CONTENTS

List of Figures		xvii-xx
List of Tables		xxi
List of Abbreviations	х	xxiii-xxiv
List of Symbols	2	xxv-xxvi
Preface	xx	vii-xxvii
CHAPTER 1	INTRODUCTION	1-26
1.1.	An Origin of High Power Microwave (HPM) Sources	3
1.2.	Definition of HPM Source	3
1.3.	Classification of HPM Sources	4
1.4.	Side-Coupled Cavity	6
1.5.	Reltron	11
	1.5.1. Literature Review	13
	1.5.2. Classification of Reltron	18
	1.5.3. Key Features	21
	1.5.4. Applications	22
1.6.	Motivation and Research Objectives	22
1.7.	Organization of the Thesis	23
CHAPTER 2	ANALYSIS OF SIDE COUPLED CAVITY (SCC)	
	STRUCTURE	27-50
2.1.	Overview	29
2.2.	Introduction	29
2.3.	Equivalent Circuit Analysis	33
	2.3.1. Equivalent Inductance (L_0)	40
	2.3.2. Equivalent Capacitance (C_0)	42
	2.3.3. Expression for the Magnetic Coupling Coefficien	t 44

	2.3.4. Simulation Study of Coupling Depth	45	
	2.3.5. Empirical Expression for $\pi/2$ -mode Frequency	48	
2.4.	Validation of Theoretical Analysis	49	
2.5.	Conclusion 5		
CHAPTER 3	BEAM-WAVE INTERACTION ANALYSIS OF THE		
	SCC STRUCTURE	51-72	
3.1.	Overview	53	
3.2.	Introduction		
3.3.	Analysis		
	3.3.1. EM-Field Expression in the Presence of the		
	Electron Beam	57	
	3.3.2. Boundary Conditions	62	
	3.3.3. Dispersion Relation	63	
	3.3.4. Temporal Growth Rate	65	
3.4.	Result and Discussion	66	
	3.4.1. Parametric Study of the Temporal Growth Rate	69	
	3.4.2. Validation of Derived Analytical Relation	70	
3.5.	Conclusion	71	
CHAPTER 4	DESIGN AND SIMULATION STUDY OF GRID-LE	SS	
	RELTRON	73-98	
4.1.	Overview	75	
4.2.	Introduction	75	
4.3.	Design Methodology	77	
4.4.	Working Principle	83	
4.5.	Simulation Study of the Grid-less Reltron	86	
	4.5.1. Cold Test Simulation Results	87	

		4.5.1.1.	Results of Eigenmode Solver	88
		4.5.1.2.	Results of Frequency Domain Solver	89
		4.5.1.3.	SCC's Structural Parametric Analysis	90
	4.5.2.	Hot Test	Simulation Results	92
		4.5.2.1.	Electrical Parametric Analysis	96
4.6.	Conclu	ision		97
CHAPTER 5	PERF	ORMANO	CE IMPROVEMENT OF GRID-LES	S
	RELT	RON		99-122
5.1.	Overvi	lew		101
5.2.	Introdu	action		102
5.3.	Simula	ition Study	7	105
	5.3.1.	Cold Tes	st Simulation Results	108
		5.3.1.1.	Results of Eigenmode Solver	109
		5.3.1.2.	Results of Frequency Domain Solver	110
	5.3.2.	Hot Test	Simulation Results	111
		5.3.2.1.	Electrical Parametric Analysis	117
5.4.	Conclu	ısion		121
CHAPTER 6	SUMN	MARY, CO	ONCLUSION AND FUTURE SCOPE	1
				123-130
6.1.	Summ	ary and Co	onclusions	125
6.2.	Sugges	stions for I	Future Research	129
References				131-136
Author's Relevant l	Publicatio	ns		137-138
Appendix				139-140



LIST OF FIGURES

Figure 1.1:	Periodic disc loaded circular waveguide structure: (a) shows the two-gap resonant structure and (b) seven coupled cavities LINAC resonator structure.	7
Figure 1.2:	The normalized axial electric fields associated with different modes in the seven coupled cavities LINAC resonator structure [Miller (2006)].	8
Figure 1.3:	Typical geometry of SCC.	9
Figure 1.4:	Schematic of the reltron system [Miller et al. (1992)].	11
Figure 1.5:	Different possible ways to classify the reltron source.	20
Figure 2.1:	Different cross-sectional view of SCC: (a) lateral cross-section view, and (b) longitudinal cross-section view with a coaxial probe.	30
Figure 2.2:	Equivalent circuit model of the SCC.	33
Figure 2.3:	Electric field distribution in the SCC: (a), (b), and (c) shows the vector plot of with 0, $\pi/2$, and π -mode respectively while (d), (e), and (f) shows the contour plot of the 0, $\pi/2$, and π -mode respectively.	35
Figure 2.4:	EM field distribution for the TM_{01} mode inside the cylindrical single-cell resonant structure [Miller (2006)].	36
Figure 2.5:	(a) Electric field distribution inside the single-cell resonant structure, and (b) its equivalent circuit.	36
Figure 2.6:	S_{11} parameter of the modeled SCC structure at different coupling depths: (a) at 6.0 mm, (b) at 7.6 mm, (c) at 8.6 mm, and (d) at 9.2 mm.	47

Figure 2.7:	Effect of coupling depth on the resonating frequency associated	47
	with the $\pi/2$ -mode.	
Figure 3.1:	Schematic of periodic SCC structure in the presence of electron beam.	55
Figure 3.2:	Different cross-section views of the unit cell of the SCC structure: (a) lateral cross-section view, and (b) longitudinal cross-section view.	55
Figure 3.3:	The proposed equivalent model of the SCC structure for the RF analysis.	56
Figure 3.4:	Dispersion curve of the periodic SCC structure in the presence of electron beam.	67
Figure 3.5:	Temporal growth rate of the periodic SCC structure.	68
Figure 3.6:	Dispersion curve of the periodic SCC structure in the presence and absence of electron beam.	68
Figure 3.7	Temporal growth rate at different electron beam radius.	69
Figure 3.8:	Comparison between dispersion curves that have been obtained by simulation and analytical procedure for the special case (i.e. $r_e = 0$).	70
Figure 4.1:	A typical reltron oscillator: (a) 3D schematic, and (b) RF interaction cavity.	78
Figure 4.2:	A typical schematic of the reltron oscillator.	82
Figure 4.3:	RF electric field distribution in the RF interaction cavity: (a) 0-mode, (b) π /2-mode, and (c) π -mode [Miller <i>et al.</i> (1992)].	84
Figure 4.4:	Electric field distribution in the RF interaction cavity (electron beam absent) of the reltron with their respective resonant frequency for different operating modes: (a) 0-mode, (b) π /2-mode, and (c) π -mode.	89

Figure 4.5:	Magnitude of the scattering parameter (S_{11}) versus frequency plot of the RF interaction cavity of the reltron.	90
Figure 4.6:	The effect of different structural parameters of the RF interaction cavity on the resonating frequency of three different modes: (a) effect of hole radius, (b) effect of coupling depth, and (c) effect of idler length.	91
Figure 4.7:	Kinetic energy distribution of the electrons: (a) during the first half of the RF cycle and (b) during the second half of the RF cycle of the designed reltron device.	93
Figure 4.8:	Growth of RF signal recorded by the waveguide port at the extraction cavity.	94
Figure 4.9:	Normalized frequency spectrum of the generated RF signal.	95
Figure 4.10:	RF output power at the extraction cavity.	95
Figure 4.11:	Effect of various electrical parameters on the RF output power of the grid-less reltron, due to variation in (a) post-acceleration voltage, (b) anode-cathode voltage, and (c) applied external magnetic field.	96
Figure 5.1:	3D schematic of the proposed variant of reltron.	106
Figure 5.2:	3D schematic view of the RF interaction cavity with coaxial pins.	107
Figure 5.3:	The RF electric field distribution inside the RF interaction cavity: (a) 0-mode, (b) π /2-mode, and (c) π -mode.	109
Figure 5.4:	Scattering parameter (S_{11}) of the RF interaction cavity.	110
Figure 5.5:	Kinetic energy distribution of the electron beam recorded by the inbuilt phase space monitor: (a) axial electron bunching at 58 ns, and (b) axial electron bunching at 980 ns.	112

Figure 5.6:	Generated RF signal when the applied cathode voltage and post-acceleration voltage of 100 kV and 400 kV, respectively: (a) amplitude and operating frequency, and (b) RF output power.	113
Figure 5.7:	Generated RF signal when the applied cathode voltage and post-acceleration voltage of 150 kV and 350 kV, respectively: (a) amplitude and operating frequency, and (b) RF output power.	114
Figure 5.8:	Generated RF signal when the applied cathode voltage and post-acceleration voltage of 200 kV and 300 kV, respectively: (a) amplitude and operating frequency, and (b) RF output power.	115
Figure 5.9:	Generated RF signal when the applied cathode voltage and post-acceleration voltage of 250 kV and 250 kV, respectively: (a) amplitude and operating frequency, and (b) RF output power.	116
Figure 5.10:	RF output power versus cathode voltage (when the applied post acceleration voltage was 400 kV).	118
Figure 5.11:	RF output power and its pulse-width versus post acceleration voltage (when the applied beam voltage of 100 kV).	119
Figure 5.12:	RF output power and its pulse-width versus external applied DC magnetic field (when the applied beam voltage and a post acceleration voltage were 100 kV and 400 kV, respectively).	120
Figure 5.13.	Comparison between the generated RF output power and pulse width of the gridded reltron, grid-less reltron, and proposed variant of the reltron.	120
Figure A.1:	Lateral cross-sectional view of the SCC.	139

LIST OF TABLES

Table 1.1:	Different ways to classify the HPM source [Benford <i>et al.</i> (2007)].	5
Table 2.1:	Structural specification of the SCC.	35
Table 2.2:	Comparison of simulated and numerically obtained results at different coupling depths.	49
Table 4.1:	Electrical specification of S-band grid-less reltron [Miller <i>et al.</i> (1995)].	87
Table 4.2:	Structural specification of S-band grid-less reltron [Miller <i>et al.</i> (1995)].	87
Table 5.1:	Electrical and structural specification of the proposed variant of reltron.	108
Table 5.2:	RF output power and operating frequency at the different applied beam and post-acceleration voltage.	117