

Contents

Agradecimientos	v
Resumen	vii
Resum	ix
Summary	xi
Contents	xiii
1 Introduction	1
1.1 Motivation	1
1.2 State of the art	4
1.3 Organization of the thesis	6
I Analysis of devices in SIW technology	11
2 Introduction	13
2.1 Description of the problem	13
2.1.1 Modes in a SIW	14
2.1.2 Equivalent waveguide of a SIW	14
2.1.3 Design rules for SIW	15
2.2 Generalized Scattering Matrix (GSM)	16
2.2.1 Introduction to obtaining the GSM with mode matching	18
3 SIW analysis with MM/MoM technique	19
3.1 Introduction	19
3.2 Review of the MM/MoM technique applied to waveguide problems	21
3.3 Problem formulation	24
3.3.1 Characterization of the via holes	24
3.3.2 Improved formulation for SIW	26

3.4	Validity of the solution for an open cavity	27
3.5	Rigorous analysis for an open cavity. Radiation losses	28
3.6	Fast frequency sweep	29
3.6.1	Asymptotic Waveform Evaluation (AWE)	30
3.6.2	Complex Frequency Hopping (CFH)	33
3.7	Conductor and dielectric losses	33
3.7.1	Conductor losses in the metal via holes	33
3.7.2	Conductor loss in the parallel metal plates	34
3.7.3	Dielectric loss in the substrate	35
3.8	Attenuation constant in SIW	35
3.9	Analysis results	37
3.9.1	Coupled-cavity filter	38
3.9.2	Hybrid ring	40
3.9.3	SIW folded filter	41
3.10	Experimental results	43
3.10.1	Coupled-cavity filter	43
3.10.2	Hybrid ring	44
3.10.3	Folded filter	47
3.11	Conclusion	47
4	SIW analysis with hybrid MM between cylindrical and guided modes	51
4.1	Introduction	51
4.2	Isolated scattering objects	53
4.2.1	Introduction. Transfer function	53
4.2.2	TM and TE transfer functions	55
4.2.3	Particularizing the concepts for SIW technology	60
4.3	Electromagnetic coupling among scatterers	62
4.3.1	Introduction	62
4.3.2	Analysis of electromagnetic coupling among multiple scatterers	64
4.3.3	Accelerating the method for SIW technology	72
4.3.4	Example of field representation	75
4.4	Global Scattering Matrix	75
4.5	Hybrid mode-matching for obtaining the GSM	78
4.5.1	Region B. Inside of the circumference. Cylindrical modes	79
4.5.2	Region C. Out of the circumference and guided accesses	81
4.5.3	Region A. L guided accesses. Guided modes	81
4.5.4	Continuity equations	85
4.5.5	Equation system	87
4.6	Convergence study	95
4.7	Analysis results	95
4.7.1	Four-cavity filter at 11 GHz	96
4.7.2	Three-pole filter at 28 GHz	98

4.7.3	Bandpass filter with dielectric posts	99
4.7.4	Dual-band filter with annular dielectric posts	101
4.7.5	Hybrid ring	102
4.8	Obtaining the field	103
4.9	Conclusions	107
 II Design of filters in SIW technology		109
 5 Introduction		111
 6 Design of different SIW filter topologies		113
6.1	Specifications of the examples	114
6.2	Designs in waveguide technology	115
6.3	Mapping the designs from rectangular waveguide to SIW	117
6.4	SIW simulation tool based on MM/MoM. Optimization	119
6.5	Conclusions	120
 7 SIW filters with coupling windows. Calibration for higher orders		125
7.1	Design of waveguide filters with rounded corners in the windows	126
7.1.1	Filter specifications	126
7.2	Mapping the designs from rectangular waveguide to SIW	128
7.3	SIW simulation tool based on MM/MoM. Optimization	129
7.4	Calibration and design of higher order filters	131
7.5	Conclusions	133
 8 Design of SIW filters with inductive posts using simulators based on open space modal expansions		137
8.1	Introduction to ASM	137
8.2	Coarse model in rectangular waveguide	139
8.2.1	Starting point in the coarse model	141
8.2.2	Mapping the designs from rectangular waveguide to SIW	141
8.3	Fine model in SIW technology	142
8.4	Parameter extraction	142
8.5	Inversion of the approximation to the Jacobian matrix	142
8.6	Results	143
8.6.1	Filter specifications	143
8.6.2	Design process and results	144
8.7	Conclusions	147

III	Transitions between SIW and microstrip line	149
9	Microstrip tapered transition	151
9.1	Introduction	152
9.2	Cascade connection of the taper to the SIW	152
9.3	Design equations and optional optimization	154
9.4	Taper design example	156
10	Exponential SIW transition	159
10.1	Microstrip tapers when $Z_{SIW} > Z_{ms}$	159
10.1.1	First example	159
10.1.2	Second example	162
10.2	Novel SIW transition topology	164
10.2.1	Analytical equations for positioning the vias	167
10.3	Experimental validation	169
10.3.1	First example	169
10.3.2	Second example	170
10.4	Conclusions	171
IV	Additional techniques	173
11	TRL calibration for measuring SIW devices	175
11.1	Introduction	175
11.2	TRL calibration	176
11.3	TRL calibration kit for SIW	176
11.3.1	Calibration procedure with ANA	179
11.4	Results	179
11.4.1	Coupled-cavity SIW filter	179
11.4.2	Band-stop SIW filter with smooth profile	181
11.5	TRL calibration calculations	183
11.5.1	Brief guidelines for applying the TRL calibration calculations	189
11.6	Conclusions	189
12	Cascading multiple multimodal N-port scattering matrices	191
12.1	Introduction	191
12.2	Cascading-by-pairs approach	193
12.2.1	Summary of the cascading-by-pairs approach	199
12.3	Extension of cascading-by-pairs approach	200
12.4	Cascading matrices using a Krylov's iterative method	204
12.5	Computational cost of the proposed iterative technique	208

12.6	Results	210
12.6.1	Comparison of the Krylov's based cascading approach with the other cascading possibilities	213
12.7	Conclusions	214
13	Design of H-plane waveguide filters considering rounded corners	217
13.1	Introduction	217
13.2	Accelerated analysis procedure	220
13.3	Specifications for two examples	221
13.4	Choice of the number of modes	222
13.5	ASM design procedure	222
13.6	Design procedure and results	223
13.6.1	Starting point in the coarse model	223
13.6.2	Optimization in the coarse model	223
13.6.3	ASM procedure	223
13.7	Conclusions	226
14	Conclusions and future work	229
14.1	Future work	232
A	Scattering objects	235
A.1	Metallic cylinder	235
A.2	Homogeneous dielectric cylinder	237
A.2.1	Metallic cylinder with finite conductivity	239
A.3	Approximation for metallic cylinder with finite conductivity	239
A.4	Multilayer cylinder	241
B	Plane-wave and cylindrical spectra of fields. Transformations	247
B.1	Cylindrical spectrum	247
B.2	Plane-wave spectrum	248
B.3	Equivalence between plane-wave spectrum and cylindrical spectrum	251
B.4	Cylindrical spectrum of an incident plane wave	251
C	Spectrum translation matrices	253
C.1	Introduction	253
C.2	Translation from emergent to incident spectrum	253
C.3	Translation from incident to incident spectrum	256
D	Global circumference	261
E	Local and global coordinate systems	263

F	Segmentation and hybrid optimization	267
F.1	Segmentation	267
F.2	Hybrid optimization	268
G	Fabrication of SIW devices	269
H	Multilayer transition	273
I	Official Acknowledgments	277
J	List of Publications	279
J.1	Book chapters	279
J.2	Journal papers	279
J.3	Conference papers	280
K	List of Acronyms	283
	List of Figures	285
	List of Tables	292
	Index	295
	Bibliography	297