Synthesis of linear arrays of series fed proximity-coupled microstrip antennas

Stéphane TESSEREAU *
Jean-Marie FLOC'H *
Jacques CITERNE *

Abstract

This paper presents a synthesis of linear standing-wave arrays of microstrip antennas such as transverse dipoles, series-fed by a proximity coupled microstrip line. Each radiating element is characterized by its self-admittance and mutual coupling admittance. The self-admittance depends on geometrical parameters and on the nature of the substrate, while the mutual coupling admittance is related to the presence of the other radiating elements. These values are computed exactly using an integral equation technique combined with a two-port model of the element. The synthesis procedure is validated with measurements of the radiation pattern and a return loss of a 20-dipole array. The importance of mutual coupling in the design process is clearly demonstrated.

Key words : Antenna array, Linear antenna, Patch antenna, Microstrip line, Antenna feed, Antenna synthesis, Mutual coupling, Modeling, Dipole.

SYNTHÈSE D'ANTENNES EN RÉSEAU RECTILIGNE D'ÉLÉMENTS MICRORUBANS À ALIMENTATION SÉRIE PAR COUPLAGE DE PROXIMITÉ

Résumé

Cet article présente une synthèse de réseaux rectilignes à ondes stationnaires d'éléments microrubans du type doublets transverses, alimentées en série par couplage de proximité. Le principe consiste à caractériser chaque élément rayonnant uniaire par son admittance propre, fonction de sa géométrie et du substrat employé, et par son admittance de couplage mutuel traduisant l'influence des autres éléments composant le réseau. Ces données sont calculées grâce à un simulateur électromagnétique reposant sur la résolution d'équations intégrales par la méthode des moments, associé à un modèle quadripolaire de l'élément rayonnant. Cette synthèse est validée par des mesures réalisées sur le diagramme de rayonnement d'une part et sur l'adaptation d'autre part d'un réseau de 20 doublets transverses. L'importance de la prise en compte du couplage mutuel dans une telle structure est clairement démontrée.

Mots clés : Antenne réseau, Antenne rectiligne, Antenne plaque, Ligne microruban, Alimentation antenne, Synthèse antenne, Couplage mutuel, Modélisation, Antenne doublet.

Contents

I. Introduction.
II. Theory: the synthesis method.
III. Computation of admittances.
IV. Synthesis of a linear array.
V. Synthesis results.
VI. Conclusion.
References (7 ref.).

I. INTRODUCTION

Linear arrays of microstrip antennas, due to their compactness and light weight combined with ease and low cost of fabrication, are ideal candidates for communications systems employing space, polarization or angle-of-arrival diversity. Series-fed electromagnetically coupled microstrip antennas (Fig. 1) feature a relatively
simple feeding architecture comprised of a single microstrip line. In this type of array, the designer must take account of coupling between the line and radiating element on one hand and coupling among radiating elements, on the other hand. This requires an electromagnetic simulation software and synthesis method incorporating interelement coupling in order to adaptively match the array.

The synthesis method used here is that initially developed by R.S. Elliot and G.J. Stern [1, 2] for parallel-fed linear arrays, and extended by H.Y. Yang [3] to series-fed arrays. The principle consists in characterizing each element independently to determine the array’s impedance match for a desired radiation pattern and frequency. The element is represented by a two-port network, simulating a matched load seen by the feedline [4]. This way, all approximation errors caused at high frequencies by an open circuit termination, as proposed by Yang in [3], are eliminated. The behaviour of the radiating element in the array is, in this case, rigorously simulated by the solution of integral equations using the method of moments [5].

In the following article, the synthesis method proposed by R.S. Elliot and G.J. Stern is briefly recalled, and demonstrations are given for certain equations in [3]. The design technique is then illustrated in the synthesis of an array operating at 15 GHz, in which the basic radiating elements are transverse dipoles.

II. THEORY: THE SYNTHESIS METHOD

The principle of the synthesis method proposed by R.S. Elliot and G.J. Stern involves extracting each element and its feed line from the array, as illustrated in Figures 2a and 2b. Seen from the feed, each radiating element is represented, in a reference plane which coincides with its longitudinal axis, by the input admittance of the multiport characterizing the linear array, as suggested by Figure 2c. Each length of line of characteristic admittance $Y_c$ can be seen in both directions, as an input to the multiport.

The input admittance of one of these lines can also be thought of as the element’s self-admittance if it were isolated, plus a mutual coupling admittance representing the influence of the other array elements. The sum of these contributions is defined in [1] as the active admittance of the elements, each of which can be considered to be isolated in the array, as shown in Figure 2d. Moreover, each element transverse dipole can be modeled by a shunt admittance $y_n^a$ on a transmission line (Fig. 3) such that:

$$I_n = V_n y_n^a = V_n (y_{nn} + y_{nm}^{\text{mut}}),$$

where $y_{nn}^a$ represents the active admittance of the $n$-th radiating element, i.e., the overall contribution of the self-admittance $y_{nn}$ and the mutual admittance $y_{nm}^{\text{mut}}$, with:

$$y_{nm}^{\text{mut}} = \sum_{m=1, m \neq n}^N \frac{V_m}{V_n} y_{nm},$$

$N$ represents the total number of array elements and $(V_n/V_m) y_{nm}$ the mutual coupling admittance between the $n$-th and $m$-th elements such that:

$$y_n^a = y_{nn} + \sum_{m=1, m \neq n}^N \frac{V_m}{V_n} y_{nm}. $$