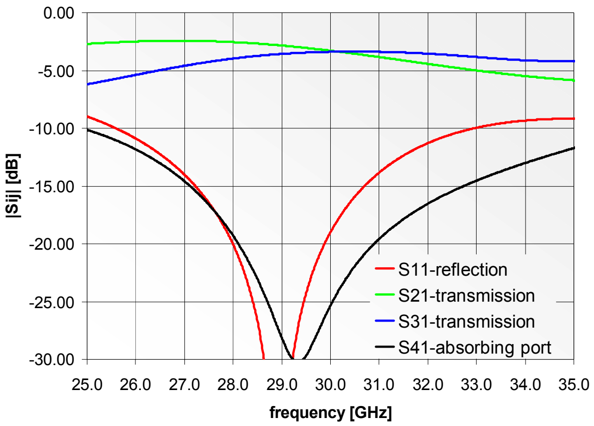


Fig. 7: Simulation results of the hybrid coupler simulated with FDTD simulator Empire^{TM} [5] .

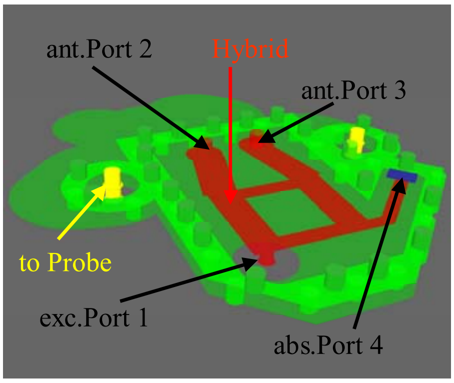
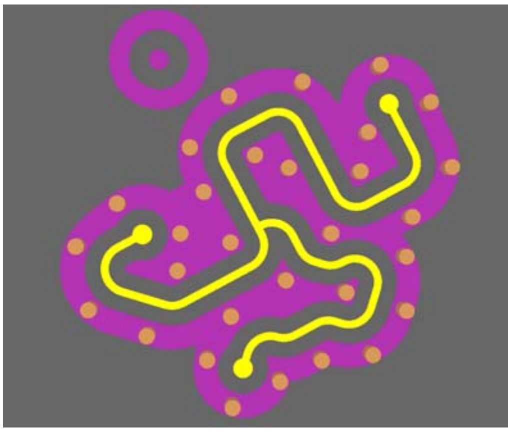


Fig. 8: Hybrid coupler iso view.

The calibration network

The calibration network of the 4×4 array is visualised in Fig. 10, Fig. 9 shows the first t-junction of this network in a larger scale. For the calibration process, one single receiver is used for the 16 elements. Due to the symmetric structure of the network, every calibration probe is connected with equal path length to the receiver. This ensures that every calibration probe is connected with equal attenuation.



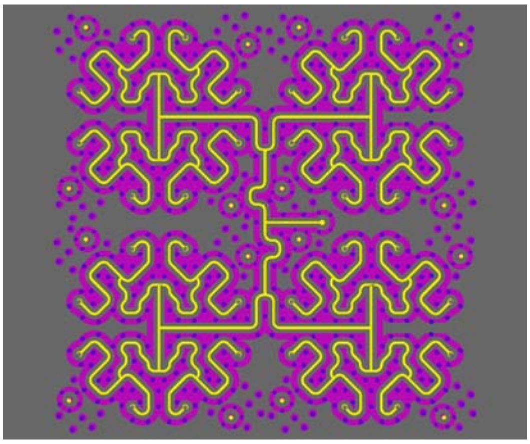


Fig. 9: Calibration network first T-junction. *Fig. 10: Whole calibration network 4x4 array.*

The technology process

The manufacturing of this antenna structure is currently in progress. Fig. 11and Fig. 12 show two ceramic tapes prior to the burning process. Measurements are expected to be carried out in near future and will be shown in the presentation.

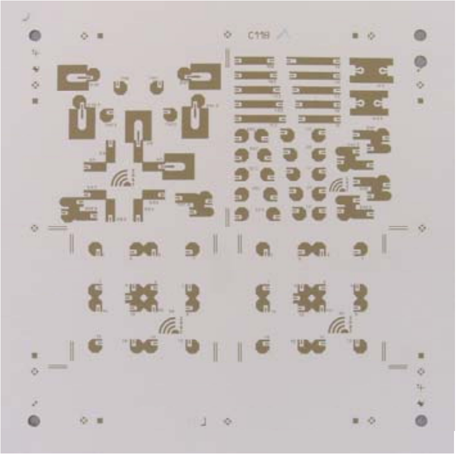


Fig. 11: Picture of the layer, which contains the measurement interfaces.
(smp connectors and cpw probes)

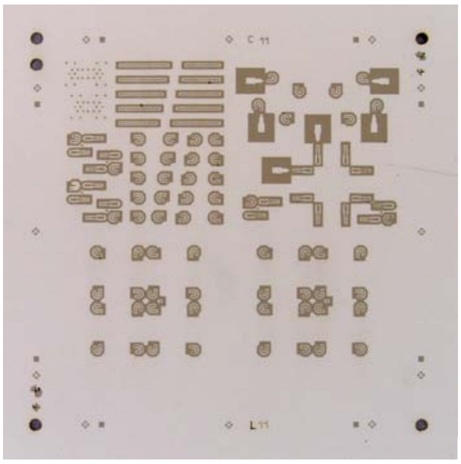


Fig. 12: Bottom layer of the measurement interfaces.

Summary

In this paper, a promising design of a 30 GHz highly integrated LTCC antenna module for digital beam forming arrays has been presented. The simulation results of the different functional blocks show that the design allows for a very good suppression of the cross polar component.

Acknowledgement

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