PERIODICA POLYTECHNICA SER. EL. ENG. VOL. 36, NO. 1, PP. 273-283 (1992)

MICROSTRIP ANTENNA APPLICATIONS

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Received: April 6, 1991.
Revised: December 12, 1991.

Abstract

The theory and practice of microstrip antennas (MSA) are well-known parts of the field of microwave integrated circuits (JAMES, J. R. et al., 1981). Research projects are going on at the Department of Microwave Telecommunications, DMT (TU Budapest) and at the Institut für Höchstfrequenztechnik und Elektronik, IHE (Universität Karlsruhe) in this field. This paper introduces some results of these projects.

Keywords: antennas, microstrip circuits, antenna arrays.

Introduction

Microstrip antennas are special types of microstrip transmission line circuits, which are the basis of microwave integrated circuits (HOFFMANN, R. K., 1983). An antenna element can be produced as a wide transmission line section with low impedance and a length near half of the wavelength (*Fig. 1*).

The generally used substrates have a thickness of 0.5–1.5 mm. To achieve the suitable mechanical strength the antenna can be mounted on a metal (aluminium) plate of 2–3 mm thickness resulting in a total thickness less than 5 mm, which is a really flat solution. This is one of the main advantages of this type of microwave antennas. On the other hand, these antennas have very light weight, which is also an important factor for the applications.

From the basic MSA elements one can build up greater two-dimensional antenna arrays (VÖLGYI, F., 1987). The radiating antenna elements and their feeding microstrip network can be realized on the same substrate (*Fig. 2*). This results in easy fabrication (photo etching) and low cost.

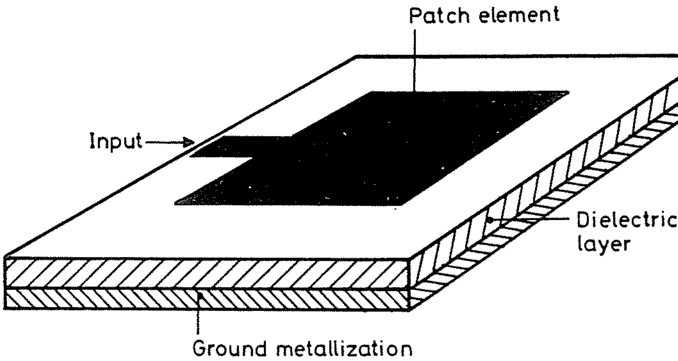

Fig. 1. A resonant element of Microstrip Antenna (MSA)

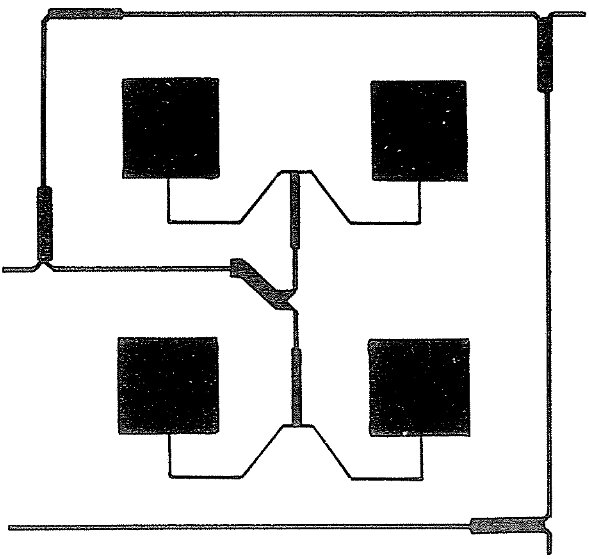

Fig. 2. An internal module of the MSA-array

Simple Model for MSA

The simplest model is a transmission line section with open ends. Describing precisely the effects on the microstrip line ends (HOFFMANN, R. K., 1983) we get a suitable model for the resonance frequency and input impedance of the antenna element.

A computer program was developed at DMT, based on the above model. The accuracy of this method was tested at IHE, where a very good agreement was found between the predicted and measured antenna parameters (*Table 1*). This is in good accordance with the results published by different authors (JAMES et al., 1981).

Table 1

f_{res} [GHz]		Error %	S_{11} [dB]	Bandwidth [MHz]	
Theory	Measured			Theory	Measured
3.98	3.98	0	-17.55	38.3	30
6.94	6.96	0.28	-28.27	98.6	100
9.87	9.877	0.07	-32.56	220.2	200
14.00	13.98	0.14	-29.08	440.4	410
17.00	17.04	0.23	-26.22	663.5	570
24.125	24.01	0.476	-25.00	2507.3	2110
5.3(R)	5.305	0.094	-33.9	206.5	221.5
5.3(Q)	5.28	0.377	-32.3	177.2	213.5

Circularly Polarized Antenna Module

A microwave moisture sensor was built to measure the moisture content of wet corn and cloth (VÖLGYI, F., 1989). The operation of the sensor is based on attenuation measurement between two microwave antennas separated from each other with the wet material to be measured. The sensors have to work in industrial environment so their antennas must not be sensitive for reflection from metal objects. That is why circularly polarized antennas were selected.

A module, designed for 10.5 GHz, with four elements was used with a special feeding network. Each element has two input lines, where 90 degrees is the phase difference in the excitation of the inputs with a uniform amplitude distribution. This excitation results in circular polarization. The layout of this antenna is shown in *Fig. 3*.

The whole size of this antenna is 50×50×1.6 mm which made it possible to produce a small sensor.

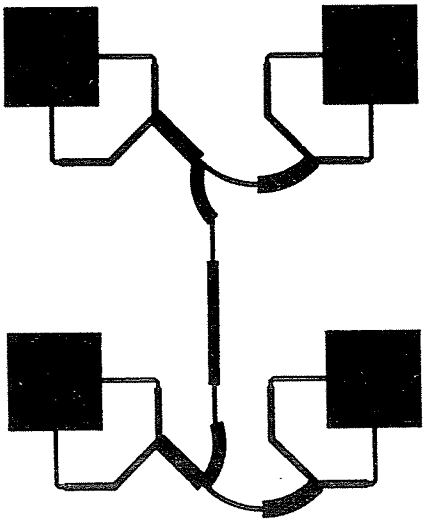

Fig. 3. Circularly polarized MSA

Airborne Antenna Array for 1.4 GHz

A flat lightweight antenna, with less than a −27 dB sidelobe level, mountable on airplanes had to be prepared for a 1.4 GHz radiometer (IJJAS, G., 1990) developed at TU, Budapest.

The antenna was made up of a 4x4 element microstrip antenna array. In the construction of the radiating elements the main aim was to provide light weight and flatness. The necessary low sidelobe level has been achieved by applying an adequate amplitude distribution (MERNYEI, F. – VÖLGYI, F., 1990b). The antenna construction can be seen in *Fig. 4*.

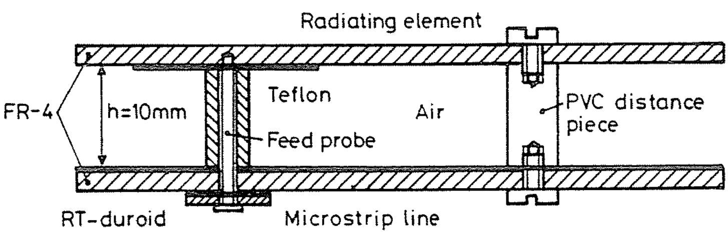

Fig. 4. L-ban MSA

In order to get the appropriate bandwidth (>6.5%) the 10 mm thick dielectric layer is air. The supporting surface of the resonant elements is commercial fiberglass FR–4 type substrate, which serves as a RADOME at the same time (inverted microstrip). The ground plane is formed by the metal layer on another FR–4 substrate. The coaxial feeding probes of the radiating elements are metal rods placed inside the cylindrical teflon distance pieces. They are connected to the microstrip power splitter circuit placed on the back side.

The measured radiation pattern of the complete antenna is shown in *Fig. 5*, its characteristic features are the following:

size:	66×66×1.5 cm
mass:	3 kg
3 dB beamwidth:	10 degrees
side lobe level	<–27 dB
gain:	20 dB
specific gain:	12.3 dB/GHz^{2}kg

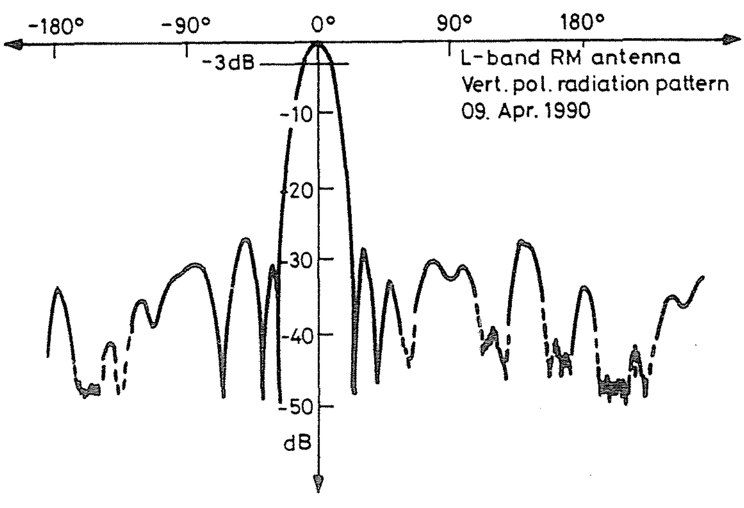

Fig. 5. Radiation pattern of MSA for microwave radiometer

The specific gain is a new suggested parameter for lightweight antennas to compare weight, gain and operating frequency in one term. The specific gain increases with gain and decreases with frequency and weight (VÖLGYI, F., 1990).

Janus-Antenna for Doppler Radar Sensor

A Janus-antenna for Doppler Radar applications in the 24 GHz frequency-range was developed at IHE (KEHRBECK, J. et al, 1990a, 1990b).

A Janus-antenna has two equal main beams, which radiate in certain directions off boresight (*Fig. 6*). An alternating phasing of 180° from element to element is required to get the Janus pattern and the element distance determines the squint angle. Using rectangular patch elements, the phase condition can be realized by feeding consecutive patches on opposite sides, taking advantage of the field distribution on the patch itself.

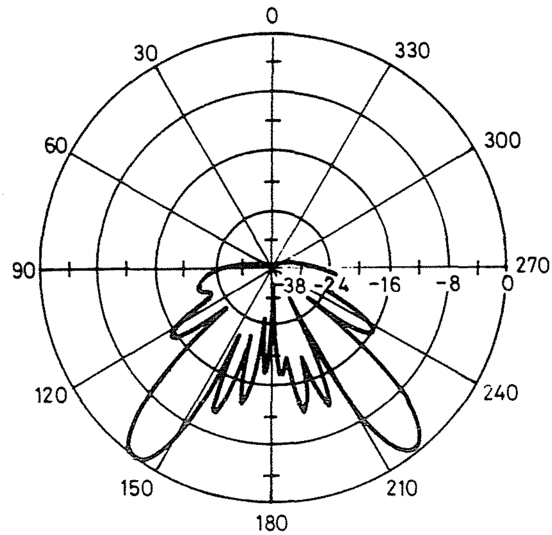

Fig. 6. Janus-antenna pattern

Fig. 7 shows the layout of a 64-element array divided into symmetrical 2×2 subarrays. The dimensions are 90×90 mm. The feeding network consists of simple transmission lines with quarter-wavelength transformers and tee-junctions. The complete array is central fed with a coaxial connector through the groundplane of the antenna substrate (*Fig. 7*).

The antenna reflection coefficient is better than −25 dB, the bandwidth is 3.5%. The 3 dB beamwidth is 9° in E- and H-plane, the gain per mainbeam is 21 dB.

With this pattern type it is possible to get information from two separate directions with the help of only one antenna and one TR-section.

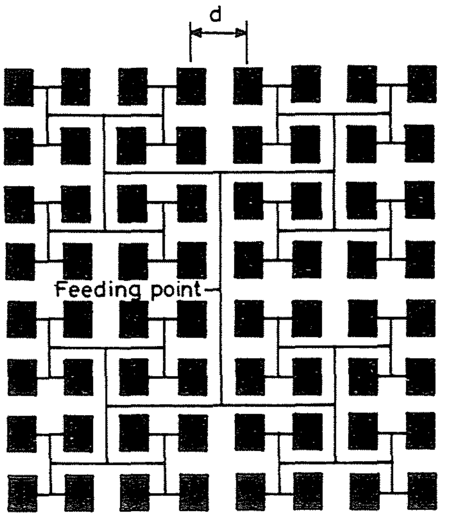

Fig. 7. Layout of Janus MSA

Measurements on Microstrip Antennas

Temperature Dependence Test

Testing the temperature dependence of MSA arrays is a 'small module test' which can be done without a climatic chamber, using thermoelectric heating/cooling (Peltier) elements (MERNYEI, F. – VÖLGYI, F., 1990a). The change of resonant frequency versus temperature is the most characteristic feature of the temperature dependence of MSA- s. *Fig. 8* shows measured values. From this, with the thermal expansion data of the substrates the thermal dependence of substrate permittivity was calculated (see *Fig. 9*).

RCS Measurements on MSA-s

Any antenna which receives power also reradiates energy, due to the current distribution that an incident electromagnetic field generates on the antenna. This reradiation process can be utilized to characterize antennas by measuring the backscattered field. These measurements have been pursued at IHE, using a wideband, polarimetric network-analyser based system (HEIDRICH, E. et al, 1989a).

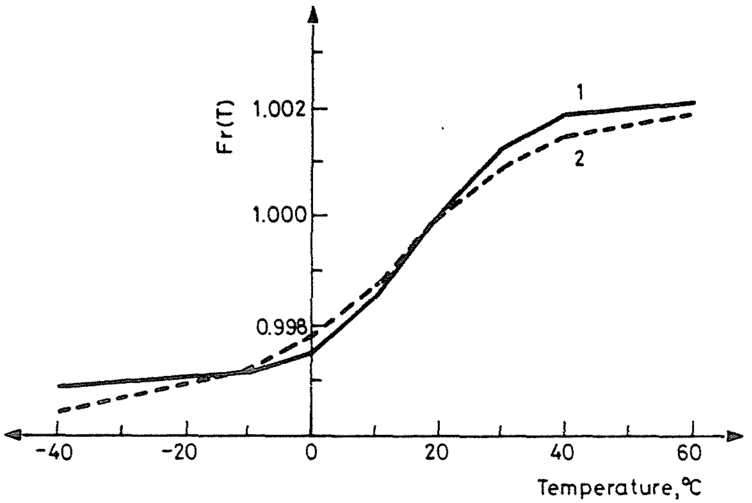

Fig. 8. Measured resonace frequency of MSA over temperature

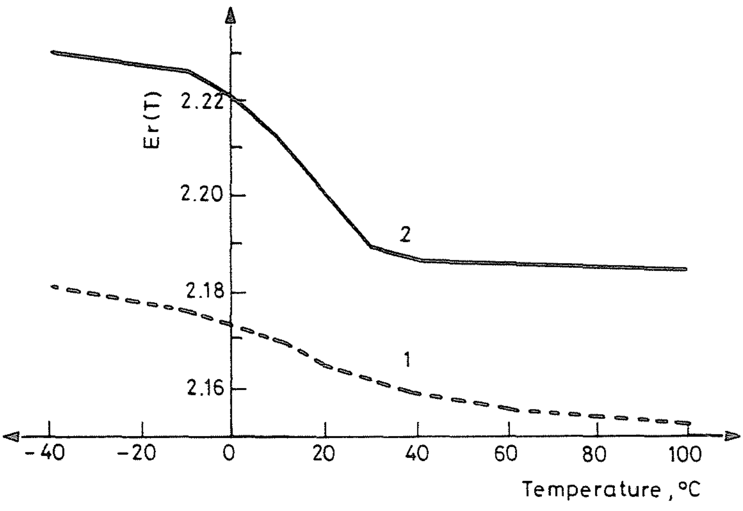

Fig. 9. Dielectric constant variation over temperature, calculated from measurement data

Applying the technique to microstrip antennas it is possible to examine the influence of a feed network on the patch element. *Fig. 10* shows the characteristic RCS-signatures of a square patch without feeding. The resonance frequency can clearly be identified. Connecting the patch element to a microstrip or coaxial feed usually changes the load as well as the resonance frequency (HEIDRICH, E. et al, 1989b).

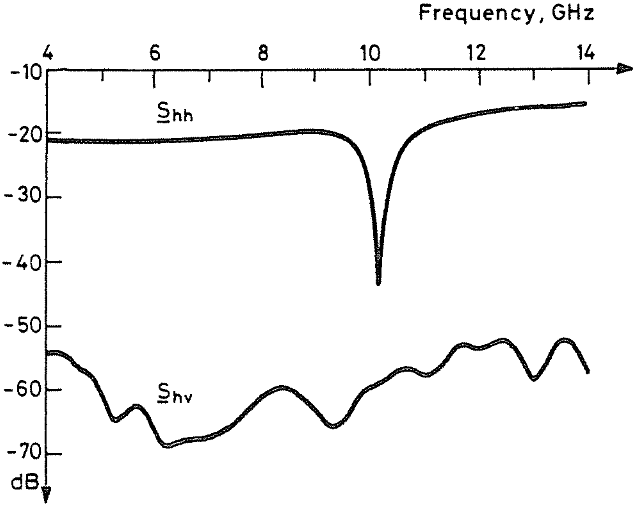

Fig. 10. Radar Cross Section of a single MSA element without feeding

Combined with a load variation principle it is also possible to determine various antenna parameters for single elements or arrays with feed network by RCS-measurement.

Fig. 11 gives an example for co- and cross-polarized gain for a 2×2 patch array with microstrip feeding designed for 10.3 GHz.

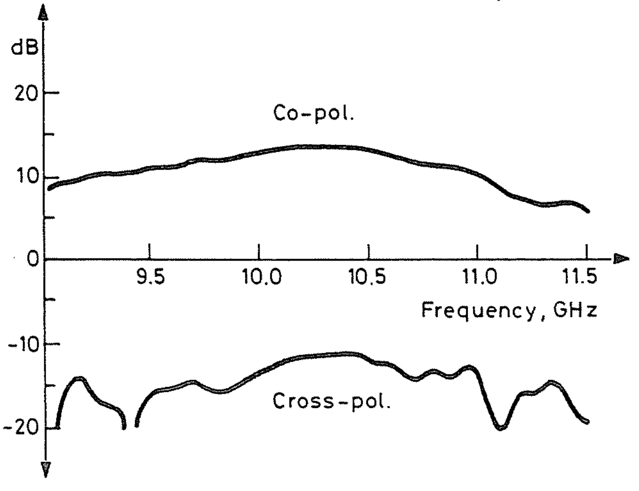

Fig. 11. Co- and cross-polarized gain of a two by two element MSA array

Conclusion

Various applications of microstrip antennas have been presented. As can be seen most of the operating instruments have great use either in industrial or commercial areas. Based on the presented ways of modelling and measurement, the understanding of the theory of these circuit elements and a precise design procedure can be obtained.

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