GE Healthcare

Wearable Monitoring

Hub and SB Antenna Test Report

Author: Hakala, Timo (GE Healthcare)

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Change history

MWS revision	Author	Description and rationale for change
1	Timo Hakala	Initial revision
2	Timo Hakala	Typo in chapter 4.2.3 line 240 fixed: +6.2 dBi → +6.8 dBi This does not impact the test results as frequency specific max. gain values (from table 11) were used in the test report calculations

Glossary

Acronym	Description
AMS	Ambulatory Monitoring Solution
EIRP	Effective Isotropic Radiated Power
HLA	High Level Assembly
MBAN	Medical Body Area Network
MVP	Mass production Validation Prototype
MWS	MY Workshop
NFC	Near Field Communication
PWA	Printed Wire Board Assembly
SAR	Specific Absorption Rate
SB	Sensor Battery
SN	Serial Number
TRP	Total Radiated Power
WLAN	Wireless Local Area Network

1 Scope

This document presents the antenna performance measurement results of the AMS V1 Hub and Sensor Battery. The antenna parameters are required in the radio standard compliance testing and also used as the design quality evidence in GE's internal Hub and SB RF unit testing.

2 DUTs, calculations and measurement configurations

The DUT antennas coved by this document are:

Sensor Battery (2360-2500 MHz):

- MBAN antenna

Hub:

- MBAN (2360-2500 MHz):
  - Bottom antenna
  - Top antenna
- WLAN 2.4GHz (2400-2483.5 MHz):
  - Top antenna
- WLAN 5GHz (5170-5835 MHz):
  - Bottom antenna
  - Top antenna

The given antenna parameter values are based on following data:

- Conducted TX power measurements:
  - Made by Timo Hakala at the GE lab on 14-18-Oct-2020
  - Measurement results reported in the document [1]
- Radiated TRP and EIRP measurements:
  - Made at Verkotan antenna laboratory on 20-22-Oct-2020
  - Measurement results reported in the document [2]
- Antenna parameter calculations:
  - Calculations combine the conducted and the radiated measurement results so that the antenna parameters (maximum gain and total radiation efficiency) can be defined.
  - Made by Timo Hakala between 20-Oct and 12-Dec-2020
  - Calculation are reported in the document [1]

The official antenna parameters are measured and calculated from a single SB and Hub DUT. More DUTs were spot check measured to make sure the selected DUTs are representative samples. The measurement results of the other DUTs are not presented in this document but the data is included in the documents [1] and [2].

Hub DUT used antenna testing:

- preMVP4 (no RF modifications)
    - After the antenna measurement on (20-22-Oct-2020), the Hub RF design was improved by adding three RF inductors to the lines connecting the MBAN RF to the MBAN antennas. The purpose of the inductors is to improve the RF matching in long antenna lines. The conducted power is measured from the test connectors after these inductors and impact to the antenna performance is seen negligible. Thus, it is seen OK to use this DUT as for the final antenna measurements.
- HLA SN: SRW20030023SP
- PWA SN: X0017480002YMB
- SW:
    - Hub: 1.0.0.1.1.12320-2.1.5c5aca7.1.0.0.1
    - MBAN test mode: 1.0.0.1.1.0-1.1.2f046a9.1.0.0.1
    - TI calibrator scripts: GIT wearable-wireless-tools 4c3f017

Sensor Battery DUT used antenna testing:

- preMVP4 with final MVP RF modifications
    - TX matching and antenna matching components we manually modified to be equivalent with the final mass production (MVP) device
- HLA SN: AXLD041
- PWA SN: X0017480004R41
- SW:
    - wearable-puck-1.0.0.1.1.1-2.1.4d124e6.1.0.0.1
    - mban-test-mode-wearable-puck-swup-1.0.0.1.1.1-2.1.4d124e6.1.0.0.1

Antenna parameters calculated from radiated and conducted measurements:

Maximum antenna gain (dBi):

- Used in radio standard measurements to define radiated TX power (i.e. defined as requirement) based on conducted measurements
- Max gain = max EIRP / conducted TX power
- max EIRP (dBm) is the power the antenna radiates to the direction of its strongest emission (over the spherical surface)
    - The EIRP value used in calculations is the sum of the horizontal and vertical polarization power to certain this direction
    - Radio standards allow using the bigger polarization value, either horizontal or vertical → this can be exploited later, if problems occur in radio standard testing
- Conducted TX power (dBm) is the power measured from 50 Ω RF test connector located in the antenna input

Total antenna efficiency (dB):

- Used to estimate antenna quality in the RF unit testing
- Total efficiency = TRP / conducted TX power

- TRP (dBm) defines the total power radiated by the antenna (integrated over the spherical surface)

The TX power modes used in testing:

- MBAN:
  - Max PA - Maximum MBAN power with external PA (MBAN test mode command --pa_ic 63 --pa_ext 1)
  - Max RFIC- Maximum MBAN power without external PA (MBAN test mode command --pa_ic 63 --pa_ext 0
  - MCAL 0 or 1: TX power according to MCAL calibration vector 0 or 1 (MBAN test mode command --pa_mcal 0 or 1)
- WLAN:
  - Maximum power allowed by the WLAN module HW and SW configuration is always used

Use cases used in antenna chamber:

- Free space:
  - DUT is in free space (i.e connected RF transparent and low loss polystyrene holder)
- Body normal:
  - DUT is connected to an artificial body block (SAR liquid tank used) according to the most common clinical use case (Hub battery side facing on body, SB sensor connector facing on body)
- Body flipped:
  - Like “body normal” use case but the DUT flipped (Hub display facing on body, SB NFC facing on body)

3 Sensor Battery

3.1 MBAN

The Sensor Battery antenna parameters are listed in Table 1 and Table 2.

- Maximum antenna gain:
  - From -4.9 dBi to +3.4 dBi (free space)
  - A separate max antenna gain number is used per radio standard.
- Total antenna efficiency:
  - From -5.7 dB to -11.1 dB (free space)
  - From -9.1 dB to -14.5 dB (on body)

Table 1: Sensor Battery maximum antenna gain

Sensor Battery Maximum antenna gain		US MBAN			ISM			EU MBAN		
		indoor		anywhere						
		low	high	mid	low	mid	high	low	high	unit
	channel	0	11	13	15	31	46	47	52	
	frequency	2362	2390	2395.4	2402	2443	2481.5	2485.5	2498	MHz
Free space	max PA	1.8			2.6	1.7	-2.4		-4.8	dBi
	max RFIC	2.3			2.1	0.5	-2.4		-4.3	
	MCAL 0	2.4	3.4	2.0	1.8	2.2	-1.3	-3.2	-4.9	
	MCAL 1				1.5	2.3	-0.5		-2.8	
	ETSI EN300328 and EN300203	N/A			2.3			-3.2		
	FCC part15 and part95	3.4		2.0	2.6			N/A		

Table 2: Sensor Battery total antenna efficiency

Sensor Battery Total antenna efficiency		US MBAN			ISM			EU MBAN		
		indoor		anywhere						
		low	high	mid	low	mid	high	low	high	unit
	channel	0	11	13	15	31	46	47	52	
	frequency	2362	2390.2	2395.4	2402	2443	2481.5	2485.5	2498	MHz
Free space	max PA	-7.5			-6.0	-7.0	-9.8		-11.1	dB
	max RFIC	-6.6			-6.3	-8.4	-9.9		-10.7	
	MCAL 0	-6.6	-5.7	-6.8	-6.8	-6.8	-8.8	-10.1	-10.8	
	MCAL 1				-7.0	-6.8	-7.8		-9.1	
Body normal	max PA	-11.5			-10.2	-12.0	-13.7		-14.5	
Body flipped	max PA	-10.4			-9.1	-10.3	-12.2		-13.1	

4 Hub

4.1 MBAN

4.1.1 MBAN Bottom Antenna

The Hub MBAN bottom antenna parameters are listed in the Table 3 and Table 4.

- Maximum antenna gain:
  - From +2.2 dBi to +3.0 dBi (free space)
- Total antenna efficiency:
  - From -1.3 dB to -2.4 dB (free space)
  - From -4.5 dB to -6.5 dB (on body)

Table 3: Hub MBAN bottom antenna maximum gain

Hub - MBAN bottom antenna Maximum antenna gain		US MBAN			ISM			EU MBAN		unit
		indoor		anywhere						
		low	high	mid	low	mid	high	low	high	
	channel	0	11	13	15	31	46	47	52	
	frequency	2362	2390.2	2395.4	2402	2443	2481.5	2485.5	2498	MHz
Free space	max PA	2.4			2.7	2.9	3.1		2.2	dBi
	max RFIC	2.1			2.3	2.6	2.6		1.8	
	MCAL 0	2.2	2.5	2.2	2.3	2.7	2.8	2.9	1.9	
	MCAL 1				2.4	2.6	3.0		2.2	
	ETSI EN300328 and EN300203	N/A			3.0			2.9		
	FCC part15 and part95	2.5		2.2	2.9			N/A		

Table 4: Hub MBAN bottom antenna total efficiency

Hub - MBAN bottom antenna Total antenna efficiency		US MBAN			ISM			EU MBAN		unit
		indoor		anywhere						
		low	high	mid	low	mid	high	low	high	
	channel	0	11	13	15	31	46	47	52	
	frequency	2362	2390.2	2395.4	2402	2443	2481.5	2485.5	2498	MHz
Free space	max PA	-1.8			-1.3	-1.5	-1.5		-2.0	dB
	max RFIC	-1.7			-1.6	-1.8	-1.9		-2.4	
	MCAL 0	-1.6	-1.4	-1.6	-1.6	-1.8	-1.7	-1.8	-2.2	
	MCAL 1				-1.6	-1.9	-1.7		-1.9	
Body normal	max PA	-5.5			-5.6	-5.5	-6.0		-6.4	
Body flipped	max PA	-4.5			-4.6	-4.9	-5.2		-5.6	

4.1.2 MBAN Top Antenna

The Hub MBAN bottom antenna parameters are listed in the Table 5 and Table 6.

- Maximum antenna gain:
  - From +4.1 dBi to +5.6 dBi (free space)
- Total antenna efficiency:
  - From -2.3 dB to -1.1 dB (free space)
  - From -6.2 dB to -4.6 dB (on body)

Table 5: Hub MBAN top antenna maximum gain

Hub - MBAN top antenna Maximum antenna gain		US MBAN			ISM			EU MBAN		unit
		indoor		anywhere						
		low	high	mid	low	mid	high	low	high	
	channel	0	11	13	15	31	46	47	52	
	frequency	2362	2390.2	2395.4	2402	2443	2481.5	2485.5	2498	MHz
Free space	max PA	4.8			5.2	5.6	5.2		5.5	dBi
	max RFIC	4.2			4.6	5.1	4.9		5.4	
	MCAL 0	4.1	4.3	4.3	4.4	5.0	5.0	5.2	5.1	
	MCAL 1				4.5	5.0	5.1		5.4	
	ETSI EN300328 and EN300203	N/A			5.1			5.4		
	FCC part15 and part95	4.3		4.3	5.6			N/A		

Table 6: Hub MBAN top antenna total efficiency

Hub - MBAN top antenna Total antenna efficiency		US MBAN			ISM			EU MBAN		unit
		indoor		anywhere						
		low	high	mid	low	mid	high	low	high	
	channel	0	11	13	15	31	46	47	52	
	frequency	2362	2390.2	2395.4	2402	2443	2481.5	2485.5	2498	MHz
Free space	max PA	-1.6			-1.1	-1.1	-1.2		-1.3	dB
	max RFIC	-2.0			-1.6	-1.6	-1.5		-1.4	
	MCAL 0	-2.3	-2.0	-1.8	-1.7	-1.7	-1.2	-1.3	-1.4	
	MCAL 1				-1.6	-1.7	-1.2		-1.2	
Body normal	max PA	-6.2			-5.3	-5.1	-5.3		-5.2	
Body flipped	max PA	-5.6			-5.3	-4.9	-4.8		-4.6	

4.2 WLAN

4.2.1 WLAN 5GHz Bottom Antenna

The WLAN 5GHz bottom antenna parameters are listed in Table 7 and Table 8:

- Maximum antenna gain:
  - From +1.0 dBi to +4.0 dBi (free space)
  - A separate gain value is used per channel
- Total antenna efficiency:
  - From -4.1 dB to -1.5 dB (free space)
  - From -6.2 dB to -3.5 dB (on body)

Table 7: Hub WLAN bottom antenna maximum gain

Hub - WLAN 5 GHz bottom antenna Maximum antenna gain		ETSI								ETSI N/A		unit
		FCC						FCC N/A		FCC		
	channel	36	48	64	100	108	116	128	140	153	165	
	frequency	5180	5240	5320	5500	5540	5580	5640	5700	5765	5825	MHz
Free space	max power	1.2	1.0	2.0	3.4	3.1	2.6	3.2	2.5	4.0	3.6	dBi

Table 8: Hub WLAN bottom antenna total efficiency

Hub - WLAN 5 GHz bottom antenna Total antenna efficiency		ETSI								ETSI N/A		unit
		FCC						FCC N/A		FCC		
	channel	36	48	64	100	108	116	128	140	153	165	
	frequency	5180	5240	5320	5500	5540	5580	5640	5700	5765	5825	MHz
Free space	max power	-4.1	-3.6	-2.9	-1.8	-1.5	-2.0	-1.7	-2.3	-2.2	-2.1	dBi
Body normal	max power	-5.7			-4.3						-4.0	
Body flipped	max power	-6.2			-3.5						-4.0	

4.2.2 WLAN 2.4 GHz Top Antenna

The WLAN 2.4 GHz top antenna parameters are listed in the Table 9 and Table 10:

- Maximum antenna gain:
  - From +4.4 dBi to +6.0 dBi (free space)
  - A separate gain value is used per channel
- Total antenna efficiency:
  - From -2.0 dB to +0.4 dB (free space)
    - Note: the positive total efficiency means that the WLAN module is better RF matched to the antenna than a 50Ω RF power probe
  - From -4.9 dB to -3.0 dB (on body)

Table 9: Hub WLAN 2.4 GHz top antenna maximum gain

Hub - WLAN 2.4 GHz top antenna Maximum antenna gain		ETSI				unit
		FCC			FCC N/A	
	channel	1	6	11	13	
	frequency	2412	2437	2462	2472	MHz
Free space	max power	5.2	4.4	6.0	4.2	dBi

Table 10: Hub WLAN 2.4 GHz top antenna total efficiency

Hub - WLAN 2.4 GHz top antenna Total antenna efficiency		ETSI				unit
		FCC			FCC N/A	
	channel	1	6	11	13	
	frequency	2412	2437	2462	2472	MHz
Free space	max power	0.4	-2.0	0.1	-1.8	dBi
Body normal	max power	-3.2			-4.9	
Body flipped	max power	-3.0			-4.8	

4.2.3 WLAN 5GHz Top Antenna

The WLAN 2.4 GHz top antenna parameters are listed in the Table 11 and Table 12:

- Maximum antenna gain:
  - From +1.3 dBi to +6.8 dBi (free space)
  - A separate gain value is used per channel

- Total antenna efficiency:
  - From -4.4 dB to -0.9 dB (free space)
  - From -6.5 dB to -4.3 dB (on body)

Table 11: Hub WLAN 5 GHz top antenna maximum gain

Hub - WLAN 5 GHz top antenna Maximum antenna gain		ETSI							ETSI N/A			unit
		FCC						FCC N/A	FCC			
	channel	36	48	64	100	108	116	128	140	153	165	
	frequency	5180	5240	5320	5500	5540	5580	5640	5700	5765	5825	MHz
Free space	max power	1.3	2.4	3.7	6.8	6.2	6.0	6.2	5.6	6.0	5.9	dBi

Table 12: Hub WLAN 5 GHz top antenna total antenna efficiency

Hub - WLAN 5 GHz top antenna Total antenna efficiency		ETSI							ETSI N/A		unit
		FCC						FCC N/A	FCC		
	channel	36	48	64	100	108	116	128	140	153	165	
	frequency	5180	5240	5320	5500	5540	5580	5640	5700	5765	5825	MHz
Free space	max power	-4.4	-3.8	-3.0	-0.9	-1.7	-2.2	-1.8	-2.6	-2.3	-2.1	dBi
Body normal	max power	-6.5			-3.0						-4.3	
Body flipped	max power	-6.5			-2.7						-4.3	

5 Summary

The measured and calculated parameters from the all antennas are summarized in XX.

Table 13: Summary of all antenna parameters

use case	DUT	radio	antenna	max gain (dBi)	total efficiency (dB) min	max
free space	SB	MBAN		3.4	-11.1	-5.7
	Hub	MBAN	bottom	3.0	-2.4	-1.3
			top	5.6	-2.3	-1.1
		WLAN 2.4GHz	top	6.0	-2.0	0.4*
		WLAN 5GHz	bottom	4.0	-4.1	-1.5
			top	6.8	-4.4	-0.9
on body	SB	MBAN		N/A	-14.5	-9.1
	Hub	MBAN	bottom	N/A	-6.4	-4.5
			top	N/A	-6.2	-4.6
		WLAN 2.4GHz	top	N/A	-4.9	-3.0
		WLAN 5GHz	bottom	N/A	-6.2	-3.5
			top	N/A	-6.5	-2.7

* positive is due to antenna input (non 50 ohm) vs. power meter (50 ohm) RF matching

6 References

[1] GE Healthcare, "AMS V1 Antenna Parameter Calculations," GE MWS DOC2503559.

[2] Verkotan, "Verkotan_AMS_V1_antenna_test_report_GEHC_ID4348_30112020," GE MWS DOC2503559.