NUMERICAL ANALYSIS OF PATCH ANTENNA AS ANTENNA ARRAY ELEMENT

Kizimenko V. and Bobkov Y.

Belarusian state university of informatics and radioelectronics
Minsk, Belarus
E-mail: yurtsev_o@tut.by.

Abstract

The patch antennas as antenna array element can be modeling by finite element method (programs Microwave Office, Ansoft HFSS and other). But this method need to use fast computer with memory large size. In this work the authors make an attempt to use thin wire integral equation method for patch antenna analysis. The results of modeling by proposed method are compared with the same of modeling by finite elements method and experimental results.

Keywords: Patch antenna, antenna array, integral equation method, finite elements method, permutational duality of Maxwell equations.

1. PREAMBLE

Phased antenna array from patch radiator are wide used in communications and radar because of they manufacturability. They relatively sample form necessary radiation pattern by assignment conform amplitude and phase execution distribution on antenna array elements.

Patch antenna arrays can be modeling by various CAD programs. However, many from them use finite element methods (FEM). At that the computer model large number of the same type elements. The time of modeling of multiple element antenna array is greatly increased.

In this work Integral Equation method (IEqM) in thin wire approximation for modeling patch antenna arrays [1]. At that the rectangular patch element is replaced by two-slots model (fig.1). This model in one's part, in accordance with permutational duality of Maxwell equation, is replaced by two-dipoles model. The effect of ground plane took into account by number of linear reflectors. In this work the modeling results is compared with experiment results.

2. CONTENT

2.1. NUMERICAL ANALISYS METHOD

At present the number of numerical methods for patch antenna modeling is known. This methods are described in [2].

One of these models is two-slots model in which the patch element is replaced by system of two slots. (fig. 1). The laugh of slots is A, distance between slots is B, this parameters conform to geometrical dimensions of patch antenna.

Input admittance of slot 2 ($Ys2$) recounted over distance B and summed to input admittance of slot 1 ($Ys1$). This recalculation conform to transformation of admittance by microstrip waveguide fragment with length B and width A. In model described in work [2] the radiation admittances of slots 1 and 2 and mutual radiation admittance are obtained.

For using of IEqM the two slots model is replased by two-dipoles model -fig.1 (on fig 1. on dipoles white circulars show feed points).

At this stage approximation consists to following facts: voltage distribution along slot and current along dipole are different.

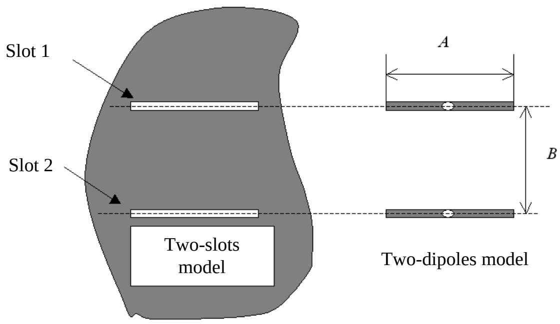

Fig. 1. Two-slots and two-dipoles of patch radiator models

It is because the radiated edges of patch in real model is disconnected. The voltage between edges of slot at its ends not equal zero. The voltage distribution along slot is close to uniform. The current at end of dipoles is equal to zero. Modeling of patch radiator by two-dipoles model end permutational duality principal allow to take to account interaction between neighbor patches in antenna array by one method. Other methods for numerical analysis of patch antennas are not permit to do it, except methods based on numerical solution of Maxwell equations and realized in MWO, Ansoft HFSS, CST Microwave Studio. Named software do not permit modeling of antenna array with large radiation number. With increasing of radiation number the running time is rice sharply. It prevents the solution of large antenna array synthesis problem by named software.

To take to account the fact that patch radiate only in half-space one can with using of lenear reslector or reflector system (fig.2).

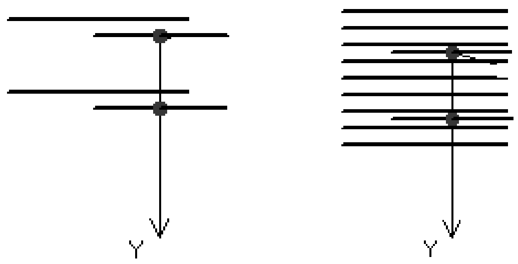

Fig. 2. Physical models of patch.

Proposed thin wire model based on IEqM permit to take to account interaction of grater number of patches in antenna array than FEM. It is because of the three-dimensional problem field calculation in same volume is changed to one-dimensional problem of current calculation in thin wire. The radiation pattern multiplication theorem can be used for calculation of interaction neighboring environment and calculation of radiation pattern of one radiator consisting in multiple-element antenna array.

2.2. Modeling results

Some patch antenna designs are modeled. The dimensional of all radiators are changed equal: a=12.75 mm, b=10.25 mm, substrate thickens h = 2mm, relative permeability of substrate is ε = 2. Antenna array pattern is calculated for frequency 9.4 GHz. The calculation results of antenna input impedance vs frequency with different number of surrounded passive elements by methods are showed on fig.3.

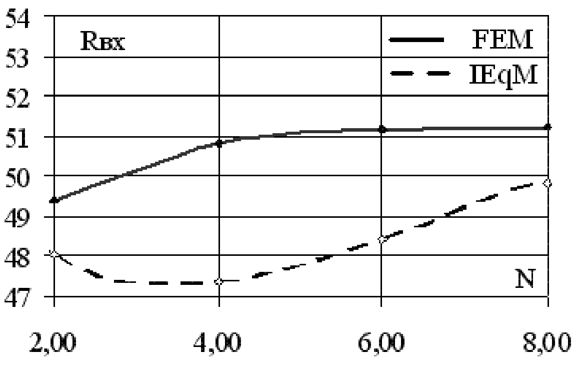

Fig. 3. One radiator resistance vs number of surrounded passive elements.

Analysis of resistance and reactance of one patch radiator vs number of surrounded passive elements calculated by IEqM and FEM shows that primary alteration of impedance occur in small number of surrounded elements up to 4. At increasing of passive elements number up 4 to 8 the differences of resistance and reactance calculated by IEqM and FEM becomes acceptable. Two methods comparison for bigger element number is not made because of running time excursion for MWO software.

Patch antenna with follow parameters a = 12 mm, b = 6 mm, h = 2 mm, ε = 4 is modeled. Distance between radiators is 21 mm (fig. 4). Radiation pattern is calculated at frequency 9.4 GHz. The impedance and VSWR are calculated for frequency band 9 – 10 GHz.

Fig. 5 shows that VSWR of antenna element surrounded by passive elements calculated by two methods are close. The difference in VSWR calculation at central frequency (9.4 GHz) is 6,5%.

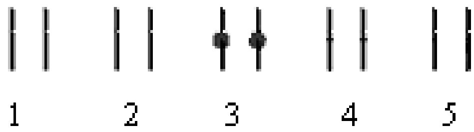

Fig.4. Model of radiator surrounded by 4 passive elements

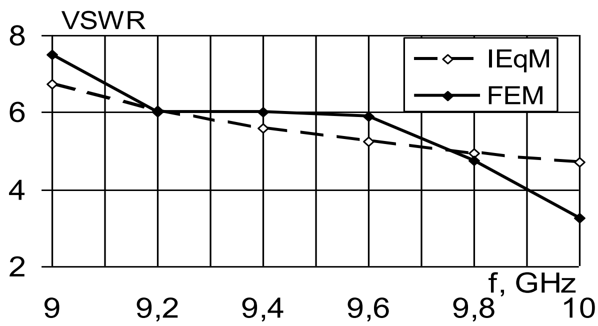

Fig. 5. VSWR vs frequency for radiator surrounded by 4 passive elements.

Some designs of patch antennas array with different passive element number are modeled. Antenna pattern beam width vs number of passive element is showed on fig.6.

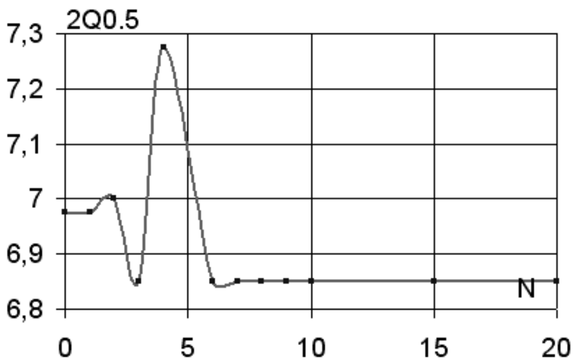

Fig. 6. Antenna pattern beam width vs number of passive element

As fig. 6 show the primary changing of beam width (from 6,85˚ to 7,28˚) at changing surrounding elements number from 1 to 6. Taking in to account of bigger surrounding elements number does not reduce to significant beam width changing. The modeling results show that increasing of passive element number located in E-plane result to beam width increasing at first and its distortion latter and increasing side lobe level (fig. 7). More accurate comparative assessment of changing of antenna pattern is not available because of dependence of shape and parameters of antenna pattern vs geometrical dimensional of calculated volume (box) in MWO software.

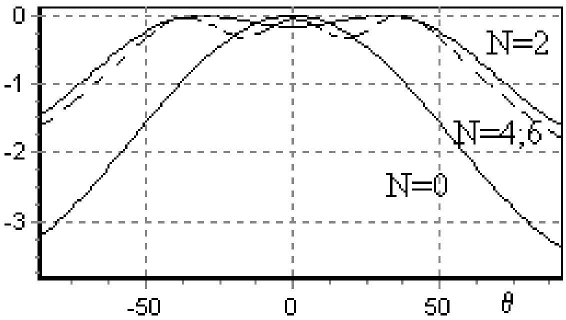

Fig. 7. One element radiation pattern for different number N of passive elements (IEqM)

Importantly that the three nearest to radiator elements cause main deposit in distortion of main lobe. Taking into account remote elements is incidentally affect on antenna pattern calculation accuracy.

The multiple element antenna array with elements interaction modeling by IEqM allows essentially reduce of calculation time and computer resources. However as comparising of modeling results by IEqM and FEM and experiments results shows the accuracy of IEqM is lower.

3. Conclusion

Integral Equation method in proposed patch antenna model has cconsiderable advantages to FEM used in HFSS software. Advantages of proposed method consist to smaller running time and bigger antenna array size. But it lose in accuracy about community radiation form.

The results of modeling by IEqM and FEM allow to conclude that three nearest circles of surrounds elements cause main deposit in distortion of antenna radiation pattern and antenna impedance. Taking into account of remote elements do not incidentally influence on calculation accuracy of radiation pattern, input impedance and VSWR. This allows to limit of number accountable elements in software modeling of entire multiple element antenna array parameters.

References

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