MICROSTRIP ANTENNA ARRAYS FED FROM THE BACKSIDE OF THE SUBSTRATE

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Abstract

Microstrip antenna arrays with a feed network on the backside of the substrate material have many advantages. Using this technique, microstrip antenna arrays with unequally spaced elements can be built to reduce the sidelobe levels and dual frequency antennas with low sidelobe levels are realizable. Additionally the cross polarization radiation is reduced intensively. In this paper it will be shown how the feed network on the backside of the antenna, the coaxial through-connection and the antenna array can be calculated with good accuracy and low numerical effort. Microstrip antenna arrays with low sidelobe levels and dual frequency antennas will be demonstrated. The influence of the coupling between the patch radiators and its numerical calculation will be discussed.

Introduction

The problem of reducing the sidelobe levels or the beamwidths of microstrip array antennas requires a tapering of the radiation amplitudes or a special spacing between the adjacent radiators. Up to now there have been difficulties in operating nonuniform element spacings if the radiators and the feed network are on the same substrate side, because the feed networks often need equal spacings between the radiators. Additionally such antennas exhibit the disadvantage that they have a large undesirable cross-polarization. All these effects can be reduced by moving the feed network to the backside of the substrate slab.

The main problem of microstrip antennas with the feed network on the backside of the substrate is, besides the technological difficulties, the correct description of the coaxial feed from the backside through the substrate material. This paper will present an equivalent network for the input impedance of a rectangular patch radiator fed from the backside of the substrate material, so that an approximate calculation of the radiating frequency, the position of the feed point on the radiator and a good match to the feedline can be achieved.

A Simple Model for the Rectangular Patch Radiator Fed from the Backside of the Substrate Material

In this chapter a simple model for describing the rectangular patch radiator which is fed from a network on the backside of the substrate material shall be described. This model is not all new but it takes together published results and new research results in a way that the radiator can be described with high accuracy and low numerical effort. All the numerical work can be done on a small desk-top computer.

Consider a microstrip resonator (as shown in Fig.1a) which is fed by a microstrip line on the backside of the substrate slab as shown in Fig.1b. Richards /1/ described an equivalent network for a microstrip resonator using a magnetic wall cavity model for the resonator wich takes into account all possible resonant modes of the structure. This equivalent network is shown in Fig.2. Because microstrip resonators used in antenna arrays normally

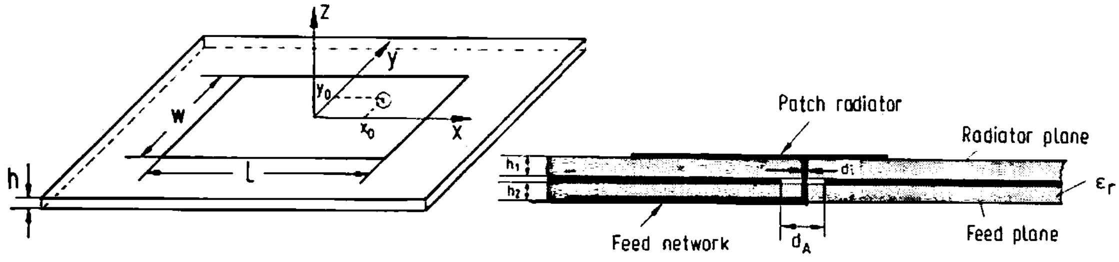
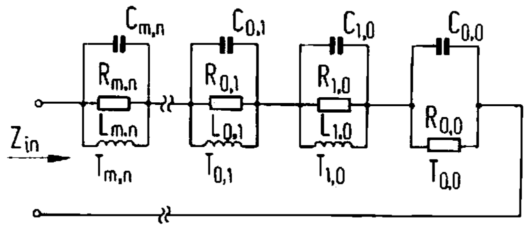


Fig.1: The microstrip patch antenna (a) with a coaxial feedline (b).

operate in the TM_{10} or in the TM_{01} fundamental mode, the network can be reduced to the network shown in Fig.3 where all the higher order modes are combined in a single inductance L_∞. C_{00} represents the static capacitance. This network describes the resonator oscillating in the TM_{10} and the TM_{01} mode and additionally for a quadratic patch resonator (W=L) the degenerated mode is considered in a good approximation.



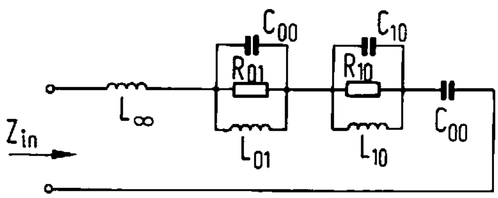


Fig.2: Equivalent circuit of the rectangular patch radiator.

Fig.3: Reduced equivalent circuit for the rectangular patch radiator.

It is known that a patch radiator can be matched to a feedline by varying the feed point location (x_0, y_0, Fig.1a). The feed point position for a radiator working in the TM_{10} mode must be determined considering also the influence of the nonresonant TM_{01} mode. This is done in a manner which principally has been described by Lier /2/ but which has been modified slightly. If the nonresonant mode is neglected, in the case of radiators with small width W the predicted frequency would be higher than the measured one and lower in the case of wide radiators.

The influence of the position x_0,y_0 of the feed point can be described by the equivalent network shown in Fig.4, where two lines represent the two fundamental modes of the rectangular microstrip radiator (TM_{10}, TM_{01} modes). Y_{EL} and Y_{ET} represent the longitudinal and the transversal end effects of the microstrip structure and their influence on the resonance.

The imaginary parts of Y_{EL} and Y_{ET} describe the fringing field at the open end of a microstrip line. If the radiator is resonant along the x-axis the real part of Y_{EL} shall include all the losses of the resonant mode such as radiation loss, dielectric loss and conductor loss. The same argument is applied for the real part of Y_{ET} in the case of a radiator which is resonant along the y-axis. The radiation resistance in general is calculated by the expressions given in /6/. However, for a wide range of applications the approximations given in /2/ and /3/ can be used for a high speed computation.

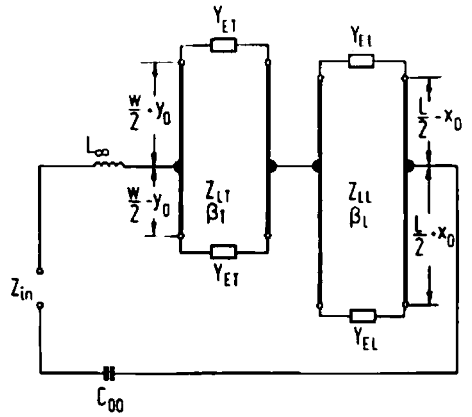


Fig.4: Equivalent circuit of the rectangular patch radiator for calculating the influence of the feed point position.

The real part of the transverse end effect Y_{ET} describes the radiation of an open microstrip line by a modified expression $(W=W_{eff})$ given in /7/. The capacity C_{00} in Fig.4 is given by the formulas for the static capacitance of the resonator. The influence of the modes with an order higher than (10) or (01) is neglected so that L_∞ represents only the inductance of the feed probe by an expression given in /8/. The parameters of the microstrip line such as the characteristic impedance, the open end effect, the effective dielectric constant and the effective width are calculated according to /4/, /5/ and /9/.

The influence of the coaxial feed line is described by an equivalent Pi-circuit as shown in Fig.5. The capacitance represents the electric field concentration in the common ground plane. L_2 is the inductance of the feed probe through the substrate and C_f represents the fringing field at the end of the antenna. In C_f the admittance of a microstrip stub used for an additional matching circuit in the plane of the feed network can also be taken into account.

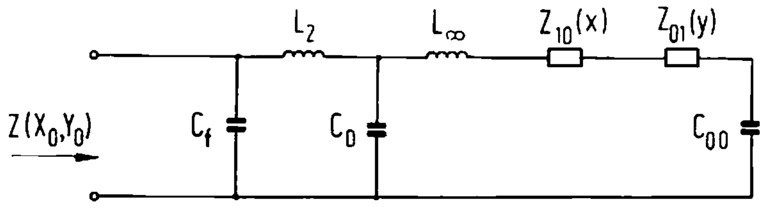


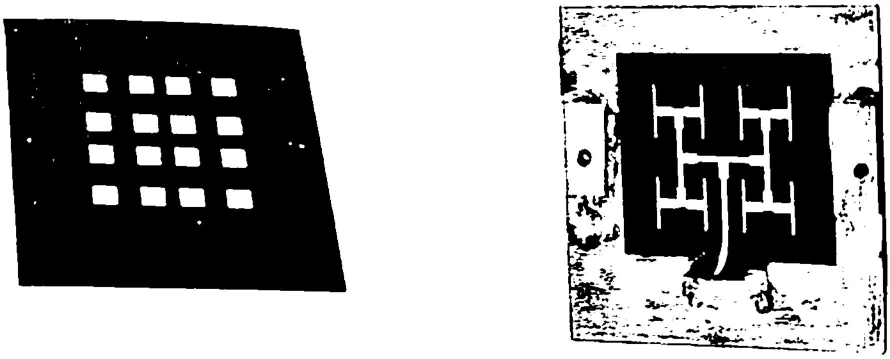
Fig.5: The complete equivalent network for the patch antenna including the coaxial feed through the two substrate materials.

C_0 is calculated according to an expression given in /10/. The inductance L_2 is given by the same expression as L_∞ if h_1 is replaced by h_2. By using all these expressions the input impedance $Z(x_0,y_0)$ of a single patch radiator is obtained as a function of the feed point position x_0, y_0.

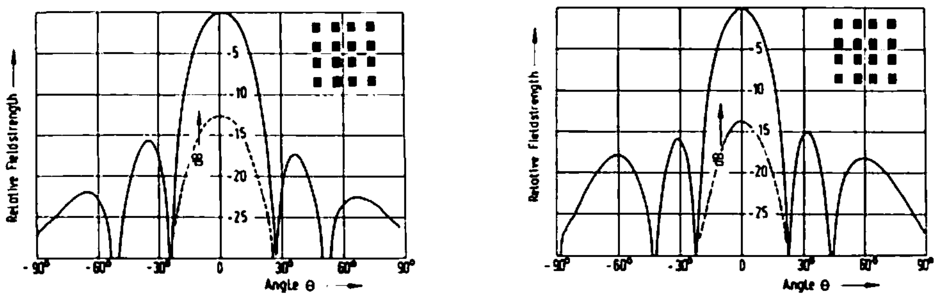
In the case of an array antenna a planar feed network is used on the backside of the antenna as it is principally shown in Fig.6. It will also be discussed how the matched power dividers are designed using a magnetic wall model for this special T-junctions.

Experimental Results

Various antennas have been designed on RT/duroid 5880 substrate material and the numerical results will be compared to experimental results. As an example a 16-element dual-frequency planar array is shown together with the H-plane radiation characteristic in Fig. 6. Using the results for 1-dimensional and 2-dimensional arrays the accuracy of the design method will be discussed intensively. Additionally the influence of the coupling between the patch radiators will be discussed using theoretical results of a spectral domain analysis and experimental results for a 4x8-array antenna.



a)



b)

10.48 GHz 12.07 GHz

Fig.6: Planar dual-frequency array antenna for 10.5 GHz and 12.0 GHz (a) together with their H-plane radiation characteristic at the two frequencies (b).

REFERENCES

/1/ W.Richards, Y.Lo, D.Harrison: IEEE Trans. AP-29 (1981), No.1, 38-46.

/2/ E.Lier: Proc. IEE, part H, Vol. 129 (1983), No.4, 161-164.

/3/ E.Lier, K.Jacobsen: IEEE Trans. AP-31 (1983), No. 6, 978-984.

/4/ M.Kirschning, R.H.Jansen: Electron. Letters, Vol.18 (1982), 272-273.

/5/ N.Koster, R.H.Jansen, M.Kirschning: Electron. Letters, Vol. 17 (1981), 123-124.

/6/ A.Derneryd: IEEE Trans. AP-26 (1978), 532-535.

/7/ H.Sobol: IEEE Trans. MTT-19 (1971), 885-887.

/8/ R.F.Harrington: Time Harmonic Electromagnetic Fields. McGraw Hill Book Company, New York 1961, p. 378.

/9/ R.H.Jansen, M.Kirschning: Arch.Elektron.Übertragungstech. (AEÜ), Vol. 37 (1983), 108-112.

/10/ F.Vilbig: Lehrbuch der Hochfrequenztechnik. Akad.Verlaggesellsch., Frankfurt a.M. 1960, p. 151.