APPLICATION NOTE

AT03303: Coin Cell operated Wireless ePaper Display

ATmega2564RFR2

Introduction

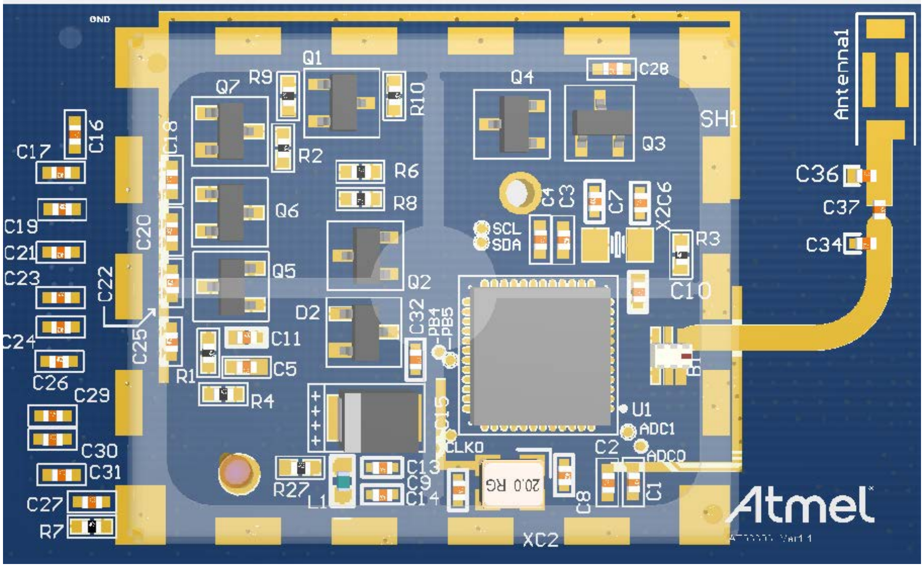
Coin cell operated ePaper Display is an Atmel® ATmega2564RFR2 based reference design specifically designed for applications like medical display devices, electronic security badges, smart tags, electronic shelf labels, display product pricing, barcode/QR codes, etc.

Pervasive Display's ePaper provides paper-like readability, high resolution, high contrast, and 180 degree viewing angle.

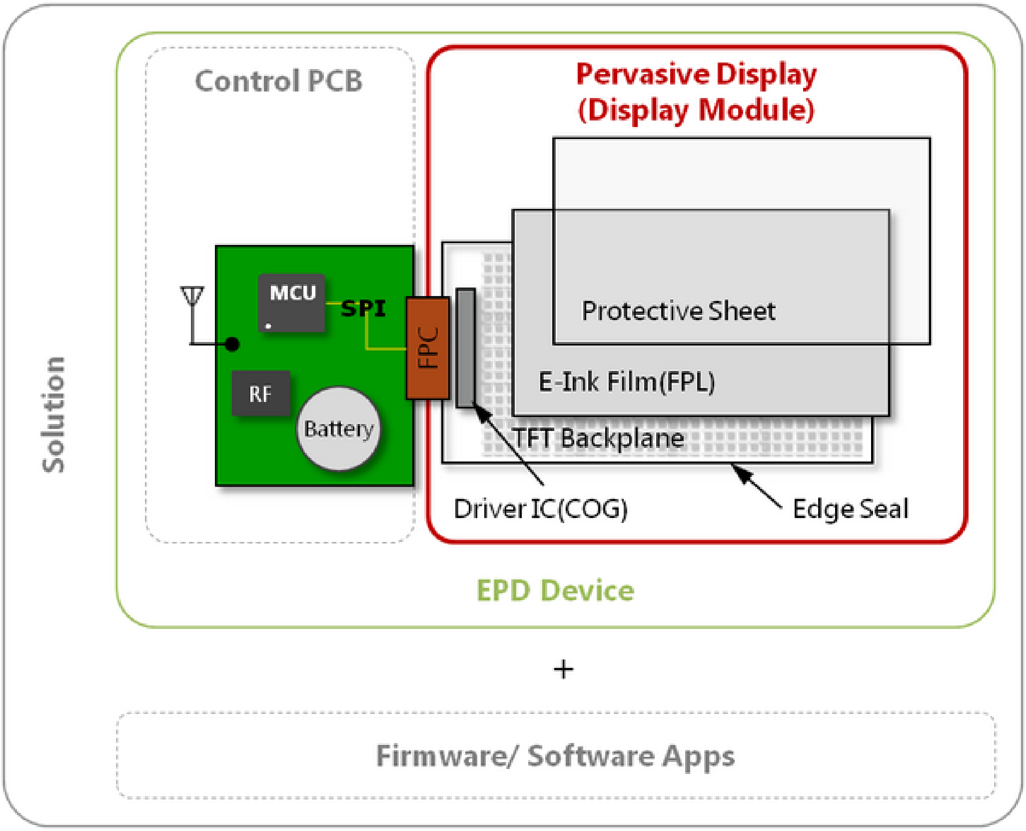
This application note covers hardware design, validation results, radiation patterns, electrical characteristics, pre-compliance testing, and example reference application.

Features

- Low cost design
- Optimized for lower power consumption
- ePaper display
- Chip antenna based design
- Temperature sensing
- Pre-compliance tested



1 Hardware Design



1.1 Atmel ATmega2564RFR2

The Atmega2564RFR2 [1] combines the industry's leading Atmel AVR® 8-bit Microcontroller and a best-in-class 2.4GHz RF transceiver in industry's best single-chip targeting IEEE® 802.15.4 and ZigBee® applications.

It offers the industry's highest RF performance for single chip devices, with a link budget of 103.5dBm while consuming 50% less current than the existing offerings.

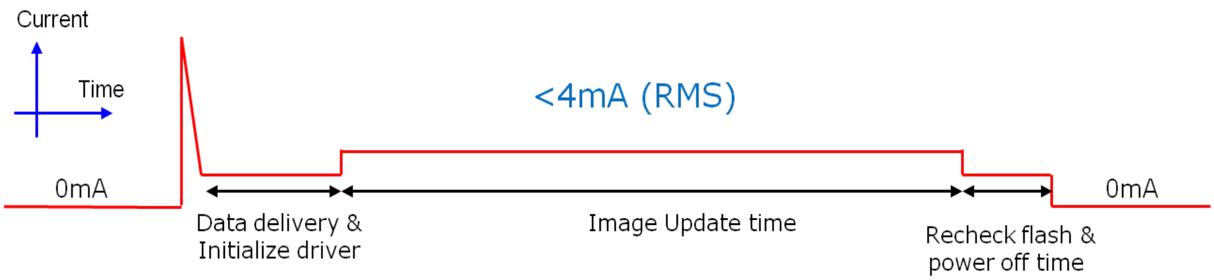
The device features hardware assisted:

- Multiple PAN address filtering (MAF)
- Wake-on radio
- Improved link efficiency and reliability using RX override
- 32-bit MAC symbol counter
- Internal temperature sensor
- Automatic transmission modes
- 128-bit AES crypto engine
- True random number generator
- Advanced hardware assisted reduced power consumption modes

1.2 Pervasive ePaper Display

ePaper Display (EPD) panel [2] is the most power efficient, easy to read, industrial purposed reflective ePaper display on the market.

Figure 1-1. EPD Current Profile



By combining the high resolution of a TFT backplane and the dependability/maturity of E Ink technology, this display offers its user the freedom to display any image with excellent definition and contrast. The small and thin form factor makes it easy to design it into a variety of applications.

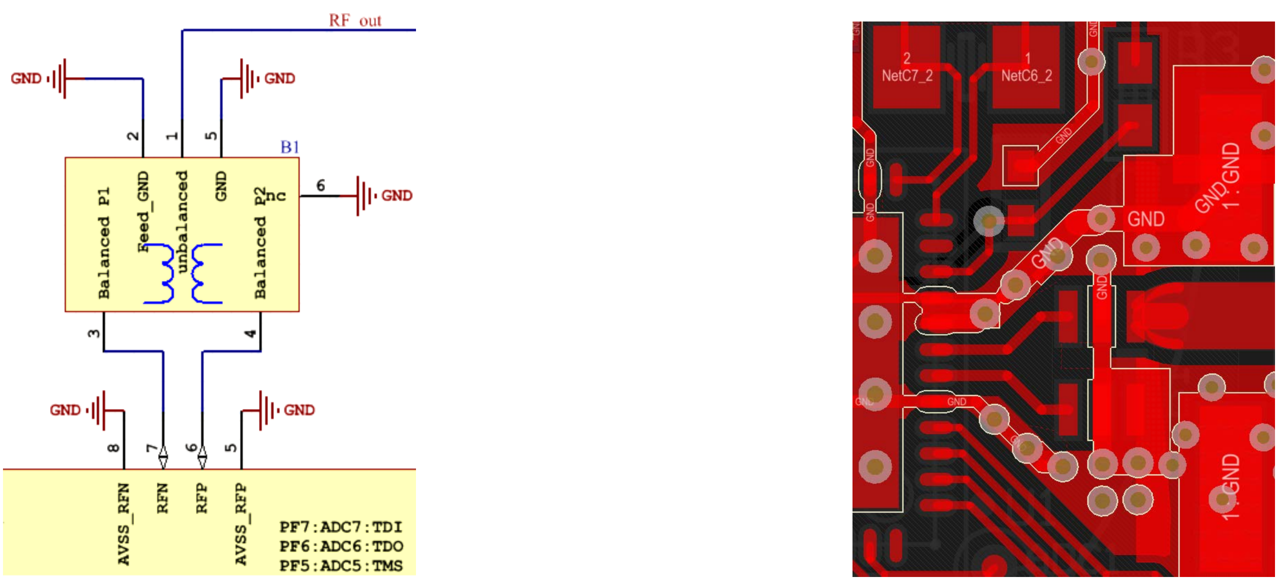
- Ultra-low-power (Battery Drive/Energy Harvest)
- Easy to Read (Sunlight readable)
- High Resolution (Display small details)
- Thin & Light (Easy to Integrate)
- Green (Paper Replacement)
- Wide Viewing Angle (180 degrees – like paper)

1.3 RF Design

Atmel ATmega2564RFR2 SoC provides 100Ω differential (balanced) impedance through RFP and RFN pins; hence a Balun is used to convert this 100Ω differential to 50Ω single-ended (unbalanced) impedance.

Johanson Balun/Filter (P/N - 2450BM15A0015) [3] is chosen for this reference design as it has integrated filter and is tuned for ATmega2564RFR2 device.

Figure 1-2. RF Design



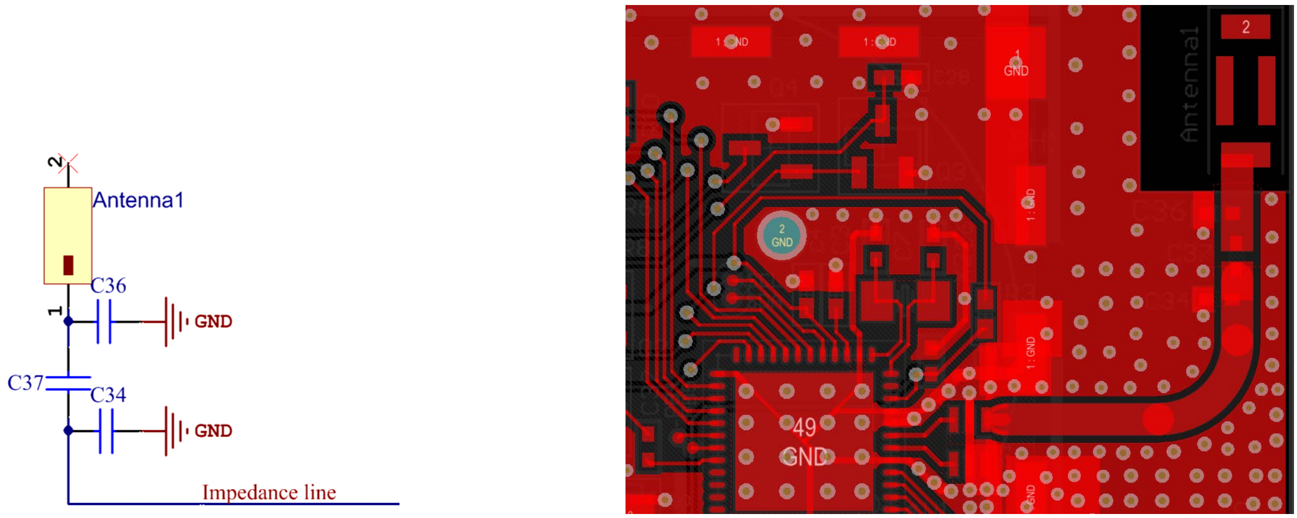
1.4 Chip Antenna Design

The single-ended (unbalanced) output from Balun/Filter needs to be connected with antenna through a transmission line of impedance 50Ω.

Johanson Chip antenna (P/N - 2450AT42B100) [4] was chosen as it is a recommended choice for small boards with limited ground plane and corner mounting.

PCB trace in combination with tuning capacitors C34, C36, and C37 are used for impedance matching.

Figure 1-3. Chip Antenna Design



1.5 Clock Circuit Design

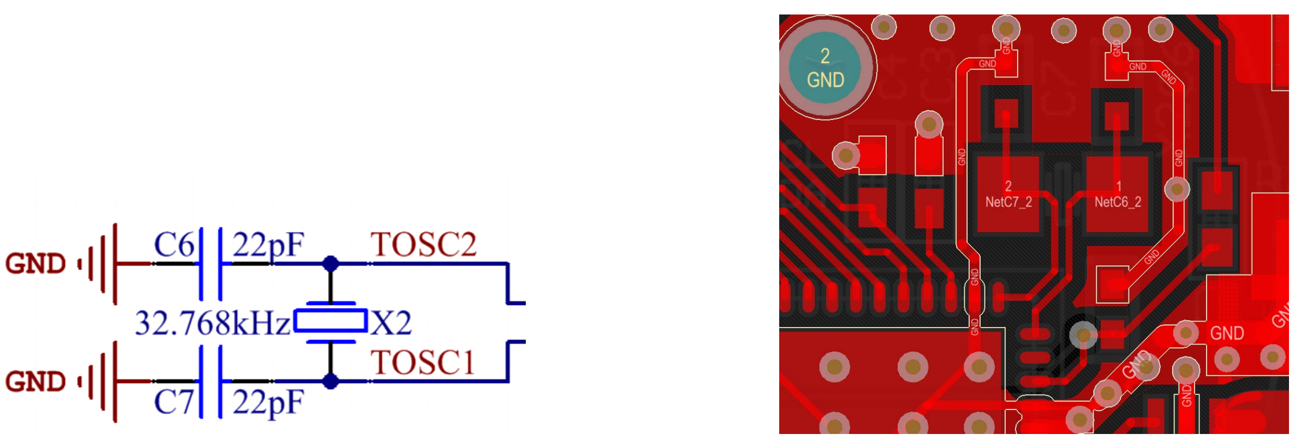
Reference board contains two external crystals as described below. Application note AVR2067: Crystal Characterization for AVR RF [5] covers different recommended crystal options.

1.5.1 32.768kHz Crystal

Due to the low power operation of 32.768kHz crystal, it is used as time keeper when the CPU enters Deep Sleep operation.

In the application 32.768kHz crystal clock is used as input to Timer/Counter2 running in asynchronous mode which acts as interrupt for waking up from Power Save mode of ATmega2564RFR2.

Figure 1-4. 32.768kHz Design



1.5.2 16MHz Crystal

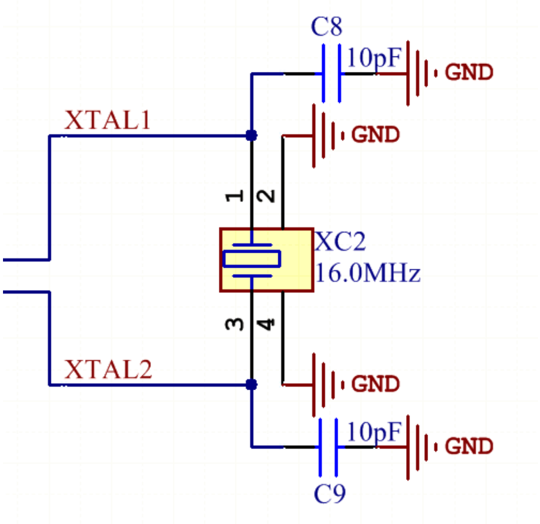
RF frequency of transceiver is derived from 16MHz crystal clock, so accuracy of this external 16MHz crystal is important for proper RF operation.

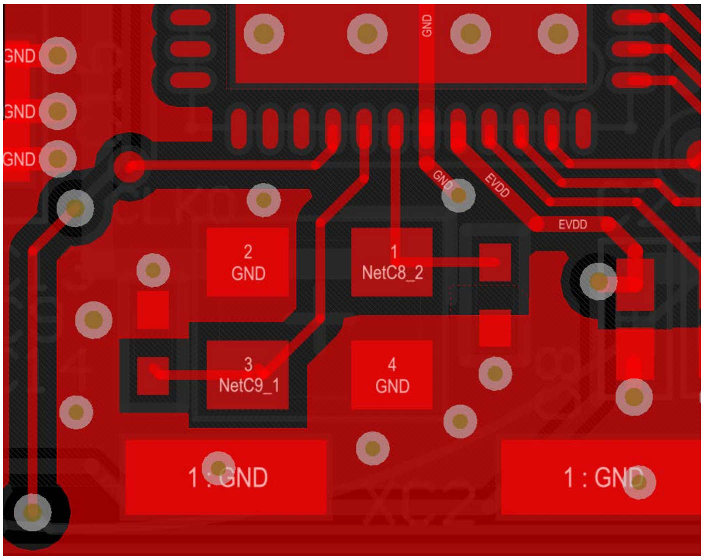
Maximum deviation of RF carrier frequency as per IEEE 802.15.4 standard is ±40ppm, so the 16MHz crystal and its load capacitance need to be chosen in order to meet this requirement.

In order to achieve the best accuracy and stability, large parasitic capacitances should be avoided. Crystal lines should be routed as short as possible.

XTAL_TRIM register can be used to tune the crystal frequency such that it exactly matches to 16MHz. Refer Section 2.1 for XTAL_TRIM tuning test results.

Figure 1-5. 16MHz Design



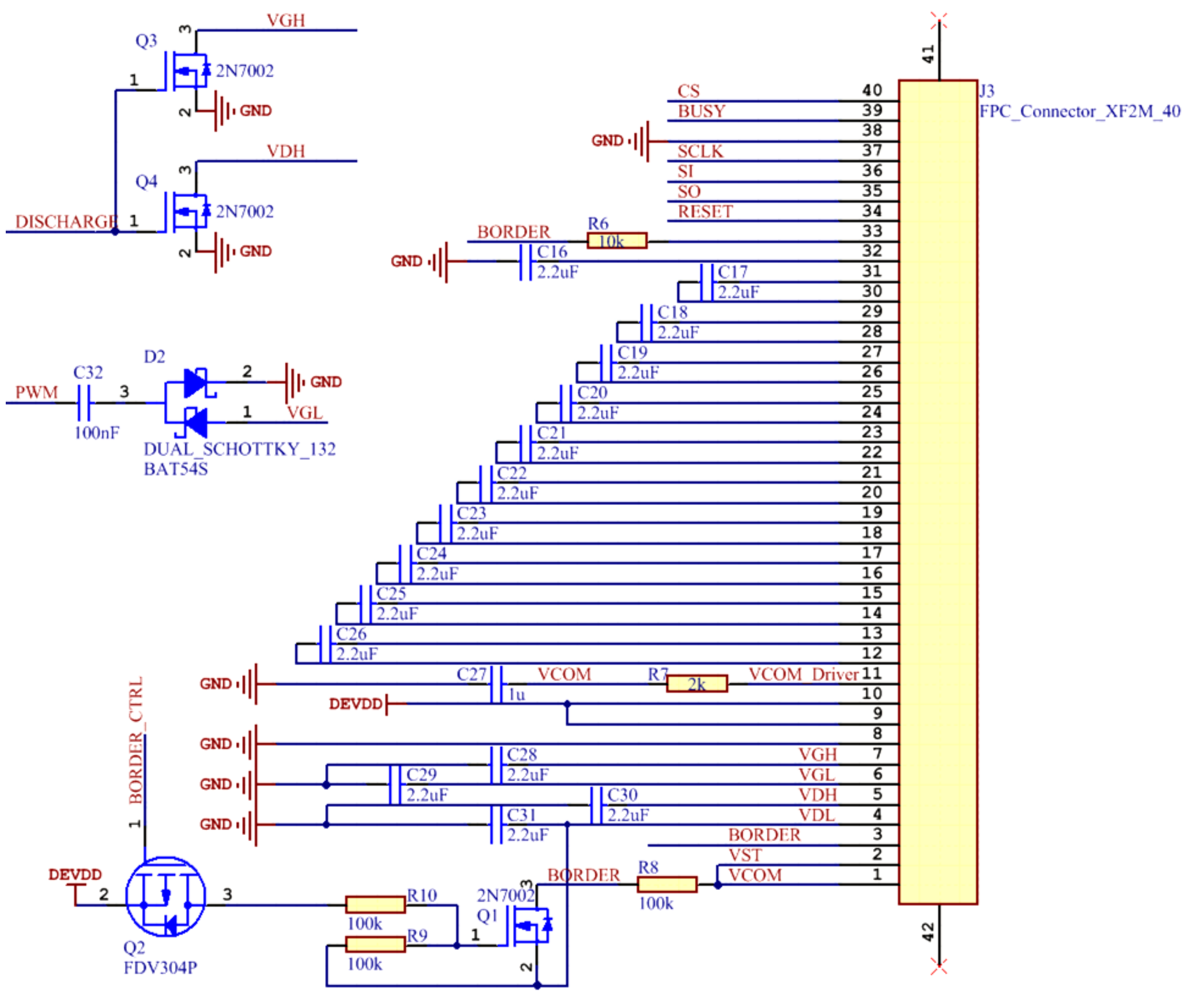


1.6 Interfacing ePaper Display

Pervasive ePaper Displays (EPD) [2] circuit design is given in Figure 1-6 and the basic components required for EPD is included in the reference design. ATmega2564RFR2 and EPD are interfaced via SPI and few GPIO lines for controlling and communicating the display information.

Current consumption profile of EPD is shown in Figure 2-4.

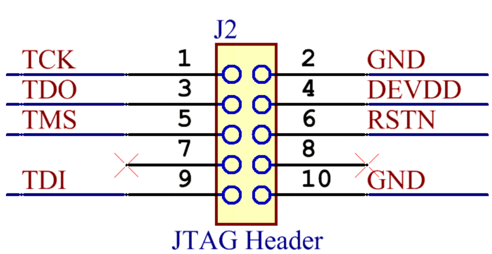
Figure 1-6. EPD Design



1.7 JTAG Connectors

JTAG connector is required for programming or debugging the reference design. Atmel Programmers/Debuggers like the JTAGICE3 can be used for this purpose.

Figure 1-7. JTAG Connectors



1.8 Test Points

Reference design contains few test points which provides access to few pins of ATmega2564RFR2. These test points can be used during validation or for connecting with external circuits.

Table 1-1. Test Points

S. no.	Test point	Test point reference
1	ADC0	ADC input pin which is connected to PF0/Pin46
2	ADC1	ADC input pin which is connected to PF1/Pin47
3	CLKO	Clock output pin which is connected to CLKO/Pin40
4	SCL	TWI Clock pin which is connected to SCL/Pin17
5	SDA	TWI Data pin which is connected to SDA/Pin18
6	PB4	Pin change interrupt which is connected to PCINT4/Pin30
7	PB5	Pin change interrupt which is connected to PCINT5/Pin31

2 Electrical Characteristics

Electrical characteristics provided in Table 2-1 correspond to the typical measurement values in room temperature, 25°C.

Table 2-1. Typical Electrical Characteristics

S. no.	Parameter	Typical value	Units
1	Supply voltage	3.0	V
2	Data rate	250	kbps
3	TX output power	3.75	dBm
4	Antenna Gain	-0.06	dB
5	Antenna efficiency	36	%

2.1 Crystal Frequency Tuning

After choosing the load capacitance of the 16MHz crystal, it is possible to slightly alter the oscillation frequency of a crystal by changing the internal capacitance of XTAL pins.

This gives the freedom for the application to tune internal trimming capacitance to compensate the environmental effects. Table 2-2 shows the pullability result (at 25°C) of 16MHz crystal achieved by changing the XTAL_TRIM register of ATmega2564RFR2.

Table 2-2. 16MHz Crystal Frequency Tuning

S. no.	XTAL_TRIM	Internal capacitance [pF]	Measured frequency [MHz]	Accuracy [ppm]
1	0x0	0	16.000143	8.937420122
2	0x1	0.3	16.000100	6.249960938
3	0x2	0.6	16.000057	3.562487309
4	0x3	0.9	16.000018	1.124998734
5	0x4	1.2	15.999974	-1.62500264
6	0x5	1.5	15.999937	-3.9375155
7	0x6	1.8	15.999899	-6.31253985
8	0x7	2.1	15.999861	-8.68757547
9	0x8	2.4	15.999825	-10.9376196
10	0x9	2.7	15.999791	-13.0626706
11	0xA	3	15.999754	-15.3752364
12	0xB	3.3	15.999722	-17.3753019
13	0xC	3.6	15.999691	-19.312873
14	0xD	3.9	15.999661	-21.1879489
15	0xE	4.2	15.999631	-23.0630319
16	0xF	4.5	15.999602	-24.8756188

2.2 Transmit Output Power

Transmit power results shown in Table 2-3 corresponds to the typical measurement values taken by enabling PRBS CW mode at room temperature 25°C.

Table 2-3. Transmit Output Power

S. no.	Channel	Frequency [GHz]	TX_PWR	Measured RF output power [dBm]	
				Supply voltage at 1.8V	Supply voltage at 3.0V
1	11	2.405	0x00	3.50	3.75
2	15	2.425	0x00	3.48	3.68
3	20	2.450	0x00	3.41	3.61
4	26	2.480	0x00	3.35	3.57

2.3 Current Consumption

Current consumption shown in Table 2-4 corresponds to the typical measurement values in room temperature, 25°C.

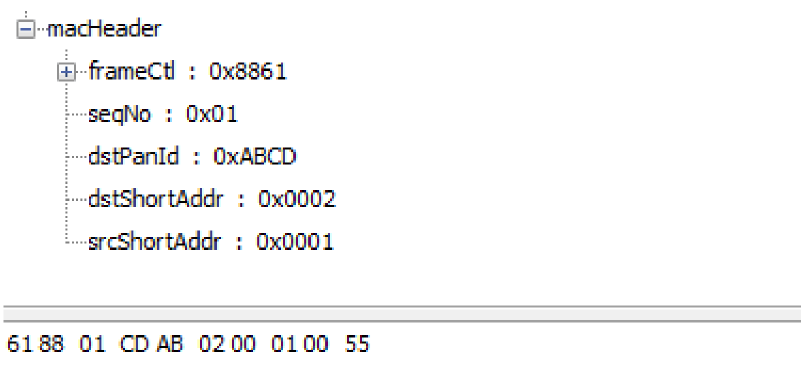
Table 2-4. Current Consumption

S. no.	Condition	Measured RF output power [mA]	
		Supply voltage at 1.8V	Supply voltage at 3.0V
1	TRX_OFF	4.4	5.12
2	PLL_ON	4.74	5.26
3	RX_AACK_ON	10.7	11.29
4	TX_BUSY	18.0	19.1
5	SLEEP	0.002	0.002
6	EPD image update (Duration – 3.6 sec)	-	2.95 (avg)

Current profile during transmission of frame with 10 bytes of data is taken. Corresponding packet structure and current profile is provided in Figure 2-2 and Figure 2-3.

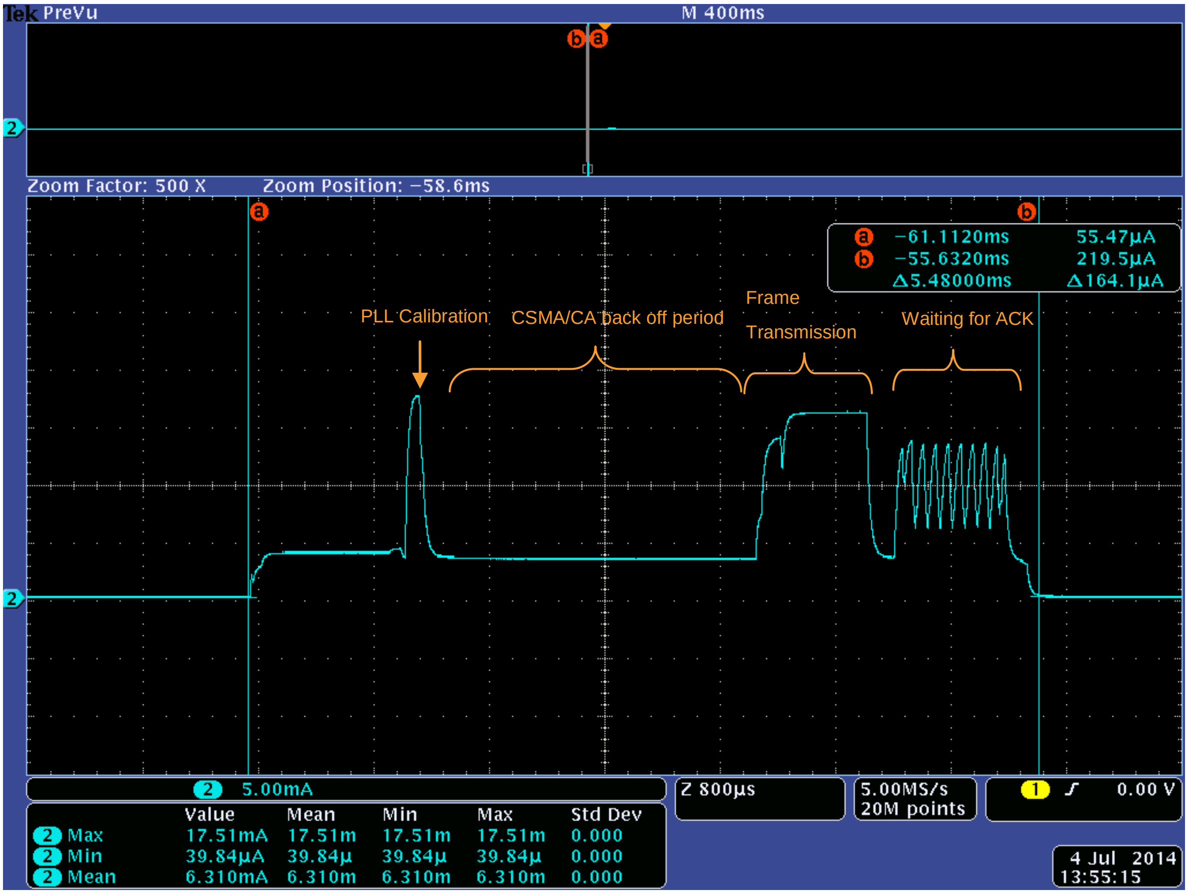
In this example frame we are transmitting 1 byte of application payload (i.e. 0x55) and the remaining bytes are MAC header information.

Figure 2-2. Transmitted Packet Structure



Current profile shows the transmission on frame followed by the wait time corresponding to ACK frame. In the example application we have enabled RPC modes. For more details, refer AT02594: Smart Reduced Power Consumption Techniques [8].

Figure 2-3. Current Consumption Profile



3 Chip Antenna Matching

Chip antenna tuning is required after assembling the RF shield and ePaper display. Final matching circuit requires two inductor values, 6.8nH and 8.2nH (Figure 3-1), for tuning the operating frequency of the chip antenna to the required band of operation (Figure 3-2).

Figure 3-1. Chip Antenna Matching Network

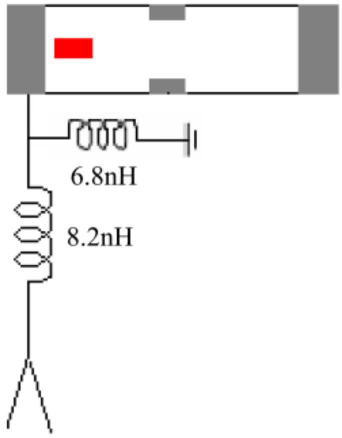
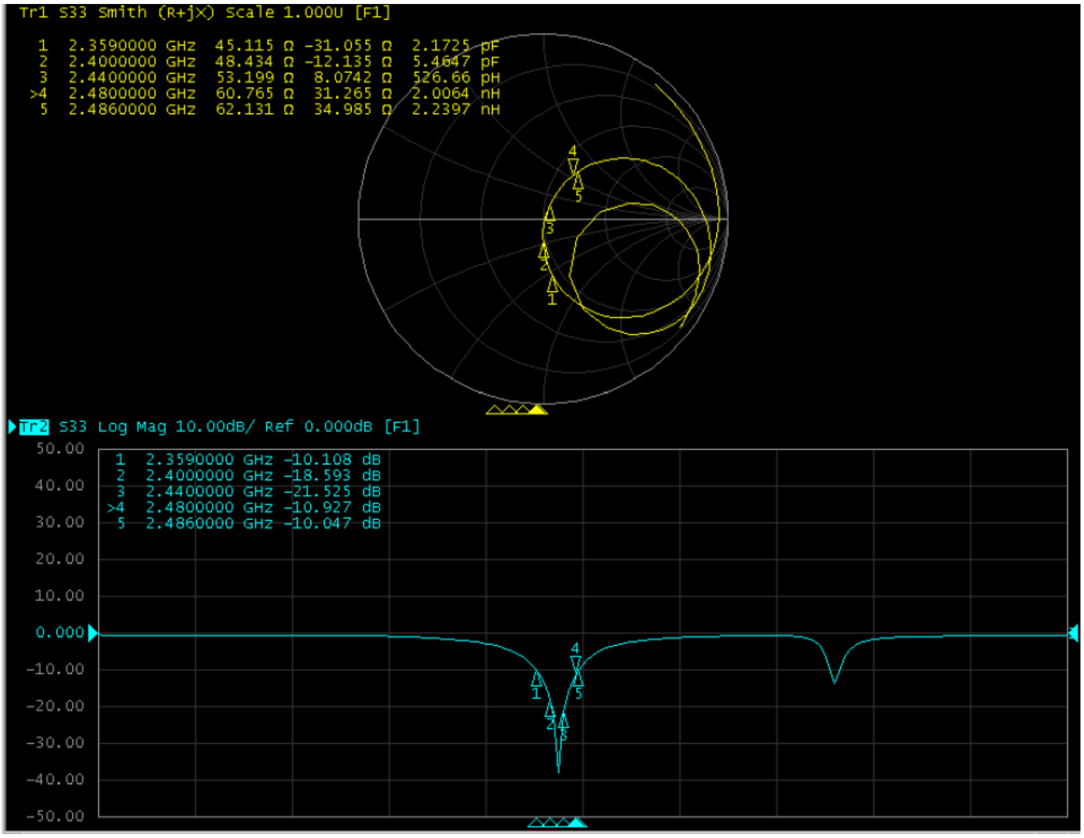
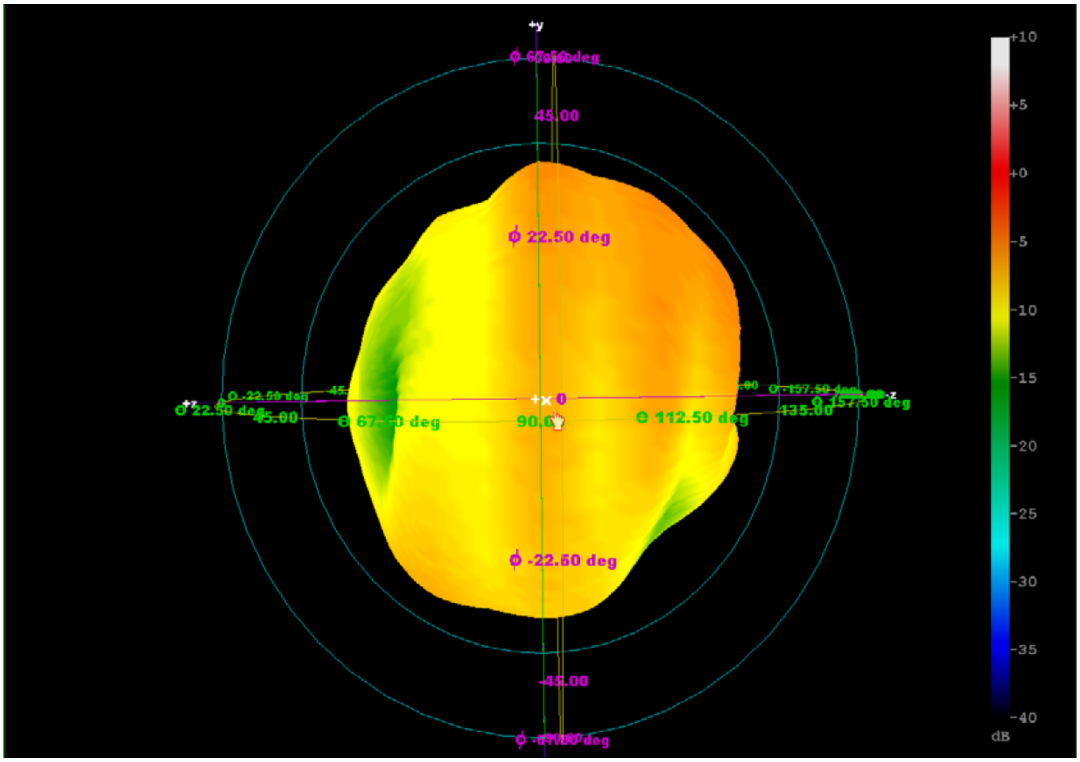


Figure 3-2. Chip antenna Matching Plots



4 Radiation Pattern of Chip Antenna at 2.44GHz



5 Pre-certification Testing

This chapter covers the pre-certification test results required for FCC [6] and ETSI [7] certification.

Figure 5-1. Peak Power at Channel 20

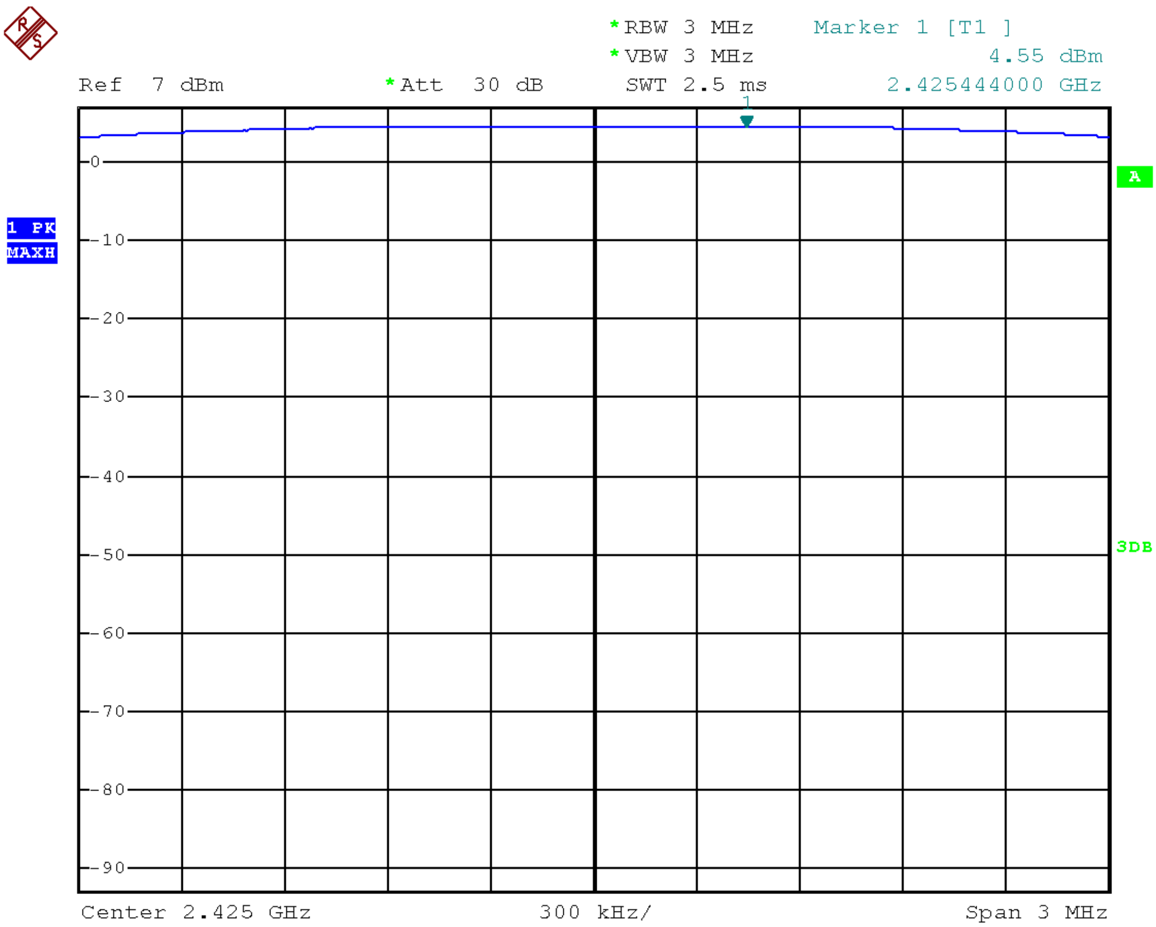


Figure 5-2. 6dB Bandwidth at Channel 20

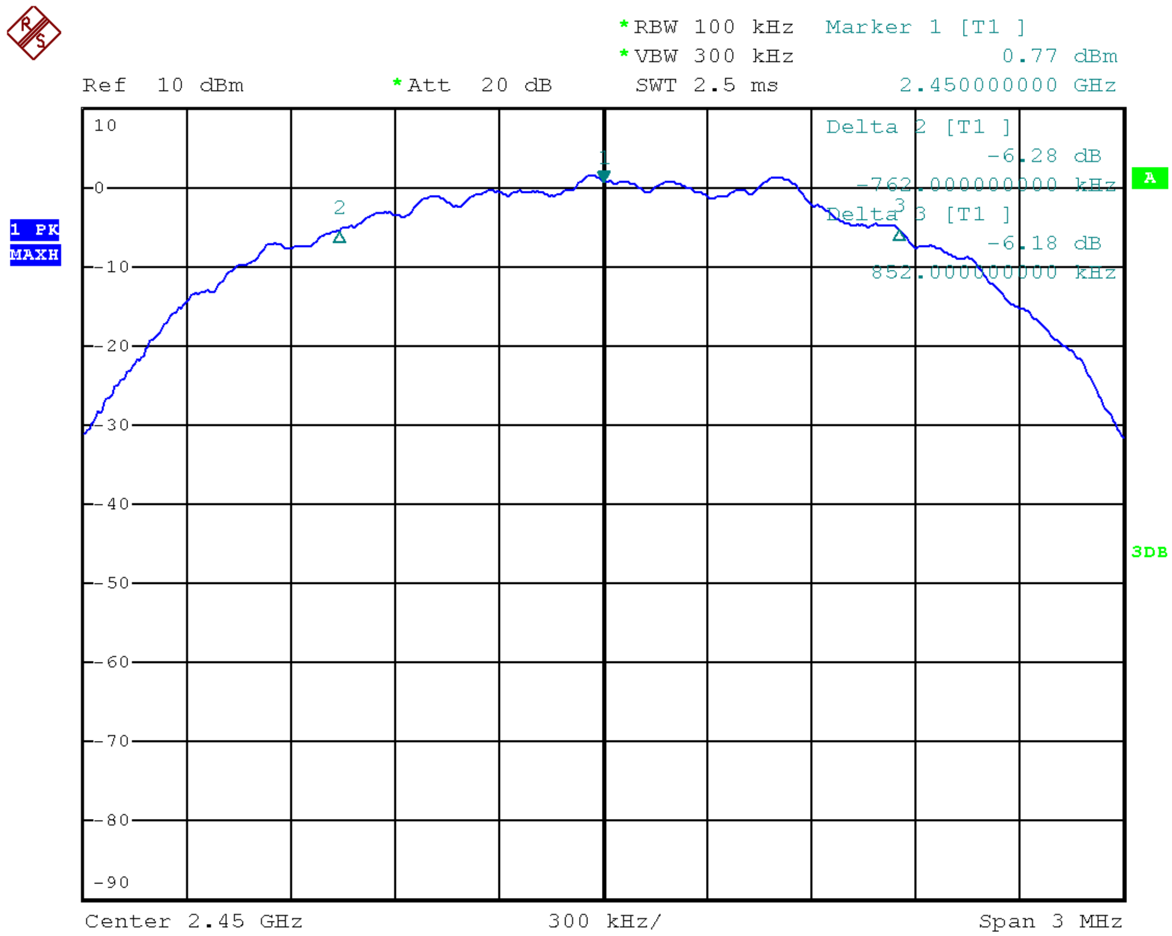


Figure 5-3. Band Edge and Frequency Range at Channel 11

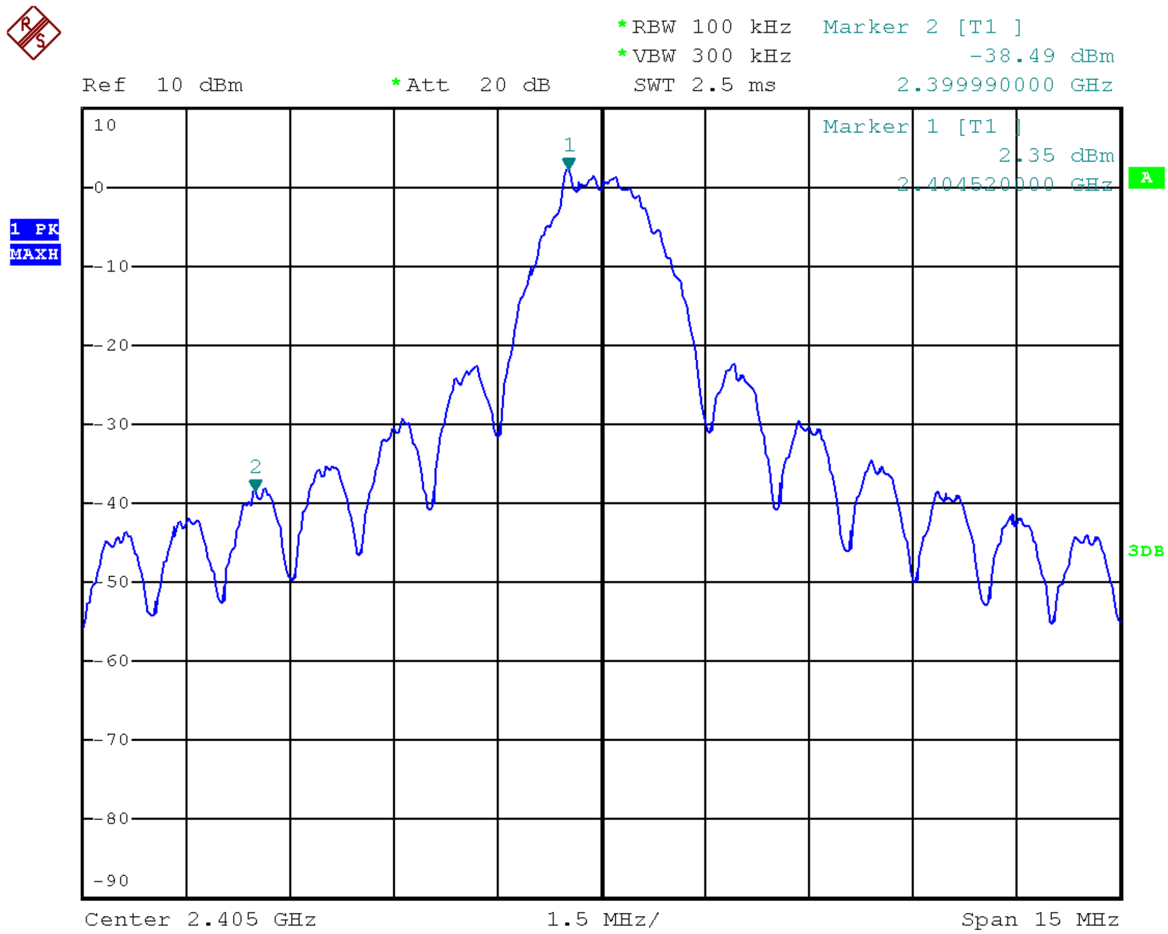


Figure 5-4. Band Edge and Frequency Range at Channel 26

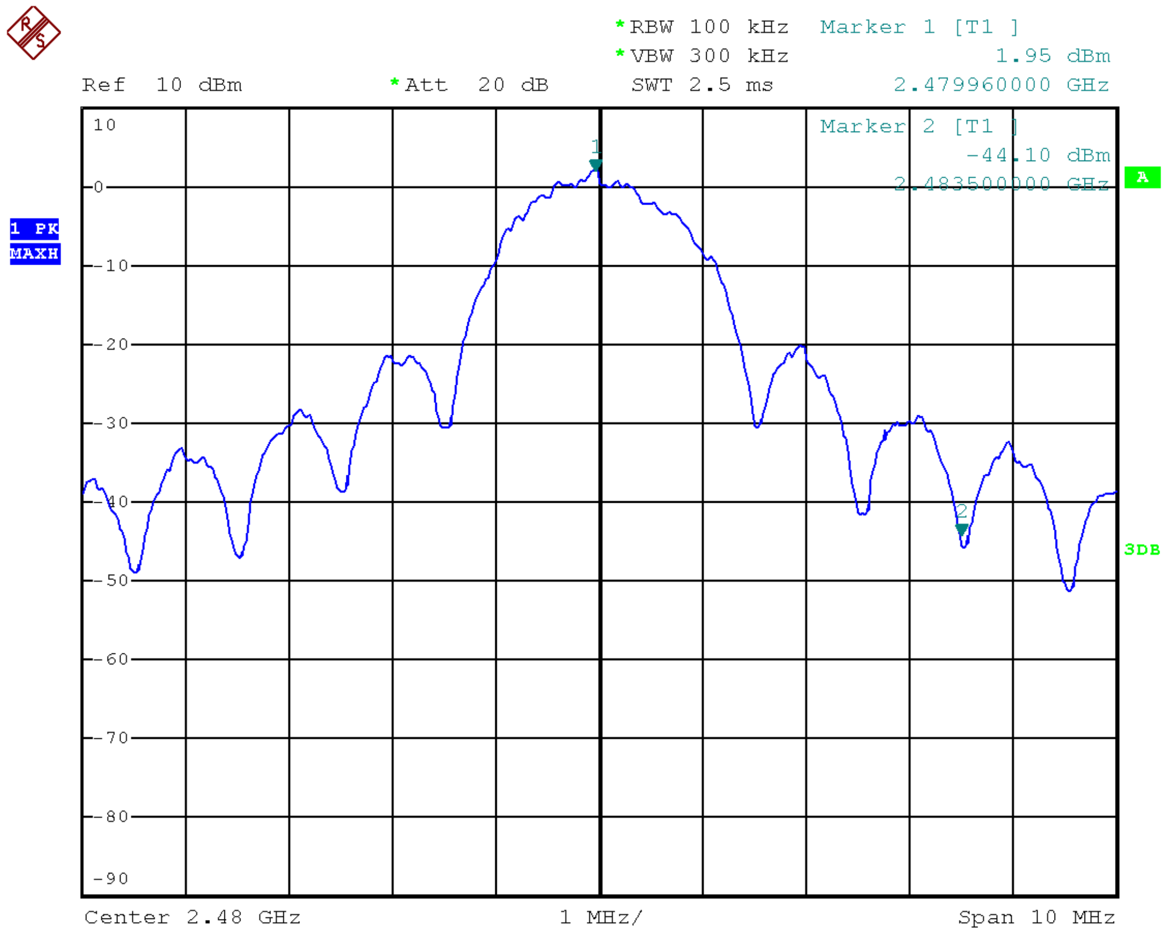


Figure 5-5. Spurious Emission between 30MHz to 1GHz

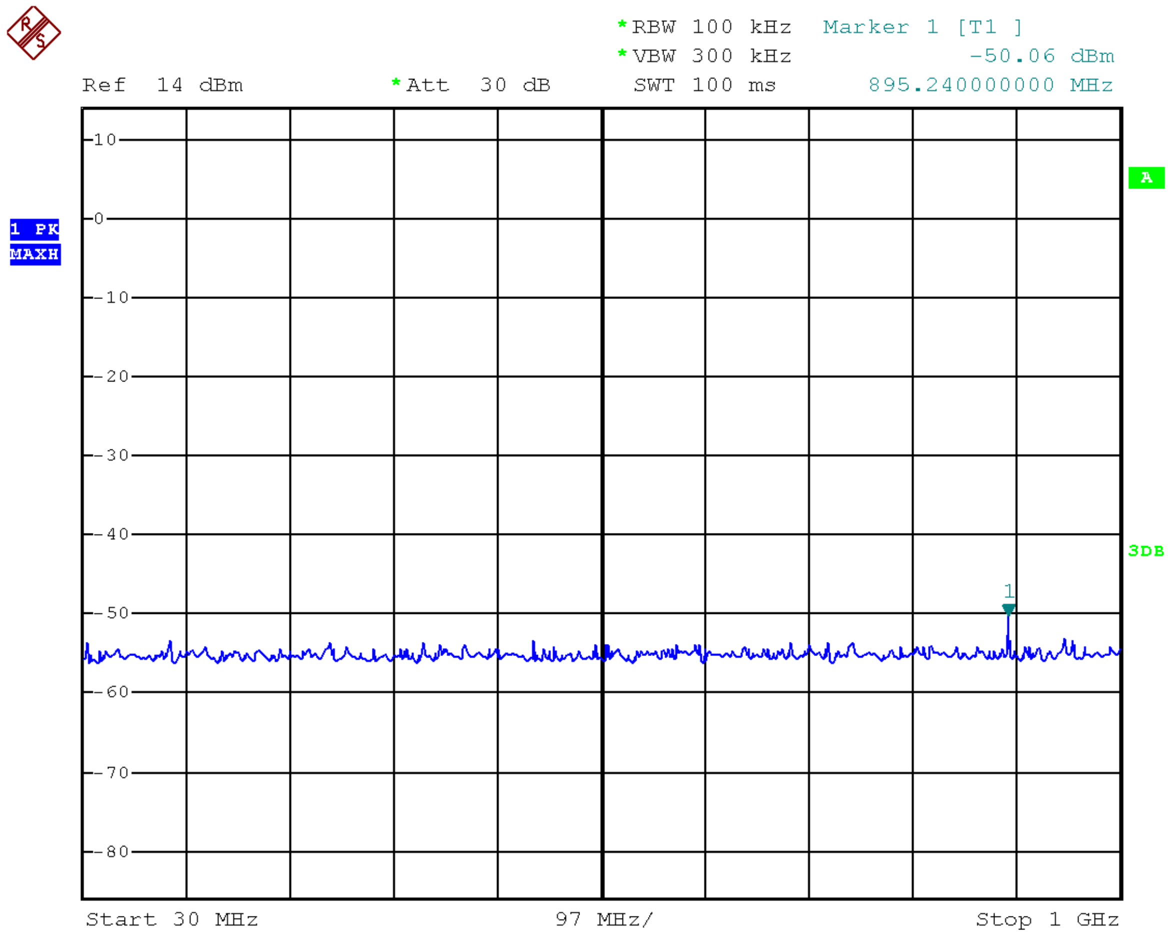
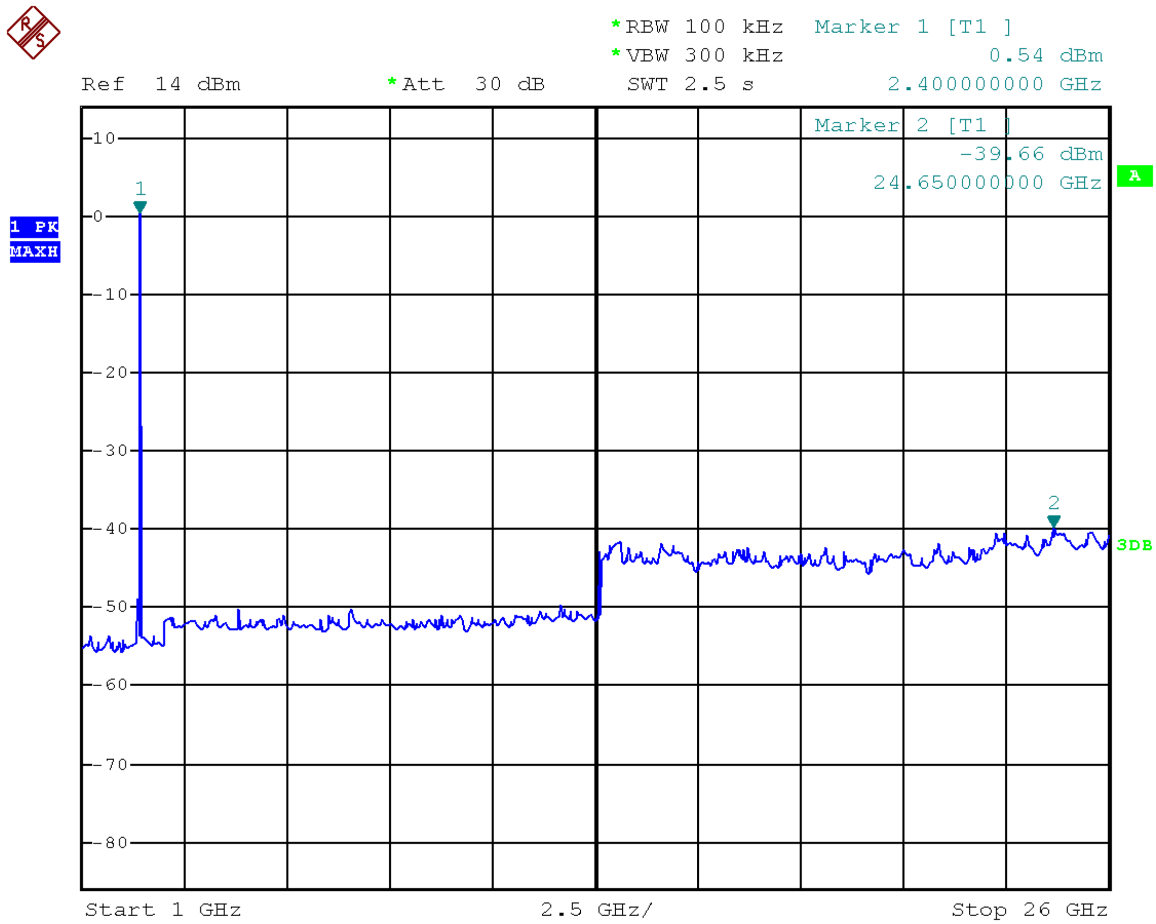


Figure 5-6. Spurious Emission between 1MHz to 26GHz



6 Appendix

6.1 Layer Stack-up

Layer Name	Gerber Document	Copper Thickness	Dielectric Height	Dielectric Material	Dielectric Constant	Dielectric Type
Top Solder Mask	(.GTS)		0.0102mm	Solder Resist	3.50	
Top Layer	(.GTL)	0.0356mm				
			1.5mm	FR-4	4.60	Core
Bottom Layer	(.GBL)	0.0356mm				
Bottom Solder Mask	(.GBS)		0.0102mm	Solder Resist	3.50	

6.2 Bill of Material

Qty	Designator	Description	MPN	Manufacturer	Comment
1	B1	2,4GHz Filter Balun, SMD 1.25x2.0mm	2450BM15A0015E	JOHANSON TECHNOLOGY	2450BM15A0015E
1	Antenna	Antennas 2.45GHz AN-TENNA	2450AT42B100E	JOHANSON TECHNOLOGY	2450AT42B100E
5	C1, C2, C3, C4,C27	Ceramic capacitor, SMD0402, X5R, 6.3V,+/- 10%	04026D105KAT2A	AVX	1uF
16	C5, C16, C17, C18,C19,C20, C21,C22,C23, C24,C25,C26, C28,C29,C30, C31	Ceramic capacitor, SMD 0402, X5R, 6.3V,+/- 10%	04026D225KAT2A	AVX	2.2uF
2	C8,C9	Ceramic capacitor, SMD 0402,50V,C0G (NP0),+/-1 %	04025A100FAT2A	AVX	10pF
2	C6, C7	Ceramic capacitor, SMD 0402, NP0, 50V, +/-5%	C1005C0G1H220J0 50BA	TDK	22pF
5	C10, C11, C13, C14, C32	Ceramic capacitor, SMD 0402, X7R, 16V, +/-10%	0402YC104KAT2A	AVX	100nF
1	C15	Tantalum capacitor,CASE B,6.3V,+/-10%	293D476X96R3B2T E3	VISHAY SPRA-GUE	47uF
1	D2	Dual schottky diode, If:30mA @Vf: 0.5V; Vrrm:30V,SOT-23	BAT54S	DIODES INC.	BAT54S
1	J1	CR2450 coin-cell battery clip, SMD	105	KEYSTONE	BATTERY HOLDER
1	J2	2x5 pin header, 1.27mm	20021121-00010C4 LF	FCI	20021121-00010C4 LF
1	J3	40 pin double sided FPC connector with 0.5mm pitch	1226-40-02-H12	MULTICOMP	1226-40-02-H12
1	L1	FERRITE, BEAD, 0805, 0.28OHM, 0.5A	BLM21AG102SN1D	MURATA	BLM21AG102SN1D

Qty	Designator	Description	MPN	Manufacturer	Comment
4	Q1, Q3, Q4, Q7	MOSFET, N, 0.2A, 60V, SOT-23	2N7002	STMICROELEC-TRONICS	2N7002
1	Q2	MOSFET, P, 50V, SOT-23	BSS84LT1G	ON SEMICON-DUCTOR	BSS84LT1G
1	Q5	MOSFET, P, -20V ,SOT-23	DMG2305UX-13	DIODES INC.	DMG2305UX-13
1	Q6	MOSFET, P,-50V, SOT-23	BSS84W-7-F	DIODES INC.	BSS84W-7-F
2	R1, R2	RESISTOR, 0402, 33K, 1%,63 mW	CRCW040233K0FK ED	VISHAY DRA-LORIC	33k0
2	R3, R6	RESISTOR, 0402,10K,1%, 63mW	CRCW040210K0FK ED	VISHAY DRA-LORIC	10k0
2	R4, R27	RESISTOR, 0402,0R, 63mW, JUMPER	CRCW04020000Z0 ED	VISHAY DRA-LORIC	0R0
1	R7	RESISTOR, 0402, 2K, 1%,63mW	CRCW04022K00FK ED	VISHAY DRA-LORIC	2k0
3	R8, R9, R10	RESISTOR, 0402,100K,1%, 63mW	CRCW0402100KFK ED	VISHAY DRA-LORIC	100k0
1	SH1	EMI Shield Frame 25x30x3mm	LT08AD4303F	Laird Technolo-gies	LT08AD4303F
1	SH2	EMI Shield Cover 25.6x30.6x2mm	LT08AD4303C	Laird Technolo-gies	LT08AD4303C
1	X2	CRYSTAL, 32.768KHZ , 12.5PF, SMD	Q13FC13500004	EPSON	32.768KHZ
1	XC2	CRYSTAL, 16MHZ,8PF,SMD	NX3225SA-16.000 MHZ-STD-CSR-1	NDK	16MHZ
1	U1	8-bit AVR Micro-controller with Low Power 2.4GHz Tran-sceiver for ZigBee and IEEE 802.15.4	ATME-GA2564RFR2- ZU	ATMEL	ATME-GA2564RFR2- ZU
1	C36	6.8nH, +/-5%, SMD 0402	L-07C6N8JV6T	JOHANSON TECHNOLOGY	Antenna tuning
1	C37	8.2nH, +/-5%, SMD 0402	L-07C8N2JV6T	JOHANSON TECHNOLOGY	Antenna tuning
1	C34	-	-	-	Not Mounted

7 References

1. ATmega2564RFR2 datasheet
2. ePaper Display datasheet
3. Johanson Balun
4. Johanson Chip Antenna
5. AVR2067:Crystal characterization for AVR RF
6. FCC Part 15 Subpart C
7. ETSI EN 300 328 V1.7.1
8. AT02594: Smart Reduced Power Consumption Techniques

8 Revision History

Doc Rev.	Date	Comments
42358A	09/2014	Initial document release.

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