Electronically Steerable Radiation Pattern of Coupled Periodic Antenna Used Floquet Analysis

Ben Latifa Nader
National Engineering School of Tunis
Tunis Elmanar University
SysCom Laboratory
Tunisia, Tunis 1002
benlatifanader@yahoo.fr

Hamdi Bilel
National Engineering School of Tunis
Tunis, Tunisia
hamdibilel1985@gmail.com

Aguili Taoufik
National Engineering School of Tunis
Tunis, Tunisia

***Abstract*—In this paper we have developed a new Floquet analysis combined to MOM-CEG method to produce 3D electronically controlled antenna arrays. This approach permits to model and optimize the antenna arrays system by the sweeping of radiation beam in several directions. A parametric study on electromagnetic performance of the antenna system based on Floquet states offer a considerable advantages in 3Dsteerable radiation beam, size and directivity. Then smart periodic antenna has been constructed by placing the main beam in the desired direction.**

I. Introduction

Periodic antenna arrays are several antennas combined and arranged together to synthesize a global radiation pattern with directional beam. To modelize the proposed structure, two formulation are given in spectral and spatial domain, where the Moment method [1] combined with generalised equivalent circuit MOM-GEC [2] is applied. In this work we introduce the Floquet Approach to reduce the formulation of periodic structure to a one reference cell with periodic walls. This Floquet modal analysis introduce all possible Floquet states and group the coupling information of the overall structure. This new method is applied to generate a tree dimensional (3D) electronically controlled antenna; the sweeping of radiation beam of smart antenna are nowadays used to improve the performance of mobile and wireless communications systems. This paper is organized as follows: First it is necessary to explain the problem formulation and how to use Floquet model analysis combined with MoM-CEG method. After that we present a numerical results and we discuss the behavior of 3D steerable radiation beam and how to derive the main beam of the overall structure in the desired direction.

A. Problem Formulation: Floquet Modal Analysis Combined to MOM-CEG Method

In this section, we start with a comparison between spatial and spectral formulation of periodic system. The theoretical results show that Floquet model analysis can be applied to synthesize directional beam of infinity element and reduce spacial electromagnetic calculus to a reference cell with periodic walls [3], [4]. These artificial walls contain all coupling information of the overall structure. After that MoM-CEG method is applied to the reference cell. This new formulation

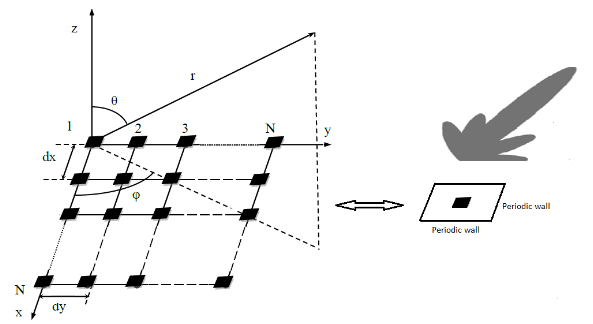

Fig. 1. Floquet modal ananysis presentation in 2-D periodic structure.

is used to achieve predictable radiation pattern and controlled beam direction. These smart antennas are common in radar and communication system. The Floquet model analysis of periodic structure are shown in Fig. 1. The formulation of MoM-CEM method is applied on this reference cell with periodic walls in modal space and α and β are the Floquet phases [5]. Based on MoM-CEM method and using impedance operator representation, we can identify the relationship between the current density and the electric field for any Floqued mode:

$$\widetilde{J}_{\alpha\beta} = \widetilde{J}_{e,\alpha\beta}; \widetilde{E}_{e,\alpha\beta} = -\widetilde{E}_{\alpha\beta} + \widetilde{Z}_{\alpha\beta} * \widetilde{J}_{e,\alpha\beta}. \tag{1}$$

The current dencity excited by the located source on the periodic structure can be computed as:

$$J(x,y) = \frac{d_x d_y}{4\Pi^2} \int\int \widetilde{J}_{\alpha\beta}(x,y) d_\alpha d_\beta. \tag{2}$$

B. Numerical Results

In this section, we present Floquet modal analysis of periodic antenna array, as an example we simulate and design a structure of 4 linear elements over matlab. We will extract all possible Floquet modes (α, β) and we will show their influence on pattern radiation:

$$\alpha_p = \frac{2\pi p}{N d_x} \text{ and } \alpha \in [\frac{-\pi}{d_x}, \frac{\pi}{d_x}].$$

Submitted On: August 23, 2018
Accepted On: October 21, 2018

TABLE I
THE DIRECTIVITY VALUE WITH STEERING ANGLE

Steering angle θ_s (deg)	0	30	45	60
Directivity (dB)	45.52	28.32	25.68	22.58

TABLE II
THE PERFORMANCE PARAMETERS OF THE PERIODIC STRUCTURE

	SLL (dB)	Peak gain (dBi)	Directivity (dB)
(α_1, β_0)	-13	-6.1	25.18
(α_0, β_0)	-23	-11.4	23.66
(α_{-1}, β_0)	-13	-6.1	25.81
(α_{-2}, β_0)	-11.5	-9.6	25.42

The behaviour of radiation pattern for all floquet modes (α_{-2}, β_0), (α_{-1}, β_0), (α_0, β_0), (α_1, β_0) and their superposition E_{tot} is shown in Fig. 3.

Fig. 2 shows a 3D surface plot of the radiation pattern of periodic antenna obtained by the supperpotion of floquet modes. The main beam can be steered to a desired direction.

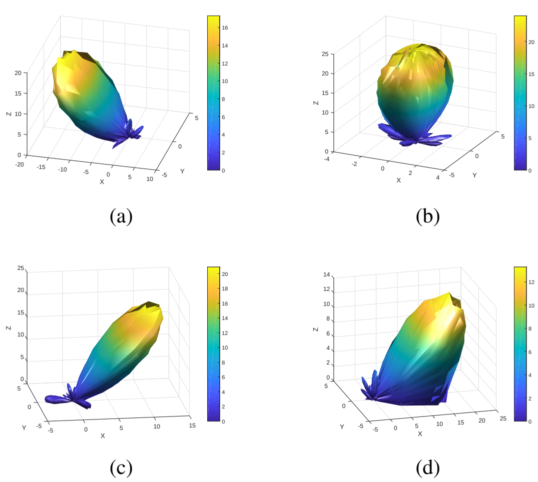

Fig. 2. 3D radiation beam pattern steering of proposed array at different angles: (a) θ_s = -45 (deg); (b) θ_s = 0 (deg); (c) θ_s = 45 (deg); (d) θ_s = 60 (deg).

Table I shows a better performance in terms of directivity at θ_s = 0 (deg).

The radiation pattern plot in Fig. 3 obtained by using Floquet modal method demonstrates the aptitude of this technique to supperpose all Floquets modes and steer the main beam to a desired direction. Table II illustrates the performance parameter (Side lobe level, Peak gain and directivity) of radiation pattern for each Floquet mode.

II. CONCLUSION

For the first time Floquet modal analysis combined to MOM-CEG method are introduced to improve the performance of smart antenna arrays. These periodic antennas are able to provide a directional beam that can be electronically steered. The result shows that by increasing the steering angle θ_s, lower value of directivity can be obtained and the maximum of directivity is achieved at $\theta_s = 0(deg)$.

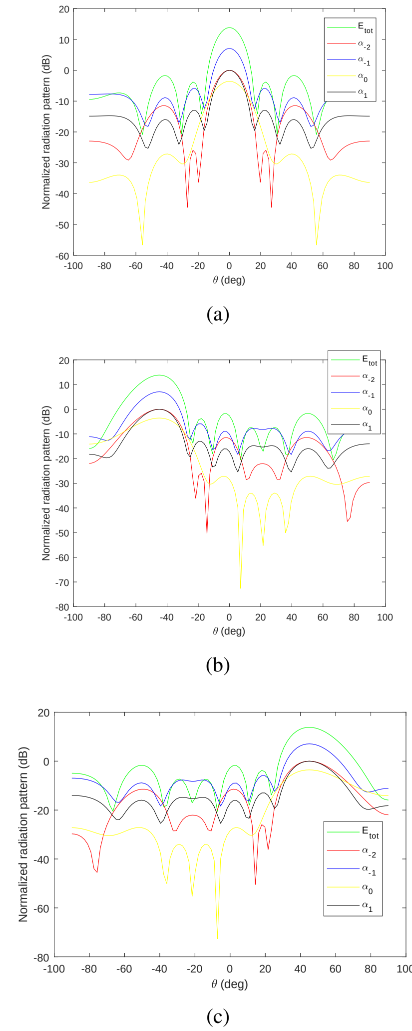

Fig. 3. Simulated 2D radiation pattern of periodic antenna en function the elevation angle theta for different steering angle: (a) θ_s = 0 (deg); (b) θ_s = -45 (deg); (c) θ_s =45 (deg).

REFERENCES

[1] H. Bilel, T. Aguili, and H. Baugrand, "Floquet modal analysis to modlize and study 2 D planar almost periodic structures in finite and infinite extend with coupled motifs," PIERS B, 2015.

[2] H. Bilel, T. Aguili, N. Ravue, and H. Baugrand, "Calculation of mutual coupling parameter and their effects in 1D almost periodic structures," PIERS B, 2014.

[3] N. Ben Latifa, H. Bilel, and T. Aguili, "Floque modal analysis to study radiation pattern for coupled almost periodic antenna array," AICCSA, TUNISIA, 2017.

[4] H. Bilel, S. Limam, and T. Aguili, "Uniform and concentric circular Antenna arrays synthesis for smart antenna systems using artificial neural network algorithm," PEARS B, 2016.

[5] Z. Mikkioui and H. Baudrand, "Bi-dimensional bi-periodic centred field microstrip leaky wave antenna analysis by a source modal decomposition in sperctal domain," IET Microwaves Antennas and Propagation, 2008.