1. Abstract

Scope of this analysis is to calculate the minimum distance from body sufficient to claim SAR test exclusion for a Model J9A Type VZ9QH Autec remote station.
On the unit a COTS Wi-Fi module, that receives a video surveillance feedback, is operating concurrently along with an Autec proprietary 915MHz radio transmitter, used for remote control functions.

Firstly we present an analysis to identify the maximum theoretical duty cycle of a Wi-Fi system implementing Wi-fi and TCP, considering the peculiar communication parameter imposed by the wi-fi router used for sending data to the Wi-fi module inside Autec Remote Station.
The analysis is done considering only Wi-fi using the 2.4GHz band, since the system configuration is imposed (and it is not accessible to the user) to IEEE 802.11.b/g/n (which only provides this band).
This is done without considering any characteristics of the data stream used by the application; otherwise, the contribution of each layer of the stack is analyzed singularly and then combined in a final parameter.
At this point, the characteristics and structure of the complete Autec system, with its application specific functions, are taken into account.

In particular, it is shown that the Wi-Fi module inside Autec Remote Station is a "data sink" in the complete system and its transmission duty cycle at the physical layer is expected to be well below the maximum values estimated above for a generic node of a generic link.

A resume of the FCC constraints to assume SAR test exclusion analysis is also given.
Separate calculations of minimum distance from antenna to body parts are then shown for both the Wi-Fi module and the Autec 915MHz radio transmitter.
Finally the two contributions are combined and the SAR exclusion limit for the complete Autec Remote Station is shown, considering also where would be located the point giving the worst combination of exposure from the two sources.
With the following analysis it was found that the system is compliant to obtain the SAR text exclusion.

	Minimum distance found to obtain the SAR test exclusion	Physical minimum distance in Autec Remote Station	PASS or FAILED
Standalone SAR test exclusion for Wi-fi radio module, limb	2.7 mm	4,30 mm	PASS
Standalone SAR test exclusion for Wi-fi radio module, body	6,8 mm	154,92 mm	PASS
Standalone SAR test exclusion for Autec radio at 915MHz, limb	3,26 mm	12,13 mm	PASS
Standalone SAR test exclusion for Autec radio at 915MHz, body	8,16 mm	114,63 mm	PASS

[W/Kg]	SAR test exclusion value	Maximum value	PASS or FAILED
Simultaneous SAR test exclusion, limb	0.36872	0.4	PASS
Simultaneous SAR test exclusion, body	0.1214	0.4	PASS

2. Duty cycle constraints due to the Wi-fi Standards

The following considerations are made to understand the IEEE802.11 (Wi-Fi) duty cycle.
Firstly it is introduced the general characteristics of all Wi-Fi system and then some additional considerations are made for a specific systema based on an access point.

2.1 General considerations

IEEE802.11 (Wi-fi) is a standard protocol for the transmission of information in wireless system. It is figured out at the physical and data-link layer of ISO/OSI model.
It provides an Half-duplex transmission, CSMA/CA, use of feedback messages, possibility of using different rate and modulations and other characteristics.
Due to these features, it is not realistic to consider a continuous transmission for a single node of a wi-fi system.
In particular the half-duplex property is a strong constrain for the duty-cycle, since at every instant any node can alternatively transmit or receive data. An acknowledge message is always needed to consider a message as received; until the reception of this feedback message or until the time-out for its reception, there will be no further transmission.
Moreover, since the air medium is shared, also the collision avoidance mechanism poses important constraints on the duty cycle at the physical interface. In particular this technique provides transmission of data only if the radio channel is sensed idle for a well defined period of time (DIFS+SIFS). The mechanism to avoid collision also uses an additional random time window which will further delay the physical transmission. This is thrown according to an uniformly distributed random variable related to the number of packet losses and/or collisions.
Clearly it is quite difficult to analyze the effect of the other devices in the network and to predict the probability of collisions from other networks in a real environment. But it is also clear that the maximum continuous transmit duty cycle of any node will be reached when no collision and no packet loss happen.

2.2 Wi-fi implementation

It is possible to be perfectly compliant with the standards using many different real-time rate adaptation algorithms.
The system used by Autec is a specific implementation of a Wi-fi network, having its own rate
adaptation algorithm, for which a description is available. It's so possible to predict which rates will be used in stable condition, i.e. not only transiently and briefly during the assessment of the algorithm, in the absence of collisions.
This algorithm forces rate reduction after 3 consecutive packet losses, as well as it attempts to increase the rate after successful transmission of 3 consecutive frames.
Moreover in case of 3 consecutive losses at the lowest rate, it provides total stop of transmission for a time interval defined by the parameter "T_disconnect".
It is clear that in stable absence of losses and/or collisions, this type of algorithm will keep on with the maximum data rate (54Mbps), corresponding to a maximum duty cycle 78%.
Should any repetitive loss or collision occur, then the algorithm would be driven down to the minimum data rate, causing the duty cycle to rise to 97%.
But, if we assume this is a stable condition, very soon it will happen that three consecutive losses happen, thus causing total stop of transmission for T_disconnect second.
This will also reduce the maximum duty cycle to some intermediate value between 78 and 97%.
What happens precisely in the transitions between these two extreme situations, or with frequent (but not continuous) collision occurrences, can be left out.
In fact, this would only cause transitional and temporary operation at intermediate data rates/intermediate duty cycles. It will so have negligible impact on a time-integrated calculation like SAR.
Moreover, in those situations the system would have also to execute the standard requirements of waiting also for a random interval before re-transmitting, which would force the effective duty cycle significantly below the max value calculated under ideal conditions.

2.3   Effect of the TCP protocol

The aforementioned considerations are valid for any generic Wi-Fi node.
But when we take into account also the specific data exchange protocol used in the network, it will be clear that not all nodes have the same privileges: some will show longer transmission intervals, other will be limited to very short responses.
In the analyzed system the TCP protocol is used. TCP is a communication protocol at the transport ISO/OSI level. It can be transferred over wi-fi, which lays at a lower level.

TCP		Transport
IP		Network
wi-fi		Physical

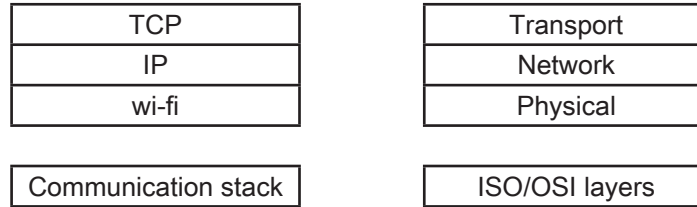| Communication stack | | ISO/OSI layers |

Figure 2: communication stack of part implementing Wi-fi in ISO/OSI model

Since the TCP protocol provides a point to point communication then it is possible to clearly identify a SOURCE device, which sends the main stream of data, and a SINK device, which transmits only acknowledgment packets after received data.
The impact of TCP on the transmission duty cycle depends on the way it uses acknowledgments: TCP specification allows to send an ACK packet every 65325 received bytes of information.
As intuitively understood this will have almost no effect on the SOURCE device.
Instead, it will limit to 50% the theoretical transmit duty cycle of the SINK device, reaching this value when it is responding to the reception of empty data packets from the source.
The latter is clearly an unrealistic situation, or at least not useful.
Moreover, it must be considered that most implementations of the TCP protocol will send ACK back from the sink to the source every two or three data packets received, so the 50% value above mentioned will be in practice reduced to a lower value (25-33 %).

2.4   Source and sink devices in the Autec system using TCP on Wi-fi at 54Mbps

The combination of the two analyses must consider that the two stacks (WI-FI and TCP) are independent. TCP will prepare its packets of N bytes to be sent.
The transmission of the TCP packets over Wi-Fi will had some overhead. As shown below, it will require a time window $T_{connectionWnd_{NbytePacket}}$ longer than the time $T_{NbytePacket}$ strictly needed to transmit N bytes at the same signaling rate:

$$T_{connectionWnd_{NbytePacket}} = DIFS + T_{NbytePacket} + SIFS + T_{wifi_{ack}}$$

Where $T_{wifi_{ack}}$ accounts for the (very short) length of the ACK responses used by wi-fi to confirm reception of every packet, which give a small contribution to the total transmission time.

TCP will also expect to receive its standard acknowledgement messages, having a length of 20 bytes (TCP header only), after $N_{packetPerAck}$ packets have been received.

This TCP ack will also trigger a Wi-fi Ack of length $T_{wifi_{ack}}$, as happens for data packets.

The complete exchange will require a time window lasting $T_{connectionWnd}$, inside which both source and sink will be effectively transmitting RF power for a time $T_{effectiveTx}$, so that

$$duty_{cycle_{TCP}} = \frac{T_{effectiveTx}}{T_{connectionWnd}}$$

A) SOURCE device

$$duty_{cycle_{TCP-SOURCE}} = \frac{T_{effectiveTxSource}}{T_{connectionWnd}} =$$

$$\frac{N_{packetPerAck} * T_{NbytePacket} + T_{wifi_{ack}}}{N_{packetPerAck} * T_{connectionWnd_{NbytePacket}} + T_{connectionWnd_{20bytePacket}}}$$

The maximum duty cycle is achieved when the source device continuously transmit packet of maximum size (1500 bytes, $Nbyte = 1500$) without considering loss and collision.
The worst case for TCP feedback is when it occurs "the least possible", that is every

$$\left\lceil \frac{65325}{1480} \right\rceil = 45 \, packets \, \left(N_{packetPerAck} = 45 \right)$$

With this number the maximum theoretical duty cycle results:

$$duty_{cycle_{TCP-SOURCE}} = \frac{T_{effectiveTx}}{T_{connectionWnd}} = \frac{45 * 254 + 34}{45 * 326 + 105.1494} = \mathbf{78}\%$$

This is a rather extreme situation considered only for determining the worst case.

B) SINK device

The SINK device send only acknowledgement packets during the connection window.
We expect $N_{packetPerAck}$ wi-fi acks and one TCP ack, that is a Wi-fi packet having N= 20 bytes.
The time dedicated for that transmission is composed by $N_{packetPerAck}$ time window for the transmission of source packet and one time window for the transmission of the feedback message.

$$duty_{cycle_{TCP-SINK}} = \frac{T_{effectiveTxSink}}{T_{connectionWnd}} =$$

@2):

$$\frac{N_{packetPerAck} * T_{wifi_{ack}} + T_{20bytePacket}}{N_{packetPerAck} * T_{connectionWnd_{NbytePacket}} + T_{connectionWnd_{20bytePacket}}}$$

Since the transmission of a wi-fi ack is longer than the transmission of the minimum TCP packet (20bytes), the highest theoretical $T_{effectiveTxSink}$ is obtained when the number of packet before a TCP ack is at its maximum, corresponding to ($N_{packetPerAck}$ =45).

If we combine this with the shortest duration of $T_{connectionWnd}$ at the denominator, occurring when all the packets received from the source are empty (i.e. they contain only the 20bytes of the TCP header), we can estimate the max duty cycle possible for the sink:

$$duty_{cycle_{TCP-SINK}} = \frac{T_{effectiveTx}}{T_{connectionWnd}} = \frac{45 * 34 + 33.1494}{45 * 105.1494 + 105.1494} = \mathbf{32}\%$$

Even in this case we are studying the worst possible scenario.
But continuous transmission of empty packets by the source is not a realistic behavior for a useable application.
Please refer again to in Appendix D which shows more realistic estimates obtainable at more likely settings of the parameters.

3.   Autec system

It is now possible to take the whole Autec system (Figure 1) and its specific usage of Wi-Fi transmission, into consideration.

3.1   Description

The system is composed by:
  - Autec Remote Station, which includes both an Autec 915MHz FHSS radio for transmitting comman-

ds to a remotely controlled machine and a wi-fi module for receiving a video stream from a remote wifi access point
- Autec Base Station, which receives the 915MHz signal and is remotely positioned on the machine, far from the operator, so it's out of interest in our SAR analysis
- A Wi-Fi access point which is connected via wi-fi with a single client, namely the Wi-fi module included in the Autec Remote Station. Like the Base Station, the access point is positioned on the machine; so, it will not be considered for SAR analysis if not for its indirect effect on the duty cycle of the Wi-fi module placed on Autec Remote Station. The access point is configured to use IEEE 802.11b/g/n protocol, considering only Wi-fi using the 2.4GHz band. This system configuration is imposed and it is not accessible to the user.

The functioning is then based on two bidirectional data flows:
- The main Autec radio link is managed by Autec Remote Station to the Base Station and its feedback path in the opposite direction.
- The Wi-fi network link is managed by the access point, using TCP data packets to send the video-stream to the wi-fi module inside the Autec Remote Station part; the wi-fi module is then the sink of TCP packets and so it responds in the opposite direction with acknowledgment feedbacks only (Wi-fi and TCP).
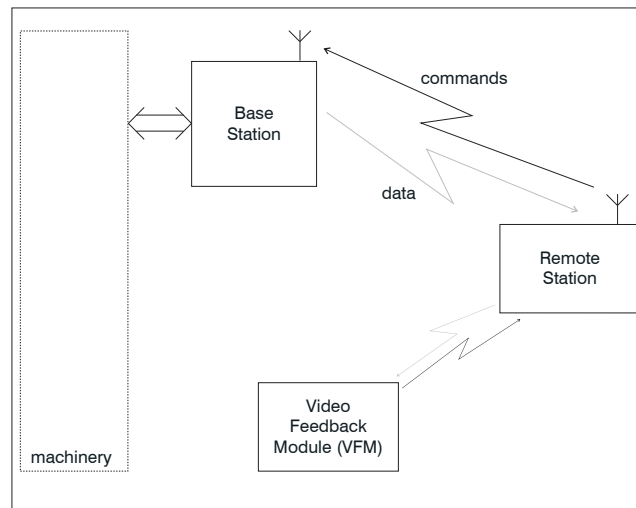

Figure 1: Autec system

As anticipated, we are interested to SAR evaluation for the Autec Remote Station only, because in it's normal usage it will be near to the operator's body for al long time, while other devices of the system that emit radio waves will be located at a distance from the operator.

Parameters of interest are:
- maximum frequency of emissions,
- RF power,
- duty cyle.

For the 915 MHz transmission they are fixed and well known; measurements from Dekra, see report R20060101, show f_{max} = 927.80 MHz, RF Power = 38.19 mW measured at the connector, duty cycle = 42% . As a worst case, we'll consider also a 2 dB tune up tolerance, so we'll use a max power of 60.5 mW in the calculations.
For the wi-fi module, max frequency and power are dictated by radio European standards, so we'll consider the nominal values 2483.5MHz and 100mW. This is the maximum allowed power for wi-fi in most countries. Actually, the module is expected to emit less power than this, as confirmed by the values reported in its FCC declaration (Grant XF6-RS9113SB DTS) and as declared in the module's data sheet (17dBm). Anyway, in our calculations we'd prefer to use this value as worst case, so as to obtain a more conservative estimation for SAR test exclusion.

If we consider only the arguments discussed in the previous sections for the SINK device, we'd be pushed to use the "worst case" estimation of 32%

But, actually, we can demonstrate that in the specific application of the wi-fi and TCP protocols in Autec system a further (and lower) limit can be set to the maximum transmission duty cycle expected from the TCP SINK device (implemented on the wi-fi module inside the Autec Remote Station).

First of all we must take into account that the access point (TCP SOURCE device) will collect from the cameras only data packets of the maximum dimensions (1500 bytes).

Wi-fi parameters will be factory set to avoid aggregation or disaggregation of raw data: this means TCP packets sent on wi-fi will keep their original dimensions.

Moreover we need to consider that the TCP stack is configured by the SINK device to send acknowledgment back every 2 TCP packets received.

Using this further two constrains, due to the specific application and implementation, the theoretical upper bound of the duty cycle obtained falls to about 13%.

A further reduction can be expected also because the data stream coming from the cameras will be less than 3 Mbps, which is only a small fraction of the throughput achievable with a continuous transmission at 54 Mbps rate.

For this reason the SOURCE device will not send continuously its packets, and in turn the SINK device will reduce accordingly the occurrence of ACK packets.

A close form calculation of this effect would be quite difficult, but it's reasonable to estimate that it will be close to reduce the actual SINK duty cycle to 3/54 of the theoretical value, meaning an effective value around 1%.

This has been confirmed by experimental measurements, as shown in the next section.

3.2 Experimental measurement of transmission duty cycle of the wi-fi module inside the Autec Remote Station

A complete system transmitting a typical video stream was set up and the transmission power envelope of the Autec Wi-fi sink device was sniffed with a broad band power meter and sampled with an oscilloscope
A set of ten measurements (10s and 10Msamples each) was recorded.

The duty cycle was then calculated as the ratio between number of samples "above trigger threshold" and total samples. Sampling time was chosen so as to be 10 times shorter than the minimum duration of a transmission, so as to avoid any aliasing and to have a predictable relation between number of samples in a transmission and the estimated duration of the transmission itself. The results show that the values fall in the range [0.62-1.30] % in all measurements, while the mean value of all measurements was 0.88%, which confirms the value of 1% roughly estimated in the previous section.

Following an example showing the results obtained.
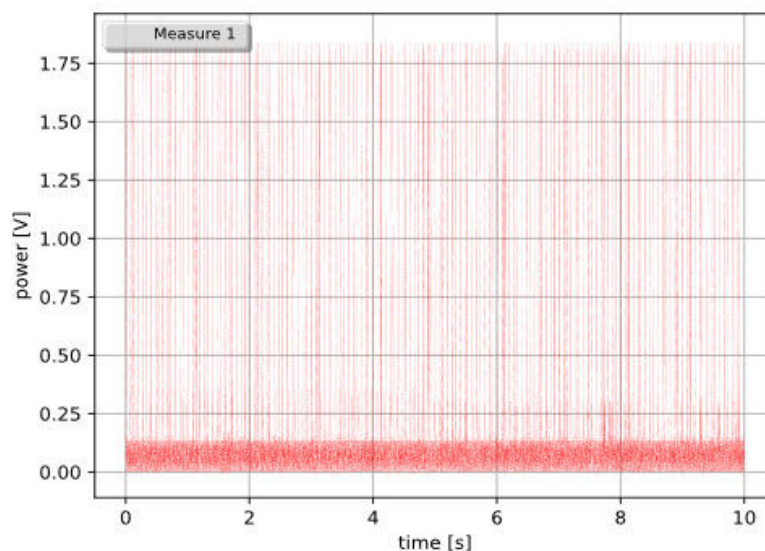
In this data set the RF power is measured higher than trigger threshold for a total of 842362 samples over 10.000.000, that is 0.0842362 s over 10s, so

$$dutycycle = \frac{transmissionTime}{totalMeasurementTime} = \frac{0.0842362}{10.0} * 100 = 0.84\,\%$$

4. SAR exclusion analysis

In this section it will be verified if the Autec Remote Station described in section 3 satisfies the SAR Test Exclusion Threshold condition.

Please refer to FCC KDB document 447498 "RF EXPOSURE PROCEDURES AND EQUIPMENT AU-THORIZATION POLICIES FOR MOBILE AND PORTABLE DEVICES", section "General SAR test exclusion guidance (4.3)", subsection "Standalone SAR test exclusion considerations" (4.3.1, page 12).

There we read:

Given a system emitting radio signal, "standalone 1-g head or body and 10-g limb SAR evaluation for general population exposure conditions, by measurement or numerical simulation, is not required when the corresponding SAR Test Exclusion Threshold condition(s), listed below, is (are) satisfied."

$$@3) \quad \frac{P_{max}}{d_{min}} * \sqrt{F_{(GHz)}} * duty_{cycle_{max}} < 7.5 \;\; with \;\; d_{min} \leq 50mm \quad 10 - \mathrm{g}\ \text{extremity SAR (limb)}$$

$$< 3 \;\; with \;\; d_{min} \leq 50mm \quad 1 - \mathrm{g}\ \text{extremity SAR (body)}$$

While in same document, subsection "Simultaneous transmission SAR test exclusion considerations", (4.3.2, page 13) we can find:

"Simultaneous transmission SAR test exclusion is determined for each operating configuration and exposure condition according to the reported standalone SAR of each applicable simultaneously transmitting antenna. When the sum of 1-g or 10-g SAR of all simultaneously transmitting antennas in an operating mode and exposure condition combination is within the SAR limit, SAR test exclusion applies to that simultaneous transmission configuration."

"When an antenna qualifies for the standalone SAR test exclusion of 4.3.1 and also transmits simultaneously with other antennas, the standalone SAR value must be estimated according to the following to determine the simultaneous transmission SAR test exclusion criteria:"

$$@4) \;\; SAR_{standalone,estimated} = \frac{P_{max}}{d_{min}} * \frac{\sqrt{F_{(GHz)}}}{x} * duty_{cycle_{max}} \qquad with \qquad d_{min} \leq 50mm$$

Using x = 7.5 for body and x = 18.75 for limb

For claiming simultaneous SAR test exclusion, the sum of the two antenna's $SAR_{standalone,estimated}$ values shall be less than 0.4 [W/kg].

Specifically focusing on the Autec Remote Station, the above requirements imply to first discuss Standalone SAR test exclusion for both the Wi-fi radio module with its antenna and for the Autec 915MHz radio with its antenna.
Then simultaneous transmission from both antennas must be considered and the distance limits for exclusion of SAR testing can be calculated on the complete Autec Remote Station.

4.1 Standalone SAR exclusion calculation for the Wi-fi radio module

As pointed out, maximum frequency used by any wi-fi radio is 2.483 GHz, while maximum power will not exceed 100mW, which is a precautionary value, but which will be not ever reached as can be seen in the module FCC declaration.

For what regards duty cycle, we'll consider two extreme values: 13%, as calculated before for a generic Data Sink receiving packets of 1500 bytes and responding with an ACK every 2 packets, and 1.3%, that is the max value experimentally measured.
The highest value will allow us to obtain a somewhat application independent evaluation, valid also if the video stream would saturate the throughput of the Wi-fi link
The lowest will give a more realistic view of the situation in practical scenarios.
By re arranging the formulas in @3, we obtain the minimum distance from Wi-fi antenna that justifies SAR test exclusion

<div align="center">for the worst case of Duty Cycle = 13%</div>

$$d_{min,limb} > \frac{P_{max}}{7.5} * \sqrt{F_{(GHz)}} * duty_{cycle_{max}} = \frac{100}{7.5} * \sqrt{2.4835} * 0.13 = 2.7 \; mm \text{ for limb}$$

$$d_{min,body} > \frac{P_{max}}{3} * \sqrt{F_{(GHz)}} * duty_{cycle_{max}} = \frac{100}{3} * \sqrt{2.4835} * 0.13 = 6.8 \; mm \text{ for body}$$

<div align="center">for the realistic case of Duty Cycle = 1.3%</div>

$$d_{min,limb} > \frac{P_{max}}{7.5} * \sqrt{F_{(GHz)}} * duty_{cycle_{max}} = \frac{100}{7.5} * \sqrt{2.4835} * 0.013 = 0.3 \; mm \text{ for limb}$$

$$d_{min,body} > \frac{P_{max}}{3} * \sqrt{F_{(GHz)}} * duty_{cycle_{max}} = \frac{100}{3} * \sqrt{2.4835} * 0.013 = 0.7 \; mm \text{ for body}$$

The wi-fi antenna is located inside the plastic case of the Autec Remote Station at least 154,92 mm (≈ 155mm) from the case face leaning the operator's body, as in the following image:
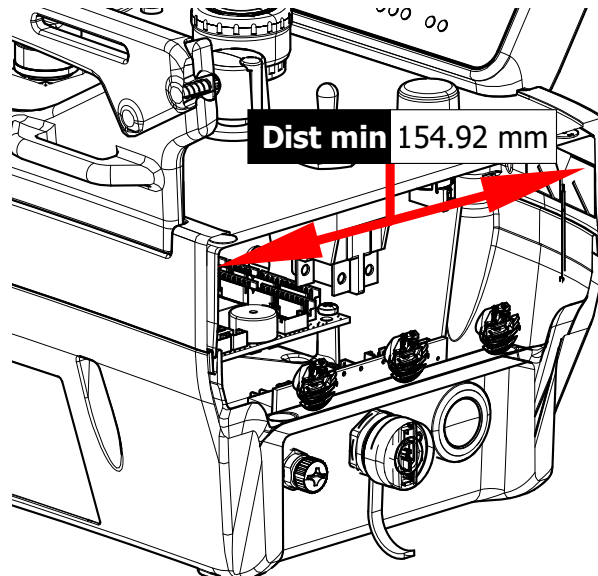
The wi-fi antenna is located inside the plastic case of the Autec Remote Station at least 4,30 mm from the case face leaning the operator's limb, as in the following image:
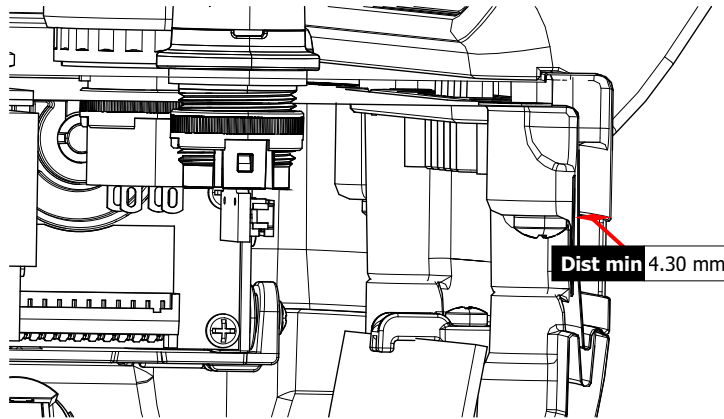
Conclusion:
- with correct usage of the unit, the minimum distances will be always respected, even in the worst case of 13% duty cycle;
- if otherwise we consider the experimentally measured value of duty cycle, minimum distances will be still respected even with improper use by the operator.

## 4.2 Standalone SAR exclusion analysis for Autec radio at 915MHz

We'll consider the values measured by Dekra and documented test report R24159101, that is:
maximum frequency of 927.80 MHz, 38.19 mW (measured at the connector), considering a tune up of 2 dB, it results a maximum transmission power of 60.5 mW and the nominal duty cycle is of 0.42 according to Autec proprietary FHSS protocol specification.
With these parameters:

$$d_{min,limb} > \frac{P_{max}}{7.5} * \sqrt{F_{(GHz)}} * duty_{cycle_{max}} = \frac{60.5}{7.5} * \sqrt{0.928} * 0.42 = 3.26 \ mm \text{ for limb}$$

$$d_{min,body} > \frac{P_{max}}{3} * \sqrt{F_{(GHz)}} * duty_{cycle_{max}} = \frac{60.5}{3} * \sqrt{0.928} * 0.42 = 8.16 \ mm \text{ for body}$$

The 915MHz antenna is located inside the plastic case of the Autec Remote Station at least 114,63 mm (≈ 115mm) from the case face leaning the operator's body, as in the following image:
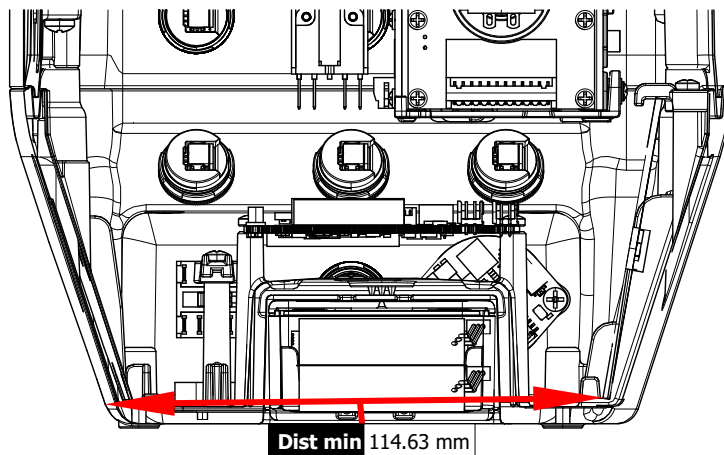
The 915MHz antenna is located inside the plastic case of the Autec Remote Station at least 12,13 mm from the case face leaning the operator's limb, as in the following image:

Dist min 12.13 mm
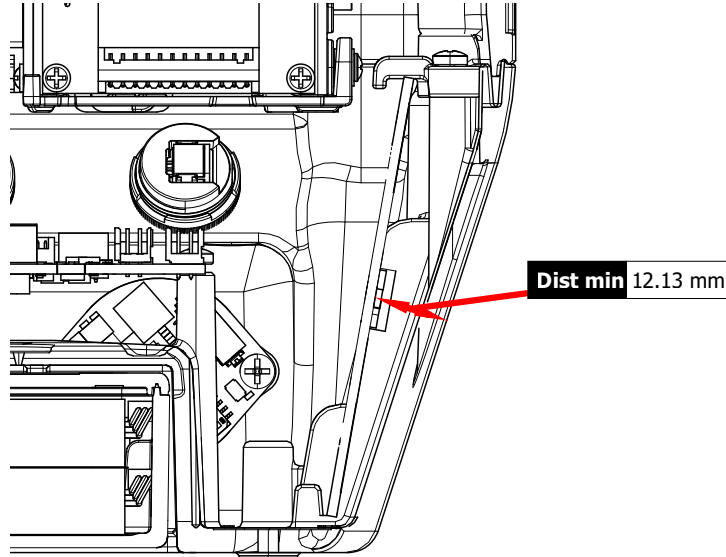
4.3 SAR test exclusion for simultaneous transmission

To obtain the simultaneous transmission SAR test exclusion for limb, it must be verified that:

$$SAR_{simultaneous,estimated\ limb} = SAR_{standalone,estimated\ Autec\ radio_{limb}} + SAR_{standalone,estimated\ Wi-Fi_{limb}} < 0.4$$

where $SAR_{standalone,estimated\ Autec\ radio_{limb}}$ and $SAR_{standalone,estimated\ Wi-Fi_{limb}}$ are calculated using @4) and x=18.75

Since the limb is composed by a vast tissue, it can not be summarized with a single point.
For this reason it is considered the case where the limb simultaneously touch the 2 maximum emission point for the two antennas. Considering the physical constraints of the system (see image below of the correct usse of the remote station as reported in the instruction manual) it results that for the wi-fi antenna d_{min}=4,30 mm while for the Autec radio d_{min}=12,13 mm

$$SAR_{standalone,estimated\ Wi-Fi_{limb}} = \frac{P_{max}}{d_{min}} * \frac{\sqrt{F_{(GHz)}}}{x_{limb}} * duty_{cycle} = \frac{100}{4.30} * \frac{\sqrt{2.483}}{18.75} * 0.13359 = 0.26109$$

$$SAR_{standalone,estimated\ Autec\ radio_{limb}} = \frac{P_{max}}{d_{min}} * \frac{\sqrt{F_{(GHz)}}}{x_{limb}} * duty_{cycle} = \frac{60.5}{12.13} * \frac{\sqrt{0.928}}{18.75} * 0.42 = 0.10763$$

And so it results:

$$SAR_{simultaneous,estimated\ limb} = SAR_{standalone,estimated\ Autec\ radio_{limb}} + SAR_{standalone,estimated\ Wi-Fi_{limb}}$$

$$= 0.26109 + 0.10763 = 0.36872 < 0.4$$

And the simultaneous transmission test exclusion is achieved.
As seen in the previous paragraphs, the operator's body will normally stay at least 154,92mm far from wi-fi antenna and 114,63mm far from Autec radio 915MHz antenna, so the estimated simultaneous SAR for body can be expected to be negligible
Anyway, just for checking, here we give the calculation's results considering a distance of 50 mm, which ensures a smaller value also for bigger distances.

$$SAR_{simultaneous,estimated\ body} = SAR_{standalone,estimated\ Autec\ radio_{body}} + SAR_{standalone,estimated\ Wi-Fi_{body}} < 0.4$$

where $SAR_{standalone,estimated\ Autec\ radio_{body}}$ and $SAR_{standalone,estimated\ Wi-Fi_{body}}$ are calculated using @5) and x=7.5

And specifically with d_{min}=100 mm for both the antennas (due to the radio remote controller constraints), it results:

$$SAR_{standalone,estimated\ Wi-Fi_{body}} = \frac{P_{max}}{d_{min}} * \frac{\sqrt{F_{(GHz)}}}{x_{body}} * duty_{cycle} = \frac{100}{50} * \frac{\sqrt{2.483}}{7.5} * 0.13359 = 0.0561$$

$$SAR_{standalone,estimated\ Autec\ radio_{body}} = \frac{P_{max}}{d_{min}} * \frac{\sqrt{F_{(GHz)}}}{x_{body}} * duty_{cycle} = \frac{60.5}{50} * \frac{\sqrt{0.928}}{7.5} * 0.42 = 0.0653$$

$$V_{exclusionSARbody} = V_{exclusionSARbody_{AutecRadio}} + V_{exclusionSAR\ body_{Wi-fi}} =$$

$$= 0.0561 + 0.0653 = 0.1214 < 0.4$$

5.   Conclusion

From the above analysis it results that the Autec Radio Remote controller is compliant to claim the SAR test exclusion for limb and body , both for standalone or simultaneous emission of the two radios, given the minimum distances warranted by its physical construction and the constraints to its wi-fi emission due to the specific application.

Correct wearing of the unit will anyway ensure that body SAR limits will never be exceeded, even without taking any application-specific constraint into consideration.