



# Contents

<b>Abstract (English/Français)</b>	<b>3</b>
<b>Acknowledgements</b>	<b>7</b>
<b>Acronyms and Abbreviations</b>	<b>11</b>
<b>List of Symbols</b>	<b>13</b>
<b>Notation and Conventions</b>	<b>15</b>
<b>1 Introduction and research context</b>	<b>17</b>
1.1 Accuracy and stability of oscillators . . . . .	18
1.2 The atom as a stable frequency source . . . . .	20
1.2.1 A simple three-level system . . . . .	21
1.3 The Rb clock based on double resonance . . . . .	23
1.3.1 Double resonance operation . . . . .	25
1.3.2 The physics package . . . . .	26
1.3.3 Sources of frequency instability related to the cavity . . . . .	28
1.3.4 Design guidelines . . . . .	31
1.3.5 Objectives and outline . . . . .	33
<b>2 Microwave cavities for DR atomic clocks</b>	<b>35</b>
2.1 General cavity theory . . . . .	35
2.1.1 Generalized cross section with translational symmetry . . . . .	36
2.1.2 Modes in a cylindrical cavity with a circular cross section and PEC boundaries . . . . .	40
2.1.3 The standard cylindrical cavity with PEC boundaries . . . . .	40
2.2 General design criteria and characterization . . . . .	48
2.2.1 Definition of the driving fields . . . . .	48
2.2.2 Figures of Merit . . . . .	50
2.3 Figures of merit in the case of the cylindrical cavity loaded with a cylindrical vapor cell . . . . .	53
2.4 Figures of merit – how to find the optimal case . . . . .	57
2.4.1 The case of a standard cylindrical geometry . . . . .	57

<b>3</b>	<b>Cavities with modified geometry</b>	<b>61</b>
3.1	State-of-the-art development . . . . .	61
3.1.1	Size reduction . . . . .	61
3.1.2	Temperature stability . . . . .	69
3.1.3	A focus on the loop-gap geometry . . . . .	70
3.2	Physics of the loop-gap cavity . . . . .	74
3.2.1	Lumped element point of view . . . . .	74
3.2.2	Field point of view . . . . .	77
3.2.3	Figures of merit in the case of the loop-gap geometry . . . . .	83
3.3	Characterization of the existing cavities . . . . .	86
3.3.1	Field imaging experiment . . . . .	87
3.3.2	Field misalignment . . . . .	92
3.3.3	Double-stem design . . . . .	96
<b>4</b>	<b>Implementation of AMC boundary conditions</b>	<b>105</b>
4.1	Generic cavity with AMC boundaries . . . . .	105
4.2	Loop-gap geometry with AMC . . . . .	121
4.2.1	Implementation of AMC based on planar structures . . . . .	122
4.2.2	Implementation of a variable tuning in the case of the loop-gap geometry	128
4.3	Complete cavity design . . . . .	131
4.3.1	Description of the proposed design . . . . .	131
4.3.2	Cavity modes . . . . .	132
4.3.3	Second design proposal – cavity with corrugations . . . . .	137
4.3.4	Feeding mechanism . . . . .	139
4.3.5	Quality of the obtained field . . . . .	140
4.3.6	Design realization and stage of development . . . . .	145
	<b>Summary and conclusions</b>	<b>147</b>
	<b>Prospective work</b>	<b>153</b>
<b>A</b>	<b>Field misalignment</b>	<b>155</b>
<b>B</b>	<b>Vapor cell study. Stability of the resonance condition</b>	<b>159</b>
B.0.1	Variation of the vapor cell dimensions . . . . .	159
B.0.2	Variation of the cell permittivity $\epsilon_d$ . . . . .	161
	<b>Bibliography</b>	<b>174</b>
	<b>Publications</b>	<b>175</b>