AN 18 GHz CIRCULARLY POLARISED MULTILAYER ACTIVE MICROSTRIP ANTENNA SUBARRAY USING MMIC AMPLIFIERS

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ABSTRACT

This paper presents an 18 GHz circularly polarised multilayer active antenna subarray using MMIC amplifiers. With the advantage of a multilayer structure, the radiation patterns from the antenna side are not affected by the radiation from circuit side. An extra gain of 15.46 dB has been measured in comparison to the passive array. This type of array can be the ideal building block for large microstrip phased array systems.

INTRODUCTION

Recently, several active antennas or active antenna arrays using FET-based amplifiers or Gunn diodes have been reported (1-2). Together with these single active elements, recent research has been reported on the use of two and three terminal devices in spatial power combining structures, which have proved to be a very efficient method to achieve high power from solid state oscillators and amplifiers (3). In addition, active antenna arrays are particularly attractive for radar, mobile and satellite applications. As pointed out by Pozar (4), a multilayer structure is highly advantageous for microstrip arrays. A single layer substrate does not have enough surface area to accommodate radiating elements, feed networks and active elements without incurring coupling between active circuitry and radiating elements. In comparison, multilayer structures provide twice the area for radiating elements, active devices and feed network, while being able to use the best substrate for each function. Likewise, spurious signal radiation from the feed network is practically eliminated due to the ground plane separating the radiation aperture from the feed network.

This paper presents a circularly polarised multilayer active microstrip antenna array using a monolithic microwave integrated circuit amplifier underneath each element. The two dimensional array is composed of four active elements, each consisting of a two-stage MMIC amplifier and a patch antenna. A two-sided structure, shown in figure 1, has been used in the design. The passive feed network, designed using Wilkinson power dividers, was built on an alumina substrate with a dielectric permittivity of ε_r=9.8 and thickness h=0.635 mm. An extra 2μm layer of nichrome was used for the resistors. The patch antenna array was built on a RT/Duroid substrate with h=1.575 mm and ε_r=2.2. It was designed using the MSant program by Pozar, and for simulation purposes *em* by Sonnet Software, which calculates S-parameters for arbitrary geometries using the Method of Moments, was selected to model the patch.

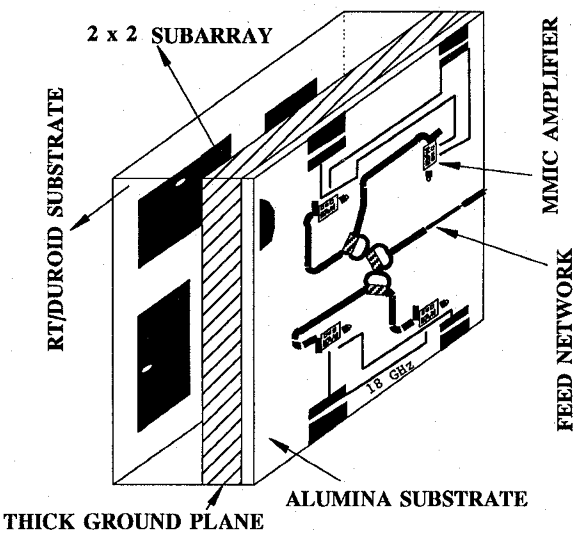

Fig. 1. Multilayer structure for the 18 GHz active antenna subarray

MMIC AMPLIFIER

The MMIC amplifier uses the standard GEC-Marconi (Caswell) foundry F20 process, which offers 0.5 μm gate-length ion-implanted MESFETs and through-GaAs via holes. The circuit topology provides both the optimum matching networks, DC blocking and DC biasing for a minimum layout size. The design was modelled with the standard foundry models and *Touchstone*^{TM}. Wavemaker (Barnard Microsystems) was used to draw the MMIC (full custom) layout based on the GaAs foundry library elements.

Two-finger and four-finger ion-implanted MESFETs with a gate length of 0.5 μm are used for the first and second stages respectively. The biasing of these MESFETs gates and drains are applied independently to allow for maximum control of the amplifier gain response. All the matching networks were optimized and synthesized to produce maximum small-signal gain flatness for high amplification and low return loss. Shown in figure 2 is a photomicrograph of the fabricated Ku-Band MMIC amplifier with a chip size of only 2 x 1 mm. The chip substrate thickness is 200 μm.

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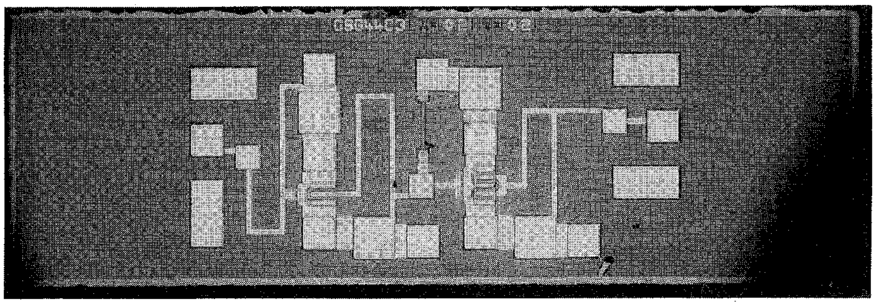

Fig. 2. Photomicrograph of the fabricated Ku-Band MMIC amplifier.

CIRCULARLY POLARISED PATCH ARRAY

Circularly polarised microstrip arrays with wide impedance and axial ratio bandwidths can be obtained by using single fed relatively thick linearly polarised elements with the well established sequentially-rotated feeding configuration (5). This is obtained with a 4-element subarray with unique angular and phase arrangements. The purpose of the diverse angular orientations is to generate two orthogonal polarisations, while the different feed phase provide the necessary phase delays for circular polarisation generation.

It has been demonstrated through several studies (6-7) that this technique significantly improve the axial ratio bandwidth since the mutual coupling between adjacent elements is expected to be less due to the orthogonal orientation of them. The application of sequential feeding to arrays can lead not only to improvements in cross-polarisation and input VSWR, but also to better polarisation isolation. The configuration selected for the array was a 0°, 90°, 180°, 270° fashion, which, at the same time, cancels most of the radiation impurity due to higher order modes from the 0° element with that of the 180° element, and likewise for the 90°-270° pair. The layout of the selected arrangement is shown in figure 3.

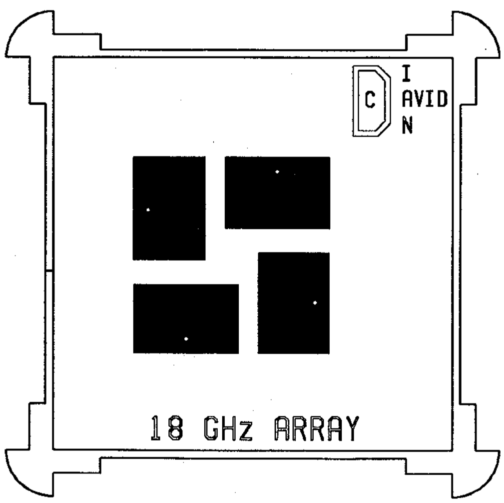

Fig. 3. Sequentially-rotated feed configuration for the patch antenna.

SIMULATION AND EXPERIMENTAL RESULTS

Based on the measured S-parameters of the MMIC amplifier, *Touchstone*^{TM} was then used to analyze and optimise the feed network to ensure that the minimum losses and best isolation between terminals would be achieved along with the proper feed phase arrangement. A photograph of the circuit side of the antenna subarray is shown in figure 4. The circuit substrate included the laser drilled holes for the MMICs and associated bias capacitors, bias lines and pads for the pass-throughs.

The alumina substrate was laser drilled to provide the space for the MMIC and interconnections. The two substrates were then bonded together using silver loaded epoxy. The thick ground plane of the RT/Duroid substrate provided a convenient base for the chip carriers that would consequently ground the MMICs. The circuit was then measured with a HP8510B network analyzer in an anechoic chamber with a reflectivity level of - 25 dB. A comparison between simulated and measured input return loss for the active antenna array is given in figure 5.

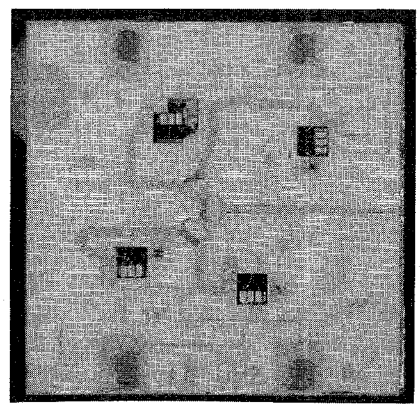

Fig. 4. Circuit side photograph of the active antenna subarray.

In order to judge the transmission performance of this active array, a reference array which is completely identical to the active array except that the active circuit is eliminated, has also been built and measured. Figure 6 shows the transmission coefficient between the active array and the reference array on one side and a standard horn on the other side.

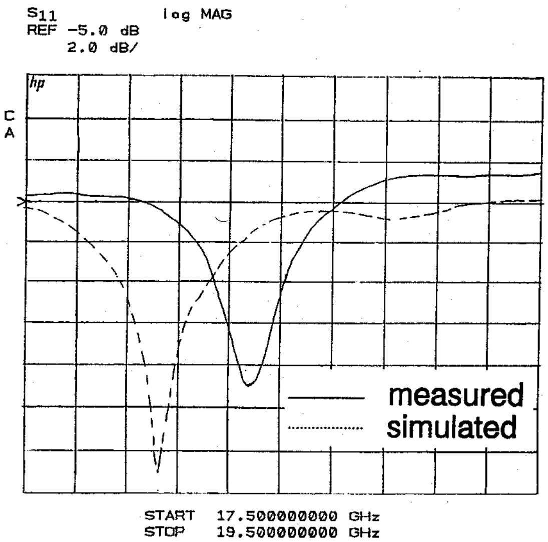

Fig. 5. Simulated and measured input return loss of the active antenna subarray.

Although the passive array showed a slight shift in its centre frequency, the active microstrip antenna array was found to have an extra gain of 15.46 dB, corresponding to a directivity of 15.56 dB. This includes the loss compensation and represents a relative power combining efficiency of 77 %. The best results for the active array were obtained with a DC gate bias voltage of - 0.96 Volts, a DC drain voltage of 2.85 volts.

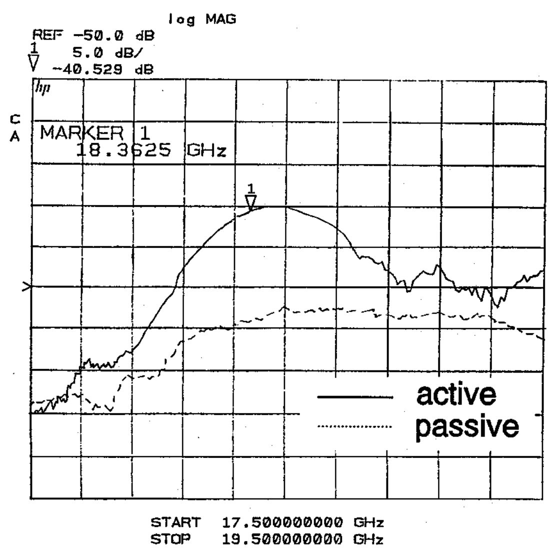

Fig. 6. Measured transmission parameter of the active and passive antenna subarray.

The field patterns for the passive and active array can be compared to the simulated ones in figures 7 and 8. The simulated patterns of the single elements and the array were calculated from *em*, and *Omnisys* was then used to compute the radiation patterns of the array.

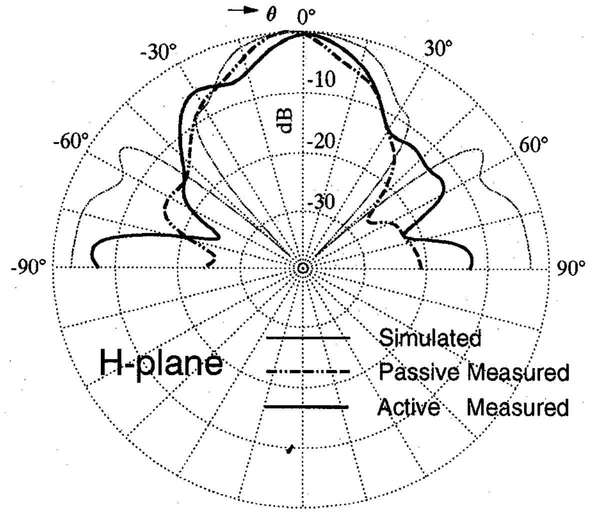

Fig. 7. Simulated and measured H-plane radiation pattern.

As an additional feature, this method takes into account the mutual coupling between elements by means of measured S-parameters between the single elements of the array, in a technique similar to that described by Chan et al. (8). As can be seeing from these figures, the measured active array patterns were consistent with the expected behaviour.

The VSWR bandwidth of the active array, the axial ratio for the passive and the active array and their radiation patterns were also measured. The measured VSWR bandwidth for the active antenna is 1.5 % (225 MHz, f_0 = 18.3625 GHz). The simulated axial ratio at boresight was 0.54 dB at 18 GHz while the measured axial ratio for the passive and active array was 1.195 and 2.539 dB respectively.

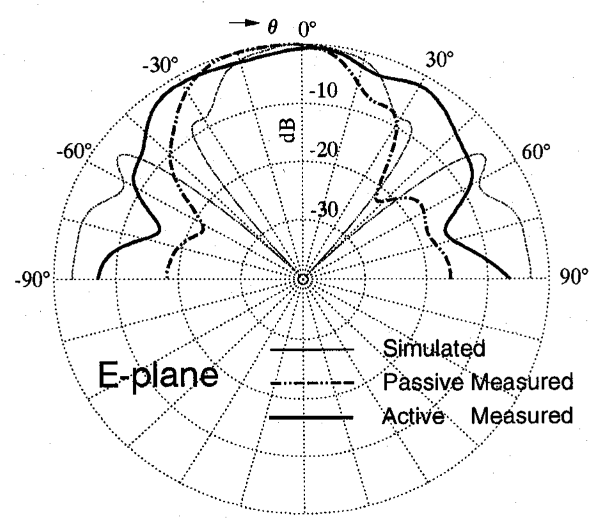

Fig. 8. Simulated and measured E-plane radiation pattern.

CONCLUSION

A Ku-Band 2x2 circularly polarised spatial power combining array with 77 % efficiency and an extra gain of 15.46 dB has been demonstrated, with a good agreement between experimental results and theory. With the advantage of a multilayer structure, the radiation patterns from the antenna side are not affected by the radiation from the circuit side. Additionally, switchable polarisation is possible by simply turning on and off pairs of MMIC amplifiers.

These structures have promising application in doppler motion detectors, non-invasive medical imaging and other systems where radiating structures are desirable. Futures areas of research include beam steering and optical control of the array, as well as an extension to higher frequencies.

ACKNOWLEDGEMENTS

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