

$$f(E_t) = \left\langle \left(\sum_{p_1=1}^{N_1} B_{p_1} g_{p_1}(x, y) \quad \dots \quad \sum_{p_M=1}^{N_M} B_{p_M} g_{p_M}(x, y) \right) \hat{Y} \begin{pmatrix} \sum_{q_1=1}^{N_1} B_{q_1} g_{q_1}(x, y) \\ \vdots \\ \sum_{q_M=1}^{N_M} B_{q_M} g_{q_M}(x, y) \end{pmatrix} \right\rangle$$

$$Q_{pq} = -j \left[\sum_{n=m_1+1}^{+\infty} \langle f_p(x, y) | \hat{Y}_n^{(1)} f_q(x, y) \rangle + \sum_{m=m_2+1}^{+\infty} \langle f_p(x, y) | \hat{Y}_m^{(2)} f_q(x, y) \rangle \right]$$

$$f(E_t) = \left\langle \sum_{q=1}^{\infty} C_q f_q(x, y) \middle| \hat{Y} \sum_{p=1}^{\infty} C_p f_p(x, y) \right\rangle$$

$$f(E_t) = \left\langle (E_{t1} \quad E_{t2} \quad \dots \quad E_{tM}) \hat{Y} \begin{pmatrix} E_{t1} \\ E_{t2} \\ \vdots \\ E_{tM} \end{pmatrix} \right\rangle$$

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Complex discontinuities cascading waveguides models studies and analysis

Chafaa Hamrouni^{1,4*}, Abdesslem Bsissa¹, Rached Hamza², Adel M. Alimi³ and Naceur Abdelkarim⁴

Abstract: The paper proposes a method for S -matrix generalization to minimize discontinuities between one-axis rectangular guides in terms of reflection and transmission coefficients. We modelate successfully rectangular metal waveguide filters with geometrical and physical discontinuities, and a succession of heterogeneous media such periodic structure and containing Meta materials are presented. Method of S -matrix generalization based on modal development operating by breaking down electromagnetic fields on orthonormal basis for each formed discontinuity. Proposed hybrid method that reference to finite element method incorporation is discussed. We conclude that the Galerkin method application leads directly to the matrix of junction diffraction.

Subjects: Engineering & Technology; Engineering Education; Systems & Control Engineering; Electrical & Electronic Engineering; Electromagnetics & Communication

Keywords: distributed energy generation (DEG); distributed energy storage (DES); demand side management (DSM); energy scheduling and distributed storage algorithm (ESDS); in-Home Energy Storage (iHES); DER distributed energy resources



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PUBLIC INTEREST STATEMENT

We introduce a new hybrid tool for modeling of complex 2D in rectangular serial discontinuities waveguides, and propose in our research work the computation results coefficient parameter S_{11} relates to reflection. We applied method of S -parameter generalized analysis for single and multiple one discontinuity of metallic rectangular wave-guides filled with Meta materials isotropic. A study of the convergence based on available modes number is no longer necessary, and then founding result is presented. Our objective is to demonstrate and analyze complex discontinuities cascading modeling between waveguides filled anisotropic medium behavior to help for optimized application. This founding result is effective and efficient, it presents an accurate results as a successful solution. We are able to analyze a complex discontinuity; our hybrid method FEM-use to save more than 95% of the computing time over the EMF-based simulation HFSS tools to have the same precision.

1. Introduction

Firstly, in the purpose to determine the matrix dispersion and to characterize the waveguide discontinuity (Green & Sandy, 1974), we study the modal coupling method (MCM) by fields decomposition modal, in this context few applications in rectangular guide are provided. In rectangular metal, we modelate filters which guides to physical junctions that assure by media discontinuities and use of MCM associated to generalized S -matrix (GSM) technique, which is analyzed by details. Secondly, in the aim to analyze an isotropic medium (Polder, 1949) rectangular filters filled which are containing complex geometric shape iris, we represent the hybridization of finite element method (FEM) and the multimodal variation on Multimodal Variational Method (MVM). We demonstrate the difference between two methods, the proposed process is more efficient than classic method.

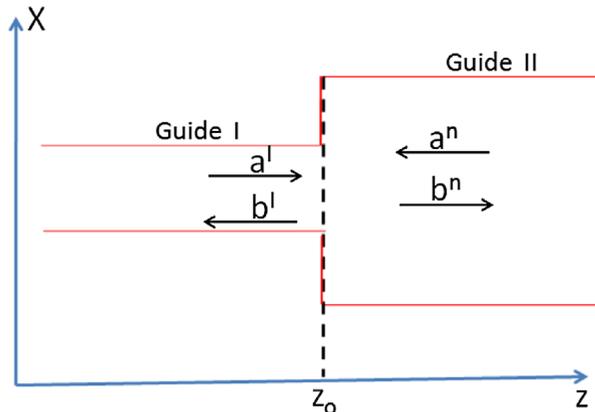
2. Complex discontinuities filters study case

By using a typical methods, the size of the dispersion matrix depends on the total number of modes at the entrance and the exit of the circuit. In our variable formulation (Zhang & Liu, 2000) multi modal, the size of the scattering matrix (Drabek, Peroutka, Pittermann, & Ceda, 2011) depends on the number of available modes, which is independent on the total number modes which contributes to the electromagnetic field as well as the series of terms discontinuities form, and this without changing the final dispersal S matrix. Therefore, the reduction of the matrix size scattering minimizes the memory storage and the convergence time (Song & Yin, 2007) compared to other modal methods as the MCM and the GSM. By analyzing discontinuities in cascades, the matrix S of each discontinuity is determined in advance. The response of the total circuit is obtained by connecting all the S matrix to the respective waveguides. Thus, the choice of the available number modes in the intermediate discontinuities studies must be accurate. The convergence is to ensure the accuracy of the total S -matrix especially when the discontinuities are reduced or the fundamental mode is generated. To avoid any convergence case, a Multi-Modal Variational Formulation (MMVF) was proposed. Our purpose is to study a simple cascade discontinuity (Jian Yi Zhou, 2004). It is recommended to use variational forms established for each discontinuity and this according to the vector of electrical fields; which include all established discontinuities. As a successful result, the size of the total dispersion matrix depends only on the number of modes which are accessible at the entrance and exit of the total structure. However, when a waveguide composed of an arbitrary cut iris, the modal basis will be analytic and numerical. The determination of the values and vectors will considerably increase the CPU Time Processor Busy (CPU-TPB). The use of the spatial technics discretization, FEM, etc. Requires an important storage time CPU (SUN-6Processors/1350Mhz.) and Memory storage (24Gbits/24SLID/512Mbits). In order to avoid these disadvantages, several hybrid technics are suggested such as spatial methods of discretization (Song, Ohnuki, Nyquist, Chen, & Rothwell, 1994) and modal hybrid FEM-MCM. We propose these technics to resolve waveguide problems (Zhou & Hong, 1997). Some researchers have presented a tool of the hybrid FEM-sue to study complex discontinuities in rectangular waveguides empty (Hasegawa, Inoue, Hiraoka, Hsu, 2007). We generalized the hybrid method to analyze one complex 2D discontinuity in cascades to design isotropic (Lindell & Sihvola, 1994) rectangular filters with complex iris (Venugopalan & Savvides, 2011) rapidly and accurately. We suggest an original hybrid model by coupling the MMVF and the GEF when it is developed in a basic model the electrical field at complex discontinuity level, will be developed in the basic of finite elements method. The surface of complex discontinuity will be divided into several rectangular or triangular elements. Within each element, the tangential electric field will be estimated by the double functions which is defined by edges of the element. The trials functions database in the entire surface discontinuity will be determined by adding the double functions. We illustrate the benefits of the proposed hybrid method compared to several computing assistance conception tools with details.

3. Multimodal variational method implementation

Multi-modal variational method (MMVM) developed in the laboratory LAPLACE, INP ENSEEIHT presents itself as a variant of the technique of modal connection (MC) (Matching mode) and proves to be a very effective tool to model one of discontinuities. However, it uses additional analytical calculations for Time Computer Processor Unit and space memory need. This method allows a successful several passive microwave components performance such as filters, antennas, the shifters, etc.

Figure 1. Discontinuity between two waveguides.



3.1. Variation multimodal classic analysis

Consider the junction between two uniaxial guides (Figure 1), the walls of the guides is similar to perfectly conductive. It defines the current density at the level of the interface between guides as the following relationship:

$$\vec{J} = (\vec{H}_t^{(1)} - \vec{H}_t^{(2)}) \times \vec{n} \quad (1)$$

$\vec{H}_t^{(i)}$ is the tangential magnetic field at the interface in the guide i ($i = I, II$) and \vec{n} the unit vector normal to the interface of the guides here \vec{z} . The current density and the tangential electric field to the interface are related by:

$$J(z_0) = \hat{Y} E_t(z_0) \quad (2)$$

where

$$\hat{Y} = \sum_{n=1}^{+\infty} y_n^{(1)}(z_0) \hat{Y}_n^{(1)} + \sum_{m=1}^{+\infty} y_m^{(2)}(z_0) \hat{Y}_m^{(2)} \quad (3)$$

\hat{Y} is the admittance of the discontinuity, with:

$$\hat{Y}_m^{(i)} = \left| j_m^{(i)} \right\rangle \frac{1}{N_m^{(i)}} \left\langle j_m^{(i)} \right| \quad (4)$$

- $\hat{Y}_m^{(i)}$ is the m in the guide i mode projector.
- $y_m^{(i)}(z_0)$ is the reduced admittance reduced to m mode plan guide i .
- $j_m^{(i)}$ is the current density of the m mode.
- $N_m^{(i)}$ is a constant of normation m mode fields in the guide i , defined by:

$$N_m^{(i)} \delta_{mn} = \left\langle \mathbf{e}_m^{(i)} \middle| j_n^{(i)} \right\rangle \quad (5)$$

$\mathbf{e}_m^{(i)}$ denotes tangential electric field.

$$\delta_{mn} \text{ is the Kronecker symbol: } \delta_{mn} = \begin{cases} 1 & s_i, m = n \\ 0 & s_i, m \neq n \end{cases}$$

The two guides interface contains two parts:

- Insulating part where the current $J(z_0)$ density is zero.
- Metal part where the tangential electric field $E_t(z_0)$ is null.

Therefore we have:

$$\hat{Y}E_t(z_0) = 0 \tag{6}$$

\hat{Y} is a self-adjoin operator.

When the metal and dielectric losses are not taken into account, the relationship (6) is a variational form.

$$f(E_t) = \left\langle E_t \mid \hat{Y}E_t \right\rangle \tag{7}$$

For a discontinuity, the search for the solution is to minimize form variation. If it breaks down the tangential electric field on a basis of testing functions. If it breaks down, the tangential electric field on the basic of appropriate test functions, we have:

$$E_t = \sum_{q=1}^{\infty} C_q f_q(x, y) \tag{8}$$

By introducing the expression of (7) in (6), we have:

$$f(E_t) = \left\langle \sum_{q=1}^{\infty} C_q f_q(x, y) \mid \hat{Y} \sum_{p=1}^{\infty} C_p f_p(x, y) \right\rangle \tag{9}$$

The form is stationary, its derivate C_p is zero:

$$\sum_{q=1}^{+\infty} \left(\sum_{n=1}^{m_1} y_n^{(1)}(z_0) \left\langle f_p(x, y) \mid \hat{Y}_n^{(1)} f_q(x, y) \right\rangle + \sum_{m=1}^{m_2} y_m^{(2)}(z_0) \left\langle f_p(x, y) \mid \hat{Y}_m^{(2)} f_q(x, y) \right\rangle \right. \\ \left. - \sum_{n=m_1+1}^{+\infty} \left\langle f_p(x, y) \mid \hat{Y}_n^{(1)} f_q(x, y) \right\rangle - \sum_{m=m_2+1}^{+\infty} \left\langle f_p(x, y) \mid \hat{Y}_m^{(2)} f_q(x, y) \right\rangle \right) C_q = 0 \tag{10}$$

With $p = 1, 2, \dots, \infty$,

where m_1 and m_2 are the accessible modes number respectively at the entrance and exit. These modes are diffracted, propagatifs and evanescent due to the succession of two coupling discontinuities.

It defines the matrices $Q, N^{(i)}, Y^{(i)}$ and as follows:

$$Q_{pq} = -j \left[\sum_{n=m_1+1}^{+\infty} \left\langle f_p(x, y) \mid \hat{Y}_n^{(1)} f_q(x, y) \right\rangle + \sum_{m=m_2+1}^{+\infty} \left\langle f_p(x, y) \mid \hat{Y}_m^{(2)} f_q(x, y) \right\rangle \right] \tag{11}$$

$$N^{(i)} = \begin{bmatrix} N_1^{(i)} & 0 & 0 & \dots & 0 \\ 0 & N_2^{(i)} & 0 & \dots & 0 \\ 0 & 0 & \cdot & \dots & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ 0 & 0 & 0 & \dots & N_{m_1 \text{ ou } m_2}^{(i)} \end{bmatrix} \tag{12}$$

$$Y^{(i)} = \begin{bmatrix} y_1^{(i)}(z_0) & 0 & 0 & \dots & 0 \\ 0 & y_2^{(i)}(z_0) & 0 & \dots & 0 \\ 0 & 0 & \cdot & \dots & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdot \\ 0 & 0 & 0 & \dots & y_{m_1 \text{ ou } m_2}^{(i)}(z_0) \end{bmatrix} \quad (13)$$

$$U_{p,n}^{(1)} = \langle f_p(x, y), j_n^{(1)} \rangle \quad n = 1, 2, \dots, m_1 \quad (14)$$

$$U_{p,n}^{(2)} = \langle f_p(x, y), j_n^{(2)} \rangle \quad n = 1, 2, \dots, m_2 \quad (15)$$

A calculation allows determining the impedance of the discontinuity that is defined matrix as follows:

$$Z = -jN^{-1}N^{+\frac{1}{2}}\Gamma N^{-\frac{1}{2}} \quad (16)$$

$$\Gamma = \begin{bmatrix} U^{(1)*T} Q^{-1}U^{(1)} & U^{(1)*T} Q^{-1}U^{(2)} \\ U^{(2)*T} Q^{-1}U^{(1)} & U^{(2)*T} Q^{-1}U^{(2)} \end{bmatrix} \quad (17)$$

The symbol (*T) represents the conjugate transpose. The analysis of a simple discontinuity by the MMVM decrease the determination of the scalar product between the basis of testing functions and modes of the two guides, i.e. the determination of the matrix Γ . From the impedance matrix Z , the matrix S of discontinuity will have the following form:

$$S = (Z + I)^{-1}(Z - I) \quad (18)$$

Theoretically, the number of modes used in the formulation is infinite. However, in practice it will consider a finite number of modes to represent any modal basis (spectral truncation). For good performance, we have to select one of them by increasing cuts frequencies guides and take the modes which appear first.

4. NMVM discontinuity analyze method

It is considered a structure with N one discontinuities cascading (Lilonga_Beyonga, Tao, & Vuong, 2007) as shown in Figure 1. \vec{H}_t^i (Respectively \vec{H}_t^{i+1}) in the transverse magnetic field guide i (respectively $i + 1$) \vec{n} . is the unit vector in the z direction.

For a structure with several one discontinuities in cascade, the dispersion of all matrixes will be obtained by chaining individual discontinuities dispersion matrices (Figure 2). These S matrices are often determined by modal techniques such as (MC), the matrix S -wide spread GSM and the MMVM (Tao & Baudrand, 1991). The advantage of the multimodal variational mover depends on the number of available modes which is independent from the total number of modes. This allows saving storage space and computing time. However for best results, studying the convergence on available basic mode number of in necessary guide constitution. To avoid this study of convergence and reduce the computation time, a new formulation of the new multi-modal variational method (NMMVM) has been proposed. In this new formulation, all modes which are recommended in the inter-mediate guides are taken into account, that improves the accuracy of the analysis.

4.1. NMV Mand finite element hybridization analysis

We consider a multiple 2D complex one discontinuities between rectangular waveguide filled with isotropic medium, and where S , represents the opening of the infinite discontinuity. ϵ_r and μ_r denote respectively the dielectric constant relative and the relative permeability of the medium. In the case

Figure 2. Circuit with N discontinuities uni-axial.

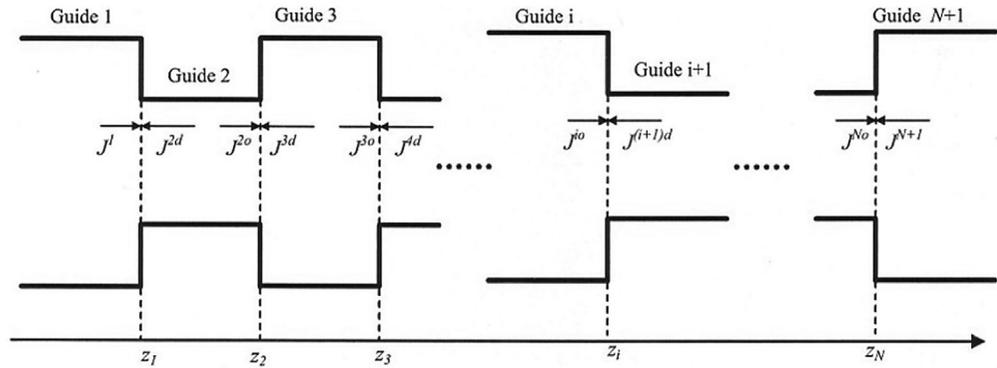
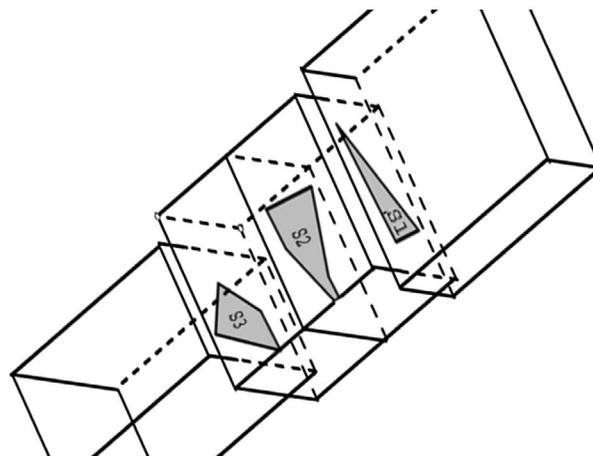


Figure 3. Circuit with N discontinuities uni-axial.



of simple discontinuities between waveguides, the MMVF provides a characterization of all the modes of the complete structure. Its principle is to minimize the variational and stationary function follows:

$$f(E_t) = \left\langle (E_{t1} \ E_{t2} \ \dots \ E_{tM}) \middle| \hat{Y} \begin{pmatrix} E_{t1} \\ E_{t2} \\ \vdots \\ E_{tM} \end{pmatrix} \right\rangle \quad (19)$$

$\langle \cdot | \cdot \rangle$ denotes the scalar product, is the number of discontinuities M and \hat{Y} being the operator matrix which is the generating matrix of complete structure. When we consider simple openings S_i of (restrictions rectangle, circle, ellipse, etc.) the tangential electric field E_{ti} of discontinuity can be decomposed on the modal basis of Eigen functions which satisfies the boundary conditions. When we consider the complex multiple openings (as Figure 3). The determination of the modal base of Eigen function is more obvious. To overcome this deficiency, we replace the spectral discretization by a space discretization. At the level of the complex discontinuity, the tangential electric field will be decomposed in the base of the vector finite elements.

Our goal is to write the electric field in a manner similar to Equation (7) as follows:

$$E_t = \sum_{q=1}^{\infty} C_q f_q(x, y) \quad (20)$$

The first step is to mesh the surface of discontinuity S only elements. In a triangular element, the electric field can be written as follows:

$$E_t^e(x, y) = \sum_{m=1}^3 E_m^e N_m^e(x, y) \quad x, y \in e \quad (21)$$

$N_m^e(x, y)$ are the functions of tweens, the E_m^e denotes tangential electric field along the same edge. We choose the first order interpolation function. After imposing the continuity condition between two adjacent elements, the tangential electric field in the opening of S_i can be expressed as follows.

$$E_{ti}(x, y) = \sum_{p_i=1}^{N_i} B_{p_i} g_{p_i}(x, y) \quad (22)$$

N_i denotes the number of edges in the opening S_i and the B_{p_i} denoted the unknown tangential electric field along the p th edge. To determine the $g_{p_i}(x, y)$ (are new interpolation functions), we have two cases: the first is if the p th edge is in the border of the opening S_i , B_{p_i} the coefficients play the same role as C_q in the relationship (20). As a result, they will be disposed of in the MVM formulation

$$g_{p_i}(x, y) = N_m^e(x, y) \quad x, y \in e \quad (23)$$

And the second case is if the p th edge is inside the opening S_i , it can be longer only for two adjacent elements. As a result, the edge will define two functions $N_m^e(x, y)$ and $N_m^{e'}(x, y)$ interpolation that have opposite directions. Thus:

$$g_{p_i}(x, y) = N_m^e(x, y) - N_m^{e'}(x, y) \quad x, y \in \{e, e'\} \quad (24)$$

By combining Equations (19) and (21), we obtain the following function:

$$f(E_t) = \left\langle \left(\sum_{p_1=1}^{N_1} B_{p_1} g_{p_1}(x, y) \quad \dots \quad \sum_{p_M=1}^{N_M} B_{p_M} g_{p_M}(x, y) \right) \hat{Y} \begin{pmatrix} \sum_{q_1=1}^{N_1} B_{q_1} g_{q_1}(x, y) \\ \vdots \\ \sum_{q_M=1}^{N_M} B_{q_M} g_{q_M}(x, y) \end{pmatrix} \right\rangle \quad (25)$$

Matrix dispersion of the complete circuit is obtained by minimizing the expression (25) by B_{p_i} . The size of the basic functions depends on only the number or edges in the discontinuity, which is different from the number of modes. So, we handle only matrices of dimension $N_i \times N_i$.

4.2. Simulations results and data analysis

In this work, we present the computation results for reflection coefficient S_{11} parameter for various studied structures. To optimize antenna function, the parameter S_{21} should be minimized and the energy absorbed by the antenna metal is null, so we supposed this transmission coefficient $S_{21} = 0$.

4.2.1. Discontinuity constitutive $M = 1$: Iris shape cross

We consider an iris shape cross centered with rounded edges in a rectangular waveguide WR90 X-band. geometry and the mesh of the opening, the related susceptances of iris inserted in two isotropic media ($\epsilon_r = 1, \mu_r = 1$) and ($\epsilon_r = 1, 5, \mu_r = 1, 5$) respectively. Where B and Y_0 denote the opening cross susceptances and admittance characteristic respectively.

The results of our method are well consistent by measurement. Nevertheless the proposed hybrid method gives an overall reduction of the convergence time more than 95% against HFSS in both cases. Studies of convergence of the results of our method against the number of items and the number of modes in the empty waveguide can be found (such the case of different modes). If we

Table 1. Calcul time for each studied method

	Calculation time
FEM-MMVF (2500 modes)	10 mn 44 s
HFSS (77950 tetrahedrons)	4 h 43 mn

compare calculation between our hybrid method and HFSS time ($\epsilon_r = 1$, $\mu_r = 1$). We mention that a discontinuity for the GEF-Sue hybrid and the hybrid FEM-MMVF are identical (Table 1).

4.2.2. Two discontinuities one axis $M = 2$: Resonator filter

At a first step, we find out a filter resonator filled isotropic medium ($\epsilon_r = 1, 3$ and $\mu_r = 1, 3$) built by two identical complex iris spaced a distance d , in second step, the geometry and the mesh of an iris. In order to choose the number of modes, we found in practice that the optimal way is first to arrange patterns by ascending cut off frequencies. Then, we placed a frequency F . Finally, we took all the modes with cutoff frequencies smaller than F in all waveguides. For the study of convergence, we have $F = 600$ GHz. The reflection coefficient of the filter for $d = 17$ and 8.5 mm respectively. The results obtained using hybridization GEF-MMVF are compared with those made by HFSS and linking matrices S by varying the number of available modes.

As simulations results with HFSS tool, we observe the finer mesh than our computer's memory, in addition, the hybrid method of FEM-MMVF and HFSS give the same accuracy. However, even using all symmetries in HFSS, our method is significantly faster. When the length of the resonator is small enough (i.e. $d = 8.5$ mm), using matrices S connection, a study of convergence according to the number of available modes must be performed. This study of convergence is necessary using our GEF-MMVF hybrid method. But when the length of the resonator is large enough (i.e. $d = 17$ mm) an accessible mode can achieve the good accuracy.

4.2.3. Computing time depending on the length of resonator

If we study the computing with depends on the length of the resonator, we not that:

- HFSS: By decreasing the length of the resonator (d), the number of elements tetrahedron will increase which increases the calculation time. This feature is observed in practice.
- The connection of the S matrices: If the length of the resonator is large enough, an accessible mode can achieve good accuracy, so that the dimensions of matrices of diffraction are 2×2 .
- Sue is faster than GEF MMVF. By decreasing the length of the resonator, the number of available modes will increase. Thus, the dimensions of the matrix S of discontinuities will increase which increases the calculation time. In addition, a study of convergence very costly in time according to the number of available modes must be made. We mention only in practical cases as in the waveguide filters, the distances between the discontinuities are small. In these cases, the FEM-MMVF is faster than FEM-MVM.
- Hybridization FEM-MMVF: by decreasing the length of the resonator, the computation time is constant, as the matrix of all the circuit depends only on the total number of modes in the circuits. This feature presents a great advantage over the first two digital methods.

4.2.4. Three complex one-axis discontinuities $M = 3$: Dual-mode filter

Dual-mode with rectangular filters find many applications in waveguide technology. We note that there are possible arrangements to implement a dual-mode (Amari, 2009) cavity. In general, the coupling elements are introduced to rotate the degenerate modes of origin. Our hybrid method, the shape of these elements can be simple (rectangle) or complex.

We consider a dual-mode, the entrance is a rectangular wave guide (WR75) which is coupled to the cavity through a focused horizontal opening of size 10 mm 6 mm. The Input/output of the filter

are the same, but turned off. $\pi/2$ The dual-mode cavity dimensions are 14.8 mm 14.8 mm 25 mm. Four 2D metals slabs square size (3 mm 3 mm) and (1 mm 1 mm) are inserted into the corners of the square cavity. The position and shape of the four square metal slabs 2D were inspired by the reference. Their sizes are chosen to improve the response of the filter. We recall that our hybrid method is versatile. It does depend on the form of discontinuities. A study of convergence, we considered all modes in the circuit of frequency below $F = 250$ GHz cuts

Using HFSS and hybrid FEM-MMVF, the reflection coefficient depends on the frequency. We considered two isotropic media ($\epsilon_r = 1.2$; $\mu_r = 1.2$) and ($\epsilon_r = 1.1$; $\mu_r = 1.1$). The frequencies of resonance and Q-3 dB response the methods studied. We have obtained a good agreement with the results of HFSS that the EMF. Nevertheless, our hybrid method is significantly faster.

5. Discussion and conclusion

In this research was applied the method of S-parameter generalized analysis of multiple and single of one discontinuity in the metallic rectangular waveguides filled with meta materials isotropic. It introduces a hybrid tool for modeling of complex 2D in rectangular serial discontinuities waveguides. The study of the convergence based on available modes number is no longer necessary. Used simulation tool is applied to the modeling of large complex structures such multimode filters where its speed compared to commercial simulation tools was highlighted. The method of generalized S-parameters was applied and it was suggested a hybrid method that combines MVM and vector FEM and this for the analysis of one or more complex discontinuities in rectangular waveguides. The surface of discontinuity was divided into several rectangular (or triangular) elements where the tangential electric field is developed in a basic functions of the first order. This founding result is effective and efficient, it presents an accurate results as a successful solution.

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