Radio Environment within Factories

~~It is true that w~~Wireless commutations are not always difficult everywhere in factories. However, we have to consider that some applications require high-reliable, low-latency and low-jitter data transmission compared with other application in other places like offices and homes in general. Furthermore, the measurement results show~~have revealed~~ that some factories are facing difficulties due to~~coming from~~ (a) severe environment for wireless communications, and/or (b) existence of uncoordinated and independent systems in the same space.

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(a) The Severe Environment for Wireless Communications

There are two ~~source~~sources of impairment to radio signal within the factory environment that cause unpredictable variations to channel capacity, namely:

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1. Fluctuation of signal strength

2. ~~Noises~~Electromagnetic interference

~~As follow~~Followings~~s~~ are examples of such impairments observed within the factory environment.

Example of Fluctuation of signal Strength:

The layout of the environment for which measurements are made is shown in the Figure 1~~Figure~~ Master and slave transceivers were located ~~in LOS condition~~ and there was no blockage by a vehicle, human body and any other objects in the line between the master and slave transceivers during measurement.

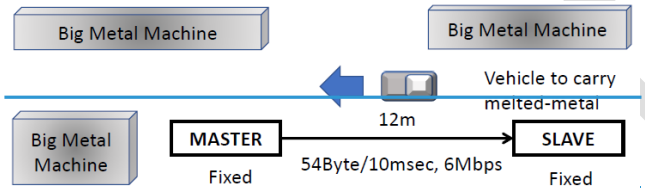

Figure 1~~3~~ Layout in factory for which measurement of RSSI is recorded

The observed RSSI measurement ~~in LOS condition~~for this layout is shown in Figure 2~~Figure 4~~ 54Byte was sent at each sequential(Seq) number with 10-msec separation at a data rate of 6Mbps.

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Commented [m1]: 135:E replace Noises by Electromagnetic interference (accepted)

Commented [m2]: 152:E replace "as follows are example" replaced by "Followings are examples" (Proposed) accept

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Commented [m3]: 145:E delete "in LOS condition" (accepted) "LOS" appears no longer in the section.

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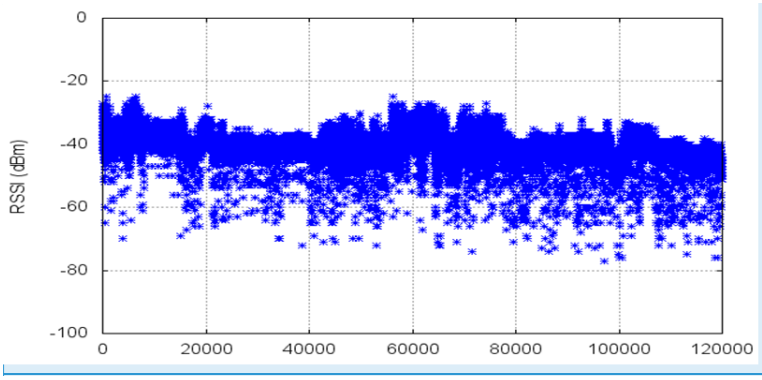
Commented [m5]: delete "in LOS condition (same as 145E) and add "for this layout"

Commented [m6]: 145:E adding words to explain Seq. number (Proposed)



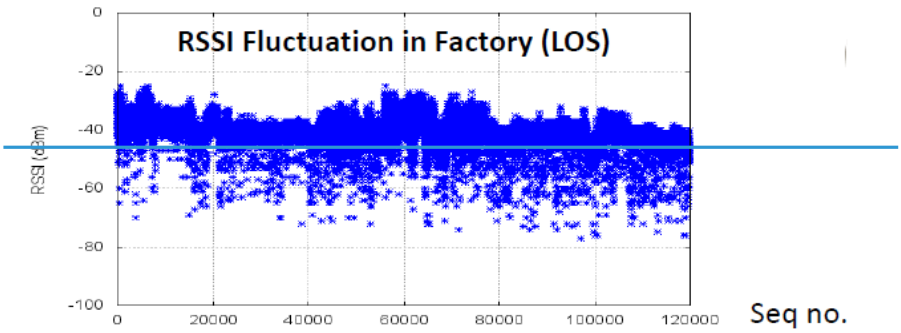


Figure 24 RSSI Fluctuation in Factory ~~(LOS)~~

This fluctuation in RSSI may be~~is~~ due to motions of materials, parts, products and carriers in closed space~~,~~ with multi-path reflections as indicated in the NIST report on "Guide to Industrial Wireless Systems Deployments."

Example of Noises:

While carrying radio measurement within the factory environment considerable~~strong~~ noise were observed within the ~~1.9 GHz band and the~~ 920MHz~~2.4 GHz~~ band. Thi~~sese~~ i~~sare~~ shown in confirmed to be Automated Guided Vehicles (AGVs) with heavy load when it stopped~~at stop time~~.

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Commented [m8]: delete "in LOS condition (same as 145E)

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Commented [m10]: 134:T, 146:T [Nader] While you are updating the radio environment section, please make use of the NIST report (Roger introduced in Nunica) on guidance of use of wireless in industry as a reference to distortion in the radio signal such as fading.

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146:T delete
(Proposed) add this report in the citation: "Guide to Industrial Wireless Systems Deployments", NIST Advanced Manufacturing Series 300-4, https://nvlpubs.nist.gov/nistpubs/ams/NIST.AMS.300-4.pdf

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The measurement data will be presented at the The 21st International Symposium on Wireless Personal Multimedia Communications (WPMC 2018). Citation will be available by the end of Nov. 2018.

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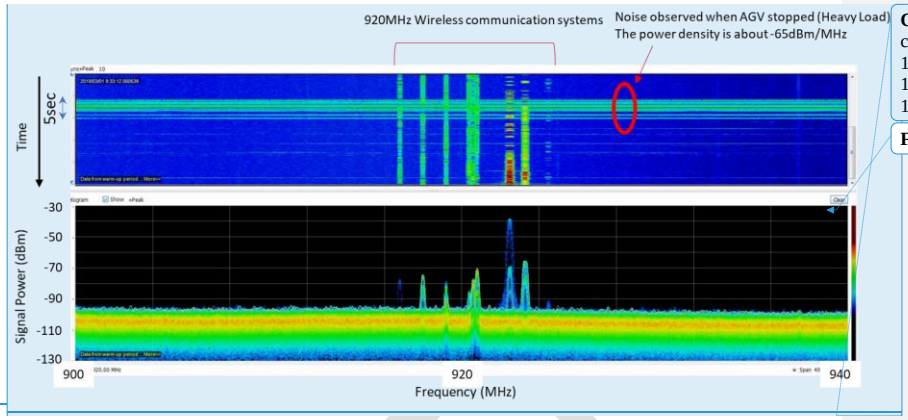

~~(a) 1.9 GHz band~~

Figure 3~~5~~ Measured noise spectral density within 920MHz band~~Measured noise spectral~~

The observed noise power was -65dBm/MHz which were above the receiving sensitivity for the 920MHz wireless systems. In the under 1 GHz band, the noise appears to cause problems for the communication with sensing systems using 920MHz band wireless communications~~In the 1.9 GHz band, the noise appears to cause problems for the communication with particular machines as well as problem for using the 1.9GHz band for internal telephone system~~.

(b) Uncoordinated and Independent Systems

This issue within the factory environment is attributed to the progressive nature which leads to stepped approach of addition and installation of machines and equipment in the factory and due to coexistence of heterogeneous and legacy devices/systems used within the factory.

(Withdraw Figure 6 and associated text)

~~An example of using wireless technology in the factory is shown in Figure 6.~~

F~~The f~~igure 7 shows ~~the current~~ wireless signals~~situation~~ observed in the existing~~at~~ factory site co-existence~~ without any interference~~. The legacy system occupies one Wi-Fi channel even its However, t~~However, t~~here are only three Wi-Fi channels that they can use without~~any~~ unsilenced~~his~~ ~~frequency~~ band. ~~As figure 7 shows, the legacy system occupies one channel.~~ communication protocols~~. Because of that~~, an independent channel~~s~~ should be assigned to each factory operation. ~~among systems using different wireless communication protocols in same radio~~ protocols to accommodate in the same frequency band and in the same site..~~overlapping of signal~~

Commented [m13]: (Proposed) Replace figures to resolve all comments.
155:T revise to more comprehensive figure
156:T adding units in the figure 5
157:T Delete 1.9GHz measurement results

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Commented [m14]: 154:T adding noise power in the text

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(Proposed) adding explanation why the source of the noise is attributed to some kinds of manufacturing machines that are causing interference for wireless communications."

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168T: delete
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Figure 6 shows video monitor application as an example of using wireless technology
This example illustrates an application in which the data flow across the wired network and bridged across to the wireless domain. In this application there are QoS requirements and latency constraints for both the video signal and the control signal. unacceptable delay may occur due to disturbance and/or degradation in the radio signal.

Commented [i17R16]: Issues of this section should cause from co-existence of multiple "uncoordinated and independent systems" in factory site. However this example shows monolithic system in factory site. Because of that, this system is not fit as example of this section. Because of that, this example is deleted from here.

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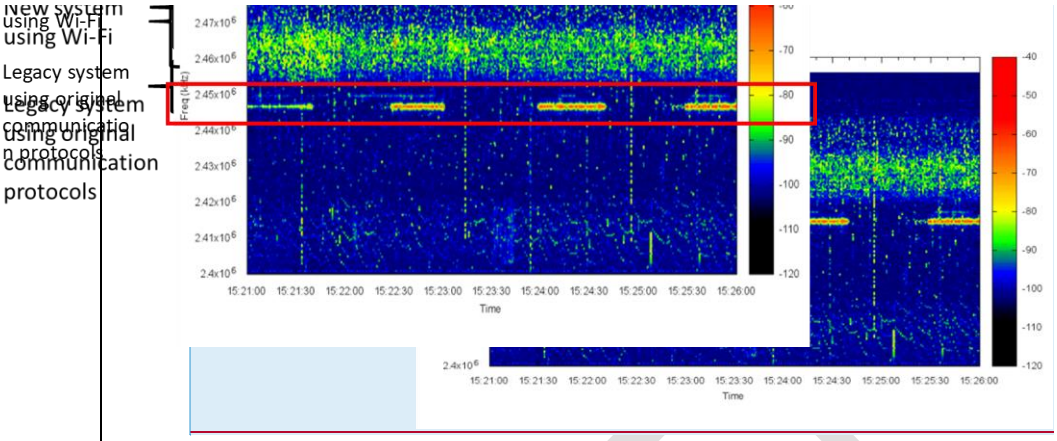

Figure 47 Wireless signals with coexistence of different wireless technologies. The x- and horizontaly axeis show s frequency (Hz) and time, and color shows signal strength in a bar on the right hand side..

(Withdraw Figure 8 and associated text)

Some of the problems observe relates to the packet delivery delay. Figure 8 shows packet loss and packet delivery delay with different interference level. The packet latency increased from 8ms in case of no interference to around 2 second in the presence interference due to lack of coordination amongst the used wireless systems used in the factory.

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Some of the problems observe relates to the packet delivery delay. Figure 8 shows packet loss and packet delivery delay with different interference level. The packet latency increased from 8ms in case of no interference to around 2 second in the presence interference due to lack of coordination amongst the used wireless systems used in the factory.

Commented [i21R20]: These experimental results are assumed the scenario of video monitor monolithic system. Moreover, this problem is based on wired-wireless bridges, and not special problem in factory site. Because of that, these results are not fit as example of this section. Because of that, they are deleted from here.