List of Figures

Figure No.	Caption of Figures	Page No.
Figure 1.1:	Information retrieval from an automatic identification system	3
Figure 1.2:	Several types of transponders used in RFID systems	3
Figure 2.1:	Configuration and equivalent circuit of a passive RFID tag	26
Figure 2.2:	Schematic of (a) conventional tag and (b) proposed dual antenna tag.	27
Figure 2.3:	An RFID trap and its virtual ground surface	31
Figure 2.4:	Measurement setup for the determination of RFID tag antenna impedances with on-wafer prober	32
Figure 2.5:	Single ended probe	33
Figure 2.6:	Balun	34
Figure 2.7:	Excitation and port definition of the asymmetrical balanced dipole antenna. (a) Excitation. (b) Virtual ground. (c) Ports definition.	37
Figure 2.8:	Network representation of the asymmetrical dipole antenna	37
Figure 2.9:	Measurement setup. (a) Schematic configuration. (b) Fixture prototype. (c) Measurement setup using network analyzer	39
Figure 3.1:	(a) Geometry and (b) fabricated proposed dual tag antenna	43
Figure 3.2:	Equivalent circuit of the inductively coupled feed structure	44
Figure 3.3:	Simulated (a) power reflection coefficient, (b) real part of input impedance, (c) imaginary part of input impedance of receiving antenna by tuning the Lx1.	46
Figure 3.4:	Simulated (a) real part and (b) imaginary part of input impedance of receiving antenna by tuning Ly2.	47
Figure 3.5:	Simulated (a) real part and (b) imaginary part of input impedance of receiving antenna by tuning 'g'	48

Figure 3.6:	Simulated (a) real part and (b) imaginary part of input impedance of receiving antenna by tuning t1.	49
Figure 3.7:	Simulated (a) real part and (b) imaginary part of input impedance of receiving antenna by tuning t2.	50
Figure 3.8:	Simulated (a) real part and (b) imaginary part of input impedance of receiving antenna by tuning Ly1.	51
Figure 3.9:	imaginary part of input impedance of backscattering antenna by tuning (a) Ly3, (b) g1, (c) Lx2, (d) Ly4 and (e) t5 when receiving antenna is matched.	54
Figure 3.10:	Differential probe with measurement Setup	55
Figure 3.11:	Simulated and measured (a) power reflection coefficient and (b) input impedance of proposed antenna with optimum values.	57
Figure 3.12:	Simulated and measured input reactance of backscattered antenna with optimum values	58
Figure 3.13:	RCS of (a) conventional antenna in two states (matched and short circuit) and (b) proposed antenna in two states (open and short circuit).	58
Figure 3.14:	Read range comparison of conventional and proposed antenna.	59
Figure 3.15:	Radiation pattern of (a) Receiving antenna and (b) Backscattering antenna at 925 MHz in terms of realized gain.	59
Figure 3.16:	Surface current of antenna at 925 MHz	60
Figure 3.17:	input (a) resistance and (b) reactance of antenna on free space, paper, plastic and metal.	61
Figure 4.1:	(a) Geometry of proposed dual antenna with zoomed section of the feed connections and (b) fabricated prototype of proposed dual tag antenna.	64
Figure 4.2:	Evolution of the broadband receiving antenna (Antenna-I) (a) input resistance and (b) input reactance	66
Figure 4.3:	(a) Simulated Input resistance and (b) Input reactance of receiving antenna by tuning Lx7	68
Figure 4.4:	(a) Simulated Input resistance and (b) Input reactance of receiving antenna by tuning Ly7	69
Figure 4.5:	(a) Simulated Input resistance and (b) Input reactance of receiving antenna by tuning Lv8	70

Figure 4.6:	Simulated power reflection coefficient of receiving antenna by tuning: (a) Lx7 (b) Ly7 and (c) Ly8	71
Figure 4.7:	(a) Simulated Input resistance and (b) Input reactance of receiving antenna by tuning Ly1	72
Figure 4.8:	(a) Simulated Input resistance and (b) Input reactance of receiving antenna by tuning Lx1	73
Figure 4.9:	(a) Simulated Input resistance and (b) Input reactance of receiving antenna by tuning Lx8	74
Figure 4.10:	(a) Simulated Input resistance and (b) Input reactance of receiving antenna by tuning Lx5	75
Figure 4.11:	(a) Simulated Input resistance and (b) Input reactance of receiving antenna by tuning Ly11	76
Figure 4.12:	(a) Simulated Input resistance and (b) Input reactance of receiving antenna by tuning Ly3.	77
Figure 4.13:	(a) Simulated Input resistance and (b) Input reactance of receiving antenna by tuning w1.	78
Figure 4.14:	Simulated input reactance of backscattering antenna by tuning the (a) Ly10 (b) w2 and (c) Lx4	80
Figure 4.15:	Measurement setup for S11 measurement	81
Figure 4.16:	Simulated and measured input impedance variation of receiving antenna (a) resistance and (b) reactance.	81
Figure 4.17:	Simulated and measured power reflection coefficient variation of receiving antenna at 925 MHz	82
Figure 4.18:	RCS variation of (a) conventional single antenna and (b) proposed antenna at 925 MHz	83
Figure 4.19:	Read range comparison of conventional and proposed antenna for UHF band	83
Figure 4.20:	Radiation pattern of Antenna-I (receiving antenna) at 925 MHz.	84
Figure 4.21:	Surface current of antenna at 925 MHz	84
Figure 4.22:	Input (a) resistance and (b) reactance of antenna on free space, paper, plastic and metal	85
Figure 5.1:	(a) Configuration and (b) fabricated prototype of the proposed Antenna-I	89
Figure 5.2:	(a) Geometry and (b) fabricated prototype of the proposed Antenna II	90
Figure 5.3:	EBG structure used in Antenna II	91
Figure 5.4:	Simulated input impedance of receiving Antenna I by	93

	tuning the Ly1 (a) input resistance and (b) input reactance.	
Figure 5.5:	Simulated Power Reflection Coefficient of receiving Antenna I by tuning the Ly1.	94
Figure 5.6:	Simulated Power Transmission Coefficient receiving Antenna I by tuning the Ly1.	94
Figure 5.7:	Simulated input impedance of receiving and backscattering Antenna I by tuning the 'g' (a) input resistance of receiving antenna and (b) input reactance of receiving antenna and (c) input reactance of backscattering antenna.	95
Figure 5.8:	Simulated input impedance of receiving and backscattering Antenna I by tuning the Ly5 (a) input resistance of receiving antenna and (b) input reactance of receiving antenna and (c) input reactance of backscattering antenna.	97
Figure 5.9:	Simulated input reactance of backscattering Antenna I by tuning the Ly2.	98
Figure 5.10:	Simulated input impedance of receiving and backscattering Antenna-I by tuning the t (a) input resistance of receiving antenna and (b) input reactance of receiving antenna and (c) input reactance of backscattering antenna.	99
Figure 5.11:	(a) Differential probe and (b) measurement setup	100
Figure 5.12:	Simulated and measured (a) input reactance of Antenna-I and Antenna-II, (b) input resistance of Antenna-I and Antenna-II	101
Figure 5.13:	Simulated and measured power reflection coefficient of proposed Antenna-I and Antenna-II	102
Figure 5.14:	Simulated and measured input reactance of backscattering Antenna-I and Antenna-II	102
Figure 5.15:	Isolation between receiving and backscattering antenna for Antenna-I and Antenna-II	103
Figure 5.16:	Realized gain of Antenna-I and Antenna-II	104
Figure 5.17:	RCS of conventional single antenna in two states (open and short circuit)	104
Figure 5.18:	RCS of proposed Antenna-I in two states (open and short circuit)	105
Figure 5.19:	Read range comparison of conventional and proposed Antenna-I	105

Figure 5.20:	Surface current distribution on 915 MHz for (a) Antenna-I and (b) Antenna-II	107
Figure 5.21:	Read range of Antenna-I and Antenna-II	108
Figure 5.22(a):	Simulated radiation patterns of receiving Antenna-I	108
Figure 5.22(b):	(b) Simulated radiation patterns of backscattering of Antenna-I	109
Figure 5.22(c):	(c) Simulated radiation patterns of receiving Antenna-II	109
Figure 5.22(d):	(d) Simulated radiation patterns of backscattering of Antenna-II	110
Figure 5.23:	(a) Gain and (b) read range of Antenna-II on Free space, Glass, Plastic, Wood and Metal	111
Figure 6.1:	(a) Geometry of proposed dual antenna with zoomed section of the feed connections and (b) fabricated prototype of proposed dual tag antenna	116
Figure 6.2:	(a) input impedance of antenna at 915 MHz and (b) PRC of antenna at 2.45 GHz at step one of designing of antenna.	117
Figure 6.3:	(a) input impedance of antenna at 915 MHz and (b) PRC of antenna at 2.45 GHz at second step of designing of antenna.	118
Figure 6.4:	(a) input impedance of antenna at 915 MHz and (b) PRC of antenna at 2.45 GHz at third step of designing of antenna	119
Figure 6.5:	Simulated real and imaginary part of Input impedance of receiving antenna about UHF band by tuning: (a), (b) <i>Lx1</i> and (c), (d) <i>t1</i>	122
Figure 6.6:	Simulated power reflection coefficient of receiving antenna about UHF band by tuning: (a) $Lx1$, and (b) $t1$	123
Figure 6.7:	Simulated input impedance of receiving antenna about SHF band by tuning: (a) LxI , and (b) tI .	124
Figure 6.8:	Simulated power reflection coefficient of receiving antenna about SHF band by tuning: (a) LxI , and (b) tI	125
Figure 6.9:	Simulated (a) input reactance at 915 MHz, (b) input resistance at 915 MHz, and (c) PRC at 2.45 GHz of receiving antenna by tuning <i>t3</i>	127

Figure 6.10:	Simulated (a) input reactance at 915 MHz, (b) input resistance at 915 MHz, and (c) PRC at 2.45 GHz of receiving antenna by tuning <i>Ly2</i>	128
Figure 6.11:	Simulated (a) Impedance and (b) Power Reflection Coefficient variation of Antenna-I by tuning <i>Lx3</i> at 2.45 GHz.	130
Figure 6.12:	Simulated (a) impedance and (b) power reflection coefficient of antenna I, by tuning the <i>Lx3</i> at 915 MHz.	131
Figure 6.13:	Simulated input impedance variation for (a) UHF band and (b) SHF band of Antenna-I by tuning <i>Ly3</i> .	132
Figure 6.14:	Simulated input impedance variation for (a) UHF band and (b) SHF band of Antenna-I by tuning <i>t2</i> .	133
Figure 6.15:	Simulated input reactance of backscattering antenna by tuning the Lx4.	134
Figure 6.16:	Simulated power reflection coefficient variation of receiving antenna by tuning <i>t5</i>	134
Figure 6.17:	Simulated (a) input impedance and (b) power reflection coefficient variation of receiving antenna by tuning $Lx4$.	135
Figure 6.18:	Isolation between receiving and backscattering antenna at 915MHz.	136
Figure 6.19:	Measurement setup for S_{11} measurement	136
Figure 6.20:	Simulated and measured input impedance variation of receiving antenna for UHF band (a) resistance and (b) reactance.	138
Figure 6.21:	Simulated and measured power reflection coefficient variation of receiving antenna at (a) UHF band and (b) SHF band.	139
Figure 6.22:	Simulated and measured input reactance of backscattering antenna for UHF band.	140
Figure 6.23:	RCS variation of (a) conventional single antenna and (b) proposed antenna for UHF band	140
Figure 6.24:	Read range comparison of conventional and proposed antenna for UHF band.	141
Figure 6.25:	Read range variation of proposed antenna for SHF band	141
Figure 6.26:	Radiation pattern of Antenna-I (receiving antenna) (a) 915 MHz and (b) 2450 MHz	142

Figure 6.27:	Simulated (a) power reflection coefficient and (b) read range of antenna in 915 MHz	143
Figure 6.28:	Simulated (a) power reflection coefficient and (b) read range of antenna in 2450 MHz	144