A 40 GHZ MICROSTRIP ARRAY ANTENNA

by Wolfgang Menzel
AEG-TELEFUNKEN
Geschäftsbereich Hochfrequenztechnik
Grundlagenentwicklung N1 E32
Postfach 1730
D-7900 Ulm, Germany

Abstract

A 40 GHz 4x24 element microstrip array consisting of rectangular microstrip resonators is described. The antenna is developed using scaling techniques. A microstrip feed network is calculated including discontinuity effects. Return loss, bandwidth and radiation characteristics are given.

Introduction

Planar antennas find increasing interest due to their flat profile, low weight, case of fabrication and low costs (/1/). In this paper, the design of a 40 GHz microstrip array is described. This antenna is planned to be integrated in a railway communication system.

The array (Fig. 1) is fabricated on a 0.25 mm thick RT-Duroid substrate material and consists of 6 subarray of 4x4 elements. The subarrays have been developed using scaling techniques. For this antenna, the array is fed by a microstrip network which has been calculated including frequency dependent discontinuity effects.

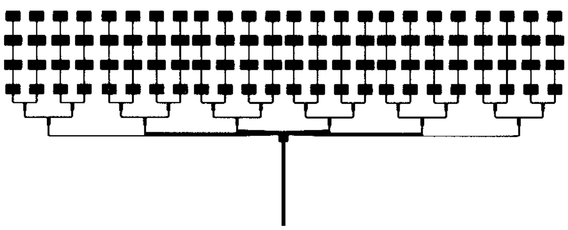

Fig. 1: Microstrip array

Array design

In a first step, a chain of 4 antenna elements (Fig. 2) was designed at 12.76 GHz on a 0.8 mm thick RT-Duroid substrate material (/2/). A taper in element width is used for sidelobe reduction. The exact input impedance and the resonance frequency of this chain was determined with a network analyser. Slight changes of the element dimensions were made for frequency adjustment, and a corporate feed for the 4x4 subarray was then calculated using simple power dividers.

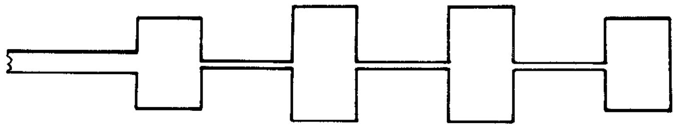

Fig. 2: Chain of 4 microstrip elements

This subarray was tested (at 12,76 GHz) and a return loss of better than 20 dB was found. The beam widths were 17^o in the H-plane and 24^o in the E-plane.

To complete the array, a suitable feed network for the six subarrays had to be found. To avoid excessive losses, a central-fed series feed was chosen instead of a corporate feed (Fig. 1). In order to achieve a power distribution and to get a simple layout, unsymmetrical T-junctions were used as power dividers. These junctions must yield a correct power distribution while reflection losses should be minimal. For the conditions given here, quasi-static calculations failed, so a mode-matching technique together with a waveguide model of the microstrip line was used to compute the frequency dependent scattering matrix of the unsymmetric T-junction (/3/, /4/). The line widths of the junctions were chosen (by an optimization routine) to match the two conditions given above. Additionally, the computation procedure was able to determine the changes of phase introduced by the junctions. Between the junctions, tapered lines were inserted to match the different line widths (/5/).

Principally, the power dividers were designed for a constant power level at the six subarrays. Due to line losses, however, an amplitude taper exists.

The complete array design was scaled to operate at 39.5 GHz without testing it at 12,76 GHz.

Array performance

Fig. 3 shows the return loss of the complete array. An error of 400 MHz in resonance frequency is found. The return loss at 39.9 GHz is 19 dB. For a VSWR ≤ 2, the bandwidth is nearly 800 MHz (2 %).

The H-plane radiation pattern is given in Fig. 4. Beamwidth is 3,5^o, and a sidelobe level of nearly 14 dB is found. In the E-plane (Fig. 5), the beamwidth is 26^o. The ripple in the plot mainly is due to the finite substrate size, as well as the radiation between 70^o and 90^o which can be suppressed by adding absorbing material at the edges. The sidelobe level in the E-plane is not very good, and in both planes, the zeros near the main beam are filled up. Two reasons for this fact may be the coupling between the elements and phase errors in the feed for the subarrays.

The most important reason, however, was found to be radiation of the feed network, especially of the junctions and bends. By screening the feed network of the 12,76 GHz subarray, a substantial reduction of the E-plane sidelobe level was found.

The gain of the array was measured to 19 dB over isotropic, compared with a calculated value of 25 dB. Part of these losses, again, are caused by the radiation of the feed, part of it by losses in the lines and the radiating elements.

In a next step, the array will be fed with a triplate network. It is estimated, that losses can be reduced to 4 or 5 dB by carefully redesigning the array. In this case, losses are of the order reported in other publications, e.g. /6/.

Another possibility to reduce losses is to use thicker substrates; then however, attention must be paid to higher order modes excited in the wider microstrip or stripline feed lines.

Acknowledgement

This work was supported by the German "Minister für Forschung und Technologie", Grant No, TV 7804/1.

References

/1/ James, J.R., Wilson, G.J.: Microstrip antennas and arrays. Pt. 1-Fundamental actions and limitations. IEE Journal on MOA, vol. 1 (1977), 165-174.

/2/ Derneryd, A.G.: Linearly polarized microstrip antennas. IEEE Trans. AP-24 (1976), 846-851.

/3/ Menzel, W., Wolff, I.: A method for calculating the frequency dependent properties of microstrip discontinuities. IEEE Trans. MTT-25 (1977), 107-112.

/4/ Menzel, W.: Calculation of the S-parameters of an unsymmetric T-junction (Computer program description). IEEE Trans. MTT-26 (1978), 217.

/5/ Menzel, W.: Calculation of inhomogeneous microstrip lines. Electronics Letters, 13 (1977), 183-184.

/6/ Hall, P.S., Garrett, C., James, J.R.: Feasibility of designing mm microstrip planar antenna arrays. AGARD Conf. Proc. No. 254, Millimeter and submillimeter wave propagation on circuits (1978), 31.1-31.9.

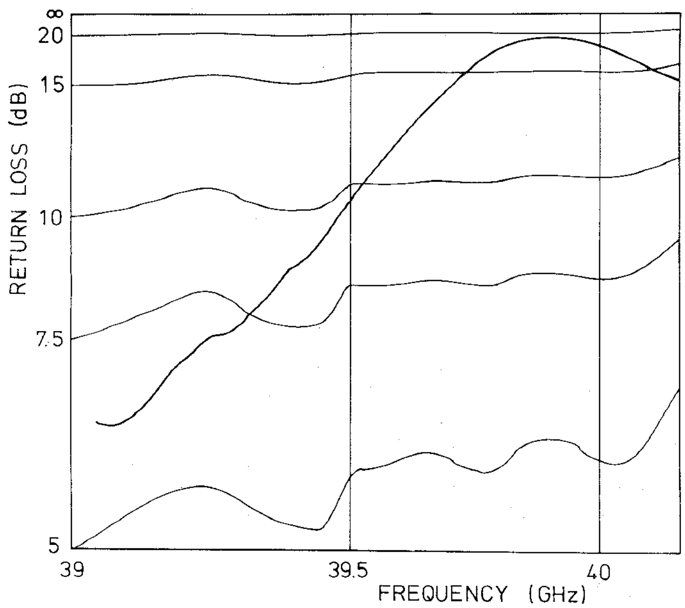

Fig. 3: Return loss of the microstrip array

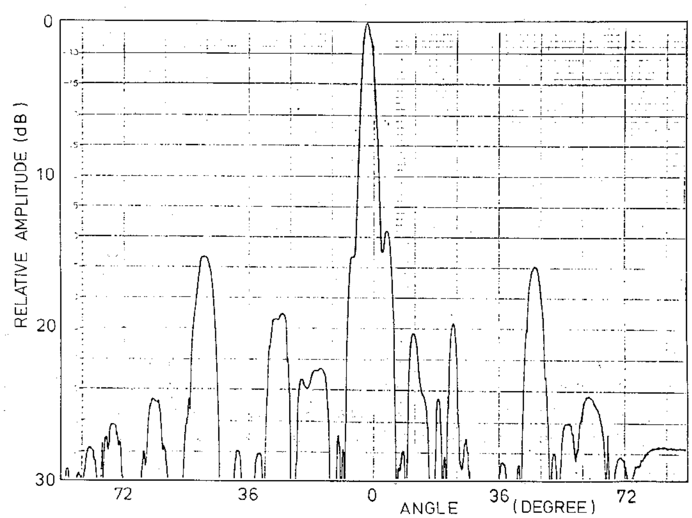

Fig. 4: H-plane radiation pattern

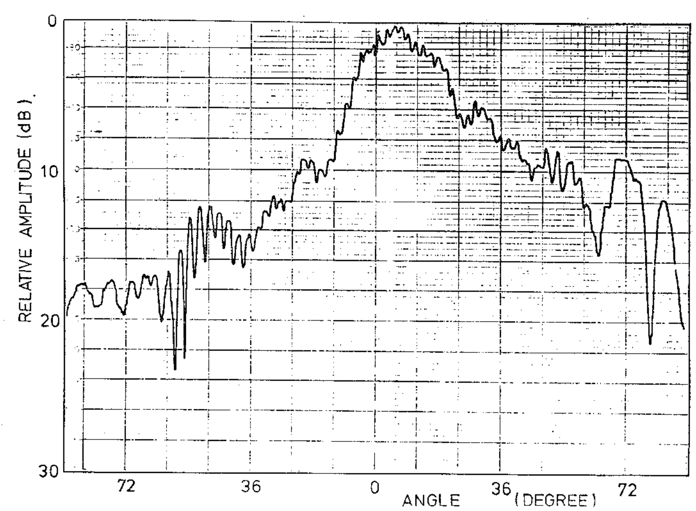

Fig. 5: E-plane radiation pattern