nRF24Z1 Coexistence Stress Tests nAN24-11

1. General

This Application Note contains descriptions and results of coexistence stress tests performed with the nRF24Z1 audio streamer device with firmware Rev. 2.0 (incorporating Adaptive Frequency Hopping (AFH) functionality).

Subjective tests have been performed for a selection of high stress coexistence scenarios where other high throughput 2.4GHz devices are present. The objective of the tests has been to get an impression of *what effect the various scenarios have on the perceived audio quality*.

The test scenarios are divided into two main categories:

- Multiple 2.4GHz devices, fixed distance between ATX and ARX
- Range test (ATX to ARX) in multi-user environment

Coexisting devices used in the tests are;

- nRF24Z1 audio streamer applications
- WLAN-nodes (diverse frequencies and datarates)
- Bluetooth audio streamer headsets
- microwave oven

All tests in this application note have been conducted as subjective listening tests. A limited test panel consisting of 4 individuals has been instructed to grade audio quality according to a predefined scale.

Table of contents

2. Test scenario I : Multiple 2.4GHz devices, fixed distance between ATX and ARX

Firmware release 2.0 incorporates Adaptive Frequency Hopping functionality implemented in order to combat audio streamer link breakdown in high stress situations. High stress is defined as streaming of high quality audio in the presence of multiple high power / high throughput units operating in the 2.4GHz band.

Four different latency and sampling rate configuration settings were used to in order to illustrate how these affect system robustness. The following settings have been used in the test:

- 32 Ks/sec with 17.8ms latency (latency setting 02)
- 32 Ks/sec with 25.8ms latency (latency setting 04)
- 44.1 Ks/sec with 13.4ms latency (latency setting 02)
- 44.1 Ks/sec with 19.2ms latency (latency setting 04)

A total of 4 nRF24Z1 audio streamer kits have been used in the subjective listening tests. The frequency hopping tables and serial numbers are listed in Appendix C.

All tests in Chapter 2 were conducted 2005-07-20 with the same test-panel personnel. All tests were performed within a timeframe of 4 hours.

2.1. Measurement criteria and definitions

2.1.1. Co-existing units used in the test

nRF24Z1-kits	nRF24Z1 audio streamer application based on nRF24Z1_EVBOARD_rev1_3. ATX audio source is Creative CTMOVOV MP3-player.
WLAN devices	WLAN1: Laptop computer with 802.54b WLAN card at maximum load; 54Mb/sec at Channel 6 (D-Link USB adapter Airplus G DWL-G122). WLAN router unit positioned approx. 1 meter from Laptop (Philips CPWBS054). WLAN2: Laptop computer with 802.11b WLAN card at maximum load; 11Mb/sec at Channel 13 (Philips USB adapter CPWUA054). WLAN router unit positioned 10 meters from the test area (Philips CPWBS054). WLAN3: 11Mb/sec 802.11g WLAN operating at Channel 6. WLAN situated at floor under test area. Present under all tests. Received power from low to moderate. Traffic load unknown.

Microwave	1000W Daewoo KOR-636T Microwave oven operated at maximum power with load consisting of 2 liters of water.
Bluetooth device	Creative wireless audio streamer (Bluetooth profile v1.2: Advanced Audio Distribution Profile [A2DP]) connected to iPod-unit carried at belt-height, headset worn by noise carrier super.

2.1.2. nRF24Z1-audio streamer kit device positioning and orientation

Devices in the test are considered to be portable equipment carried either in belt/pocket or bag/rucksack. Individuals carrying an nRF24Z1-kit are expected to carry the receiving end close to the head, application wise most commonly integrated in a headset.

Antenna orientation of the receiver is thus considered to be relatively stable

The streamer output unit may be carried in belt/pocket/bag and antenna orientation of this unit is therefore considered to be unknown.

Maximum distance between units in an nRF24Z1-kit is given by Figure 1.

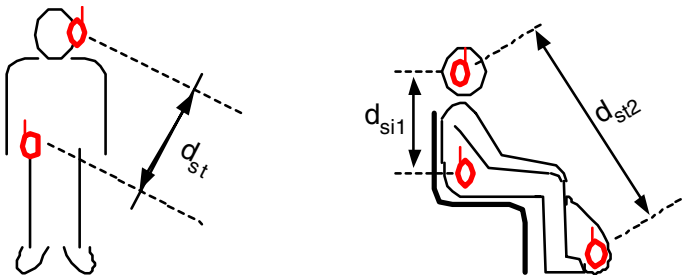

Figure 1 – Transceiver unit locations and physical distances

(Left: upright scenario, Right: seated scenario)

In the test, the maximum distance between units has been limited to 0.85m for mobile personnel and for seated personnel carrying the streamer output unit in belt/pocket (d_{st}= d_{si1}=0.85m). For seated personnel carrying the output streamer unit in a bag/rucksack positioned at the floor, the maximum distance is set to 1.3m (d_{st2}=1.3m).

2.1.3. Test subcategories

The tests in this chapter have been divided into 5 subcategories;

Test A:	2-4 *stationary* nRF24Z1 audio streamers in small area
Test B:	2-4 *moving* nRF24Z1 audio streamers in small area
Test C:	1-4 *moving* nRF24Z1 audio streamers in small area with WLAN
Test D:	1-4 *moving* nRF24Z1 audio streamers in small area with 1-2 WLAN nodes and microwave oven
Test E:	1-4 *moving* nRF24Z1 audio streamers in small area with 1-2 Bluetooth devices

2.1.4. Evaluation scale

The test-panel participants were asked to grade the perceived audio quality according to the evaluation scale shown in Table 1.

0	1	2	3	4	5
Flawless/ Inaudible	**Noticeable when concentrating**	**Slightly noticeable**	**noticeable**	**annoying**	**Loss of audio**

Table 1 – Subjective test evaluation scale

Results are listed for each scenario together with the corresponding average value.

2.2. Test A; 2-4 stationary nRF24Z1 audio streamers in small area

This test scenario investigates audio link quality in an environment with coexistence of multiple *stationary* nRF24Z1 units in a confined area. This is typically settings such as crowded urban areas and public transport (i.e. queues, buses, subways etc).

2.2.1. Test A-1; Perception of sound quality in one-on-one situation (standing, radius <1m)

This test reports the perceived audio quality of an immobile nRF24Z1 audio streamer in an environment where another immobile nRF24Z1 audio streamer is present in close proximity. Results are listed in Table 2.

Noise sources present:

- 1 nRF24Z1 audio streamer kit
- Low/moderate power WLAN operating at Channel 6, unknown load (WLAN3)

Physical setup:

Principle shown in Figure 2. Test panel representative in standing, immobile position with streamer output unit positioned in belt. Super positioned in similar position with identical carrying position. Distance between individuals is less than 2 meters. Location as described in Appendix B; Test environment description.

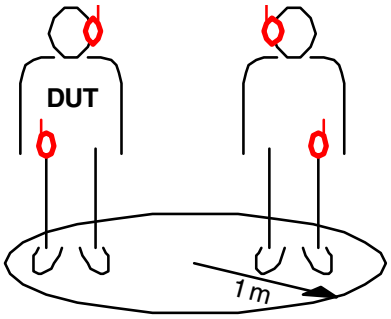

Figure 2 - Test scenario principle (A-1)

	0 Flawless/ Inaudible	1 Noticeable when concentrating	2 Slightly noticeable	3 Noticeable	4 Annoying	5 Temporary loss of audio	Average rating
32Ks/s – 17.8ms (02)	4						0
32Ks/s – 25.8ms (04)	4						0
44.1Ks/s – 13.4ms (02)	3	1					0.25
44.1Ks/s – 19.2ms (04)	4						0

Table 2 – Subjective test results for test A-1

2.2.2. Test A-2; Perception of sound quality in one-on-two situation (standing, radius <1m)

This test reports the perceived audio quality of an immobile nRF24Z1 audio streamer in an environment where two immobile nRF24Z1 audio streamers are present in close proximity. Results are listed in Table 3.

Noise sources present:

- 2 nRF24Z1 audio streamer kits
- Low/moderate power WLAN operating at Channel 6, unknown load (WLAN3)

Physical setup:

Principle shown in Figure 3. Test panel representative in standing, immobile position with streamer output unit positioned in belt. Supers positioned in similar positions with identical carrying position. Distance between individuals is less than 2 meters. Location as described in Appendix B; Test environment description.

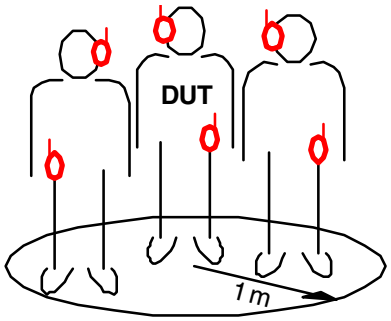

Figure 3 - Test scenario principle (A-2)

	0 Flawless/ Inaudible	1 Noticeable when concentrating	2 Slightly noticeable	3 Noticeable	4 Annoying	5 Temporary loss of audio	Average rating
32Ks/s – 17.8ms (02)	3	1					0.25
32Ks/s – 25.8ms (04)	4						0
44.1Ks/s – 13.4ms (02)		1	2	1			2
44.1Ks/s – 19.2ms (04)	4						0

Table 3 – Subjective test results for test A-2

2.2.3. Test A-3; Overall perception of sound quality in seated situation with 4 units present (radius <1m)

This test reports the perceived audio quality of an immobile nRF24Z1 audio streamer in an environment where two immobile nRF24Z1 audio streamers are present in close proximity. Results are listed in Table 4.

Noise sources present:

- 3 nRF24Z1 audio streamer kits
- Low/moderate power WLAN operating at Channel 6, unknown load (WLAN3)

Physical setup:

Principle shown in Figure 4. Test panel representative in seated position with streamer output unit positioned in rucksack/bag between legs. Supers positioned in similar positions with identical carrying position. Distance between individuals is 1 meter. Location as described in Appendix B; Test environment description.

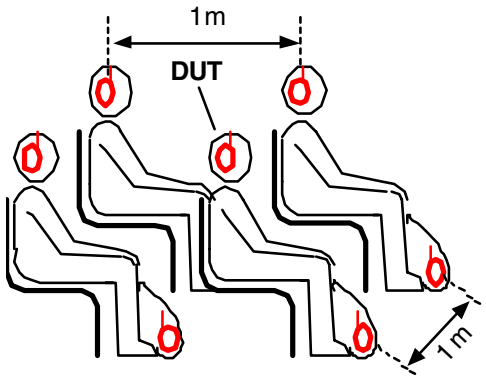

Figure 4 - Test scenario principle (A-3)

	0 Flawless/ Inaudible	1 Noticeable when concentrating	2 Slightly noticeable	3 Noticeable	4 Annoying	5 Temporary loss of audio	Average rating
32Ks/s – 17.8ms (02)	4						0
32Ks/s – 25.8ms (04)	4						0
44.1Ks/s – 13.4ms (02)		1	1	2			2.25
44.1Ks/s – 19.2ms (04)	4						0

Table 4 – Subjective test results for test A-3

2.2.4. Test A-4; Overall perception of sound quality in upright position with all units present (radius <3m)

This test reports the perceived audio quality of an immobile nRF24Z1 audio streamer in an environment where three immobile nRF24Z1 audio streamers are present in close proximity. Results are listed in Table 5.

Noise sources present:

- 3 nRF24Z1 audio streamer kits
- Low/moderate power WLAN operating at Channel 6, unknown load (WLAN3)

Physical setup:

Principle shown in Figure 5. Test panel representative in standing, immobile position with streamer output unit positioned in belt. Supers positioned in similar positions with identical carrying position. Individuals positioned at random in area with radius approx 3 meters or less.
Location as described in Appendix B; Test environment description.

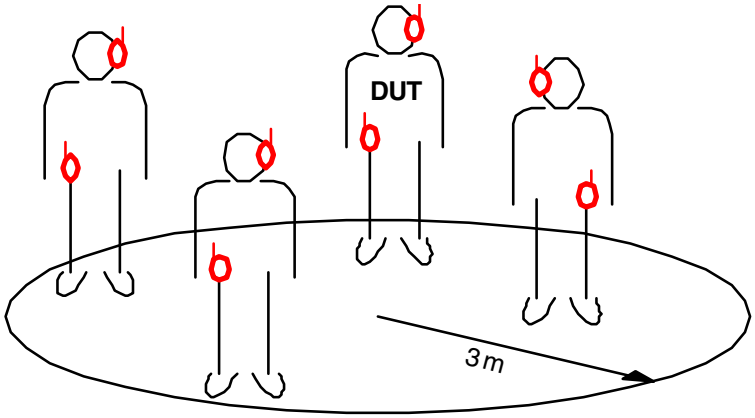

Figure 5 - Test scenario principle (A-4)

	0 Flawless/ Inaudible	1 Noticeable when concentrating	2 Slightly noticeable	3 Noticeable	4 Annoying	5 Temporary loss of audio	Average rating
32Ks/s – 17.8ms (02)	4						0
32Ks/s – 25.8ms (04)	4						0
44.1Ks/s – 13.4ms (02)		1	2		1		2.25
44.1Ks/s – 19.2ms (04)	4						0

Table 5 – Subjective test results for test A-4

2.3. Test B; 2-4 moving nRF24Z1 audio streamers in small area

This test scenario investigates audio link quality in an environment with coexistence of multiple *mobile* nRF24Z1 units in a confined area. This is typically settings such as crowded urban areas and public transport (i.e. queues, subways, train stations, café's etc).

2.3.1. Test B-1; Perception of sound quality in one-on-one situation (radius <1m)

This test reports the perceived audio quality of a mobile nRF24Z1 audio streamer in an environment where another moving nRF24Z1 audio streamer is present in close proximity. Results are listed in Table 6.

Noise sources present:

- 1 nRF24Z1 audio streamer kit
- Low/moderate power WLAN operating at Channel 6, unknown load (WLAN3)

Physical setup:

Principle shown in Figure 6. Test panel representative and super mingling in test area shown in Figure B.1. Continuous variation of unit position (distance) and orientation. Streamer output unit positioned in belt. Super mimic's similar movement pattern with identical audio streamer carrying position. Distance between individuals is less than 2 meters.

Location as described in Appendix B; Test environment description.

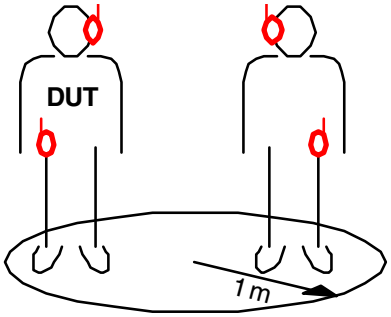

Figure 6 - Test scenario principle (B-1)

	0 Flawless/ Inaudible	1 Noticeable when concentrating	2 Slightly noticeable	3 Noticeable	4 Annoying	5 Temporary loss of audio	Average rating
32Ks/s – 17.8ms (02)	4						0
32Ks/s – 25.8ms (04)	4						0
44.1Ks/s – 13.4ms (02)	2	2					0.5
44.1Ks/s – 19.2ms (04)	3	1					0.25

Table 6 – Subjective test results for test B-1

2.3.2. Test B-2; Perception of sound quality in one-on-two situation (radius <1m)

This test reports the perceived audio quality of a mobile nRF24Z1 audio streamer in an environment where two other moving nRF24Z1 audio streamers are present in close proximity.
Results are listed in Table 7.

Noise sources present:

- 2 nRF24Z1 audio streamer kits
- Low/moderate power WLAN operating at Channel 6, unknown load (WLAN3)

Physical setup:

Principle shown in Figure 7. Test panel representative and supers are mingling in test area shown in Figure B.1. Continuous variation of unit position (distance) and orientation. Streamer output unit positioned in belt. Supers mimic similar movement pattern with identical audio streamer carrying position. Distance between individuals is less than 2 meters.
Location as described in Appendix B; Test environment description.

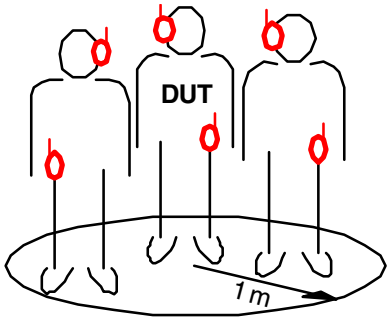

Figure 7 - Test scenario principle (B-2)

	0 Flawless/ Inaudible	1 Noticeable when concentrating	2 Slightly noticeable	3 Noticeable	4 Annoying	5 Temporary loss of audio	Average rating
32Ks/s – 17.8ms (02)	3	1					0.25
32Ks/s – 25.8ms (04)	4						0
44.1Ks/s – 13.4ms (02)		3			1		1.75
44.1Ks/s – 19.2ms (04)	4						0

Table 7 – Subjective test results for test B-2

2.3.3. Test B-3; Overall perception of sound quality in mingling situation with all units present (radius <1m)

This test reports the perceived audio quality of a mobile nRF24Z1 audio streamer in an environment where three other moving nRF24Z1 audio streamers are present in close proximity.
Results are listed in Table 8.

Noise sources present:

- 3 nRF24Z1 audio streamer kits
- Low/moderate power WLAN operating at Channel 6, unknown load (WLAN3)

Physical setup:

Principle shown in Figure 8. Test panel representative and supers are mingling in test area shown in Figure B.1. Continuous variation of unit position (distance) and orientation. Streamer output unit positioned in belt. Supers mimic similar movement pattern with identical audio streamer carrying position. Distance between individuals is less than 2 meters.
Location as described in Appendix B; Test environment description.

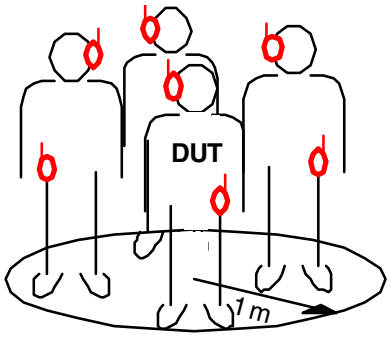

Figure 8 - Test scenario principle (B-3)

	0 Flawless/ Inaudible	1 Noticeable when concentrating	2 Slightly noticeable	3 Noticeable	4 Annoying	5 Temporary loss of audio	Average rating
32Ks/s – 17.8ms (02)	2	1	1				0.75
32Ks/s – 25.8ms (04)	4						0
44.1Ks/s – 13.4ms (02)			1	2	1		3
44.1Ks/s – 19.2ms (04)	3	1					0.25

Table 8 – Subjective test results for test B-3

2.3.4. Test B-4; Overall perception of sound quality in mingling situation with all units present (radius <3m)

This test reports the perceived audio quality of a mobile nRF24Z1 audio streamer in an environment where three other moving nRF24Z1 audio streamers are present in close proximity.
Results are listed in Table 9.

Noise sources present:

- 3 nRF24Z1 audio streamer kits
- Low/moderate power WLAN operating at Channel 6, unknown load (WLAN3)

Physical setup:

Principle shown in Figure 9. Test panel representative and supers are mingling in test area shown in Figure B.1. Continuous variation of unit position (distance) and orientation. Streamer output unit positioned in belt. Supers mimic similar movement pattern with identical audio streamer carrying position in area with radius approx 3 meters or less.
Location as described in Appendix B; Test environment description.

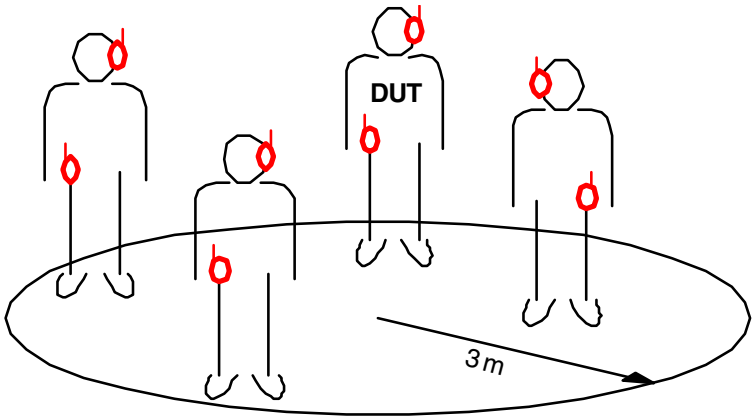

Figure 9 - Test scenario principle (B-4)

	0 Flawless/ Inaudible	1 Noticeable when concentrating	2 Slightly noticeable	3 Noticeable	4 Annoying	5 Temporary loss of audio	Average rating
32Ks/s – 17.8ms (02)	3	1					0.25
32Ks/s – 25.8ms (04)	4						0
44.1Ks/s – 13.4ms (02)		2	1		1		2
44.1Ks/s – 19.2ms (04)	4						0

Table 9 – Subjective test results for test B-4

2.4. Test C; 1-4 moving nRF24Z1 audio streamers in small area with WLAN

This test scenario investigates audio link quality in an environment with coexistence of multiple *mobile* nRF24Z1 units in a confined area covered by WLAN nodes at full transmission load. This is typically settings such as urban areas and public transport (i.e. offices, train stations, airports, café's etc).

2.4.1. Test C-1; Perception of sound quality in close proximity of WLAN-node (one audio streamer active, radius <1m)

This test reports the perceived audio quality of a mobile nRF24Z1 audio streamer in close proximity of a high throughput WLAN node.
Results are listed in Table 10.

Noise sources present:

- High power 54Mb/s WLAN operating at Channel 6, maximum load (WLAN1)
- Low/moderate power WLAN operating at Channel 6, unknown load (WLAN3)

Physical setup:

Principle shown in Figure 10. Test panel representative is moving about in test area shown in Figure B.1. Continuous variation of unit position (distance) and orientation. Streamer output unit positioned in belt. Distance to WLAN-node is less than 1 meters. Location as described in Appendix B; Test environment description.

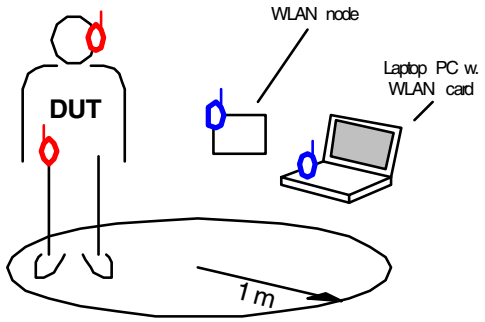

Figure 10 - Test scenario principle (C-1)

	0 Flawless/ Inaudible	1 Noticeable when concentrating	2 Slightly noticeable	3 Noticeable	4 Annoying	5 Temporary loss of audio	Average rating
32Ks/s – 17.8ms (02)	3	1					0.25
32Ks/s – 25.8ms (04)	4						0
44.1Ks/s – 13.4ms (02)	3	1					0.25
44.1Ks/s – 19.2ms (04)	4						0

Table 10 – Subjective test results for test C-1

Remarks: Low/no degradation of audio quality experienced even when audio streamer receiver unit is positioned on top of WLAN node.

2.4.2. Test C-2; Overall perception of sound quality in mingling situation with all units and WLAN present (radius <3m)

This test reports the perceived audio quality of a mobile nRF24Z1 audio streamer in an environment where three other moving nRF24Z1 audio streamers and a high throughput WLAN node are present in close proximity.
Results are listed in Table 11.

Noise sources present:

- 3 nRF24Z1 audio streamer kits
- High power 54Mb/s WLAN operating at Channel 6, maximum load (WLAN1)
- Low/moderate power WLAN operating at Channel 6, unknown load (WLAN3)

Physical setup:

Principle shown in Figure 11. Test panel representative and supers mingling in test area shown in Figure B.1. Continuous variation of unit position (distance) and orientation. Streamer output unit positioned in belt. Supers mimic similar movement pattern with identical audio streamer carrying position in area with radius approx 3 meters or less. The high throughput WLAN node and its recipient are positioned within mingling area.
Location as described in Appendix B; Test environment description.

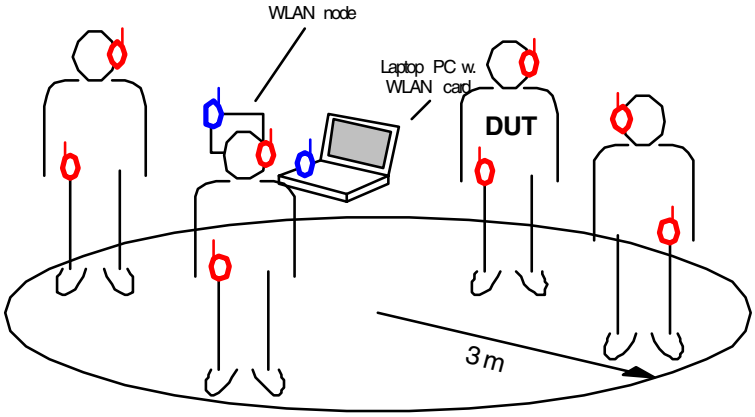

Figure 11 - Test scenario principle (C-2)

	0 Flawless/ Inaudible	1 Noticeable when concentrating	2 Slightly noticeable	3 Noticeable	4 Annoying	5 Temporary loss of audio	Average rating
32Ks/s – 17.8ms (02)	1		3				1.5
32Ks/s – 25.8ms (04)	4						0
44.1Ks/s – 13.4ms (02)				4			3
44.1Ks/s – 19.2ms (04)	2	2					0.5

Table 11 – Subjective test results for test C-2

2.5. Test D; 1-4 moving nRF24Z1 audio streamers in small area with 1-2 WLAN nodes and Microwave oven

This test scenario investigates audio link quality in an environment with coexistence of multiple *mobile* nRF24Z1 units in a confined area covered by multiple WLAN nodes at full transmission load as well as microwave oven radiation. This is typically settings such as fast food restaurants and café's).

2.5.1. Test D-1; Perception of sound quality in close proximity of microwave oven (one audio streamer active, radius <1m)

This test reports the perceived audio quality of a mobile nRF24Z1 audio streamer in close proximity of a microwave oven operating at full power.
Results are listed in Table 12.

Noise sources present:

- Microwave oven operating at maximum power (1000W)
- Low/moderate power WLAN operating at Channel 6, unknown load (WLAN3)

Physical setup:

Principle shown in Figure 12. Test panel representative is moving about in test area shown in Figure B.1. Continuous variation of unit position (distance) and orientation. Streamer output unit positioned in belt. Distance to microwave oven is less than 1 meters.
Location as described in Appendix B; Test environment description.

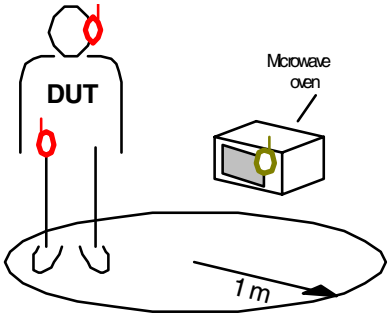

Figure 12 - Test scenario principle (D-1)

	0 Flawless/ Inaudible	1 Noticeable when concentrating	2 Slightly noticeable	3 Noticeable	4 Annoying	5 Temporary loss of audio	Average rating
32Ks/s – 17.8ms (02)	3	1					0.25
32Ks/s – 25.8ms (04)	4						0
44.1Ks/s – 13.4ms (02)	2	2					0.5
44.1Ks/s – 19.2ms (04)	3	1					0.25

Table 12 – Subjective test results for test D-1

Remarks: Degradation of audio quality is only evident at extreme proximity of microwave oven.

2.5.2. Test D-2; Overall perception of sound quality in mingling situation with all units, WLAN and microwave active (radius <4m)

This test reports the perceived audio quality of a mobile nRF24Z1 audio streamer in an environment where three other moving nRF24Z1 audio streamers, a high throughput WLAN node and a microwave oven are present in close proximity.
Results are listed in Table 13.

Noise sources present:

- 3 nRF24Z1 audio streamer kits
- High power 54Mb/s WLAN operating at Channel 6, maximum load
- Microwave oven operating at maximum power (1000W)
- Low/moderate power WLAN operating at Channel 6, unknown load (WLAN3)

Physical setup:

Principle shown in Figure 13. Test panel representative and supers are mingling in test area shown in Figure B.1. Continuous variation of unit position (distance) and orientation. Streamer output unit positioned in belt. Supers mimic similar movement pattern with identical audio streamer carrying position in area with radius approx 4 meters or less. The microwave and the high throughput WLAN node with its recipient are positioned within the mingling area.
Location as described in Appendix B; Test environment description.

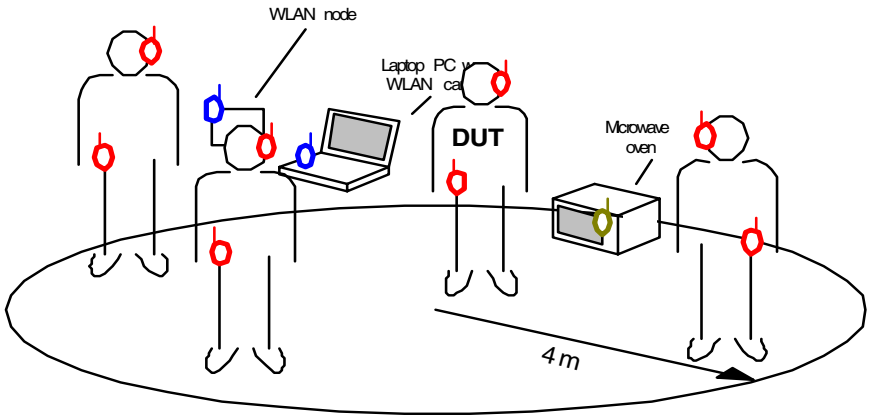

Figure 13 - Test scenario principle (D-2)

	0 Flawless/ Inaudible	1 Noticeable when concentrating	2 Slightly noticeable	3 Noticeable	4 Annoying	5 Temporary loss of audio	Average rating
32Ks/s – 17.8ms (02)			1	3			2.75
32Ks/s – 25.8ms (04)	3	1					0.25
44.1Ks/s – 13.4ms (02)				2	2		3.5
44.1Ks/s – 19.2ms (04)	1		1	1	1		2.25

Table 13 – Subjective test results for test D-2

2.5.3. Test D-3; Overall perception of sound quality in mingling situation with all units, multiple WLAN and microwave active (radius <4m)

This test reports the perceived audio quality of a mobile nRF24Z1 audio streamer in an environment where three other moving nRF24Z1 audio streamers, two high throughput WLAN nodes operating at different frequencies and a microwave oven are present in close proximity.
Results are listed in Table 14.

Noise sources present:

- 3 nRF24Z1 audio streamer kits
- High power 54Mb/s WLAN operating at Channel 6, maximum load (WLAN1)
- High power 11Mb/s WLAN operating at Channel 13, maximum load (WLAN2)
- Microwave oven operating at maximum power (1000W)
- Low/moderate power WLAN operating at Channel 6, unknown load (WLAN3)

Physical setup:

Principle shown in Figure 14. Test panel representative and supers are mingling in test area shown in Figure B.1. Continuous variation of unit position (distance) and orientation. Streamer output unit positioned in belt. Supers mimic similar movement pattern with identical audio streamer carrying position in area with radius approx 4 meters or less. The microwave and the two high throughput WLAN nodes are positioned within the mingling area.
Location as described in Appendix B; Test environment description.

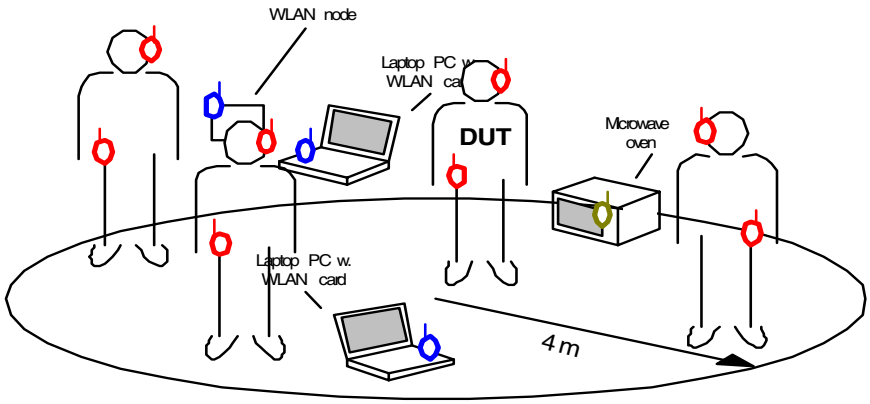

Figure 14 - Test scenario principle (D-3)

	0 Flawless/ Inaudible	1 Noticeable when concentrating	2 Slightly noticeable	3 Noticeable	4 Annoying	5 Temporary loss of audio	Average rating
32Ks/s – 17.8ms (02)				1	2	1	4
32Ks/s – 25.8ms (04)	1	3					0.75
44.1Ks/s – 13.4ms (02)					1	3	4.75
44.1Ks/s – 19.2ms (04)	2		1	1			1.25

Table 14 – Subjective test results for test D-3

2.6. Test E; 1-4 moving nRF24Z1 audio streamers in small area with 1-2 Bluetooth devices

This test scenario investigates audio link quality in an environment with coexistence of multiple *mobile* nRF24Z1 units in a confined area occupied by Bluetooth audio streamer users. This is typically settings such as urban areas and public transport (i.e. queues, train stations, airports, café's etc).

2.6.1. Test E-1; Perception of sound quality in one-on-one Bluetooth situation (radius <1m)

This test reports the perceived audio quality of a mobile nRF24Z1 audio streamer in an environment where another moving Bluetooth audio streamer is present in close proximity. Results are listed in Table 15.

Noise sources present:

- 1 Bluetooth unit streaming iPOD data
- Low/moderate power WLAN operating at Channel 6, unknown load (WLAN3)

Physical setup:

Principle shown in Figure 15. Test panel representative and Bluetooth super mingling in test area shown in Figure B.1. Continuous variation of unit position (distance) and orientation. Streamer output unit positioned in belt. Super mimic's similar movement pattern with identical audio streamer carrying position. Distance between individuals is less than 2 meters.

Location as described in Appendix B; Test environment description.

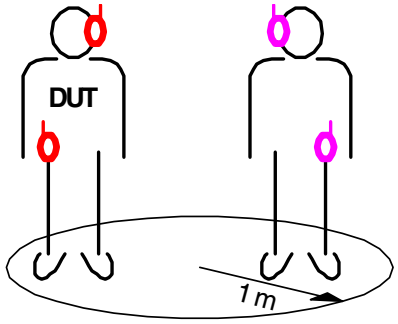

Figure 15 - Test scenario principle (E-1)

	0 Flawless/ Inaudible	1 Noticeable when concentrating	2 Slightly noticeable	3 Noticeable	4 Annoying	5 Temporary loss of audio	Average rating
32Ks/s – 17.8ms (02)	4						0
32Ks/s – 25.8ms (04)	4						0
44.1Ks/s – 13.4ms (02)	4						0
44.1Ks/s – 19.2ms (04)	4						0

Table 15 – Subjective test results for test E-1

Remarks: No observations of audio quality degradation even at close proximity of Bluetooth unit (<0.5m)

2.6.2. Test E-2; Perception of sound quality in one-on-two Bluetooth situation (radius <1m)

This test reports the perceived audio quality of a mobile nRF24Z1 audio streamer in an environment where two other moving Bluetooth audio streamers are present in close proximity.
Results are listed in Table 16.

Noise sources present:

- 2 Bluetooth units streaming iPOD data
- Low/moderate power WLAN operating at Channel 6, unknown load (WLAN3)

Physical setup:

Principle shown in Figure 16. Test panel representative and Bluetooth supers mingling in test area shown in Figure B.1. Continuous variation of unit position (distance) and orientation. Streamer output unit positioned in belt. Supers mimics similar movement pattern with identical audio streamer carrying positions. Distance between individuals is less than 2 meters.
Location as described in Appendix B; Test environment description.

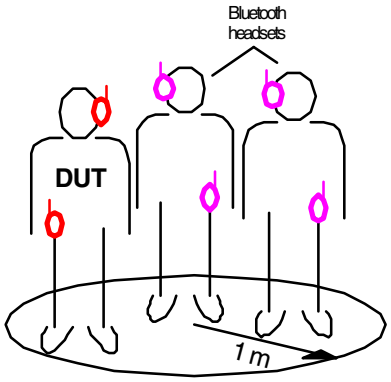

Figure 16 - Test scenario principle (E-2)

	0 Flawless/ Inaudible	1 Noticeable when concentrating	2 Slightly noticeable	3 Noticeable	4 Annoying	5 Temporary loss of audio	Average rating
32Ks/s – 17.8ms (02)	4						0
32Ks/s – 25.8ms (04)	4						0
44.1Ks/s – 13.4ms (02)	3	1					0.25
44.1Ks/s – 19.2ms (04)	4						0

Table 16 – Subjective test results for test E-2

Remarks: Occasional noise occurring in Bluetooth headsets

2.6.3. Test E-3; Overall perception of sound quality in mingling situation with all units and two Bluetooth streamers present (radius <3m)

This test reports the perceived audio quality of a mobile nRF24Z1 audio streamer in an environment where three other mobile nRF24Z1 audio streamers and two other moving Bluetooth audio streamers are present in close proximity.
Results are listed in Table 17.

Noise sources present:

- 3 nRF24Z1 audio streamer kits
- 2 Bluetooth units streaming iPOD data
- Low/moderate power WLAN operating at Channel 6, unknown load (WLAN3)

Physical setup:

Principle shown in Figure 17. Test panel representative, Bluetooth- and nRF24Z1 audio streamer supers mingling in test area shown in Figure B.1. Continuous variation of unit position (distance) and orientation. Streamer output unit positioned in belt. Supers mimics similar movement pattern with identical audio streamer carrying positions. Individuals are moving within an area with radius less than 3 meters. Location as described in Appendix B; Test environment description.

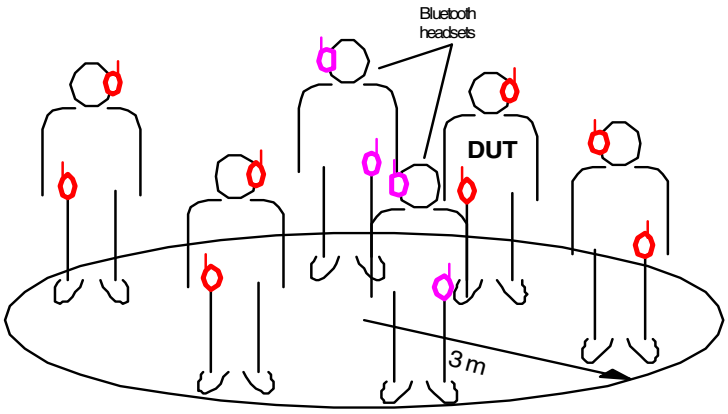

Figure 17 - Test scenario principle (E-3)

	0 Flawless/ Inaudible	1 Noticeable when concentrating	2 Slightly noticeable	3 Noticeable	4 Annoying	5 Temporary loss of audio	Average rating
32Ks/s – 17.8ms (02)	2	1	1				0.75
32Ks/s – 25.8ms (04)	4						0
44.1Ks/s – 13.4ms (02)		1		2	1		2.75
44.1Ks/s – 19.2ms (04)	4						0

Table 17 – Subjective test results for test E-3

Remarks: Frequent collapse of audio link in both Bluetooth headsets. Significantly better audio quality for nRF24Z1 audio streamers than for Bluetooth units for all configuration setups.

2.7. Test summary (Scenario I)

Table 18.a and 18.b contain the subjective test summary.

Test	Configuration Setting	Average
A-1: Perception of sound quality in one-on-one situation (standing, radius <1m)	32K / 02	0
	32K / 04	0
	44.1K / 02	0.25
	44.1K / 04	0
A-2: Perception of sound quality in one-on-two situation (standing, radius <1m)	32K / 02	0.25
	32K / 04	0
	44.1K / 02	2
	44.1K / 04	0
A-3: Overall perception of sound quality in seated situation with 4 units present (radius <1m)	32K / 02	0
	32K / 04	0
	44.1K / 02	2.25
	44.1K / 04	0
A-4: Overall perception of sound quality in upright position with all units present (radius <3m)	32K / 02	0
	32K / 04	0
	44.1K / 02	2.25
	44.1K / 04	0
B-1: Perception of sound quality in one-on-one situation (radius <1m)	32K / 02	0
	32K / 04	0
	44.1K / 02	0.5
	44.1K / 04	0.25
B-2: Perception of sound quality in one-on-two situation (radius <1m)	32K / 02	0.25
	32K / 04	0
	44.1K / 02	1.75
	44.1K / 04	0
B-3: Overall perception of sound quality in mingling situation with all units present (radius <1m)	32K / 02	0.75
	32K / 04	0
	44.1K / 02	3
	44.1K / 04	0.25
B-4: Overall perception of sound quality in mingling situation with all units present (radius <3m)	32K / 02	0.25
	32K / 04	0
	44.1K / 02	2
	44.1K / 04	0
C-1: Perception of sound quality in close proximity of WLAN-node (one audio streamer active, radius <1m)	32K / 02	0.25
	32K / 04	0
	44.1K / 02	0.25
	44.1K / 04	0
C-2: Overall perception of sound quality in mingling situation with all units and WLAN present (radius <3m)	32K / 02	1.5
	32K / 04	0
	44.1K / 02	3
	44.1K / 04	0.5

Table 18.a – Subjective test summary (tests A-1 thru C-2)

Test	Configuration setting	Average
D-1: Perception of sound quality in close proximity of microwave oven (one audio streamer active, radius <1m)	32K / 02	0.25
	32K / 04	0
	44.1K / 02	0.5
	44.1K/ 04	0.25
D-2: Overall perception of sound quality in mingling situation with all units, WLAN and microwave active (radius <4m)	32K / 02	2.75
	32K / 04	0.25
	44.1K / 02	3.5
	44.1K/ 04	2.25
D-3: Overall perception of sound quality in mingling situation with all units, multiple WLAN and microwave active (radius <4m)	32K / 02	4
	32K / 04	0.75
	44.1K / 02	4.75
	44.1K/ 04	1.25
E-1: Perception of sound quality in one-on-one Bluetooth situation (radius <1m)	32K / 02	0
	32K / 04	0
	44.1K / 02	0
	44.1K/ 04	0
E-2: Perception of sound quality in one-on-two Bluetooth situation (radius <1m)	32K / 02	0
	32K / 04	0
	44.1K / 02	0.25
	44.1K/ 04	0
E-3: Overall perception of sound quality in mingling situation with all units and two Bluetooth streamers present (radius <3m)	32K / 02	0.75
	32K / 04	0
	44.1K / 02	2.75
	44.1K/ 04	0

Table 18.b – Subjective test summary (tests D-1 thru E-3)

3. Test scenario II : Range test (ATX to ARX) in multi-user environment

The motivation of the tests described in this chapter has been to investigate the maximum practical range between the ATX and ARX units in the presence of 2.4GHz devices.

At some point, the QoS-engine is unable to maintain a flawless audio link. This may be the result of stretched range, excessive interferer noise or both. Normally, the corrupt or lost information is retransmitted and corrected within the latency timeframe.
If this is not achieved, corrupt samples will be submitted to the DAC and audible noise may result. In order to avoid excessive noise, the DAC output may be muted.

In this case, two parameters are of interest, LNKERR (LiNKERRor) and LNKETH (LiNKErrorTHreshold). The first parameter is changing with time and represents the number of corrupt packages (in a 256 package window) submitted to the DAC*. These represent packages that the QoS engine was unable to retrieve within the given latency period. The second is a parameter set by the user. This represents the allowed number of corrupt packages within the same 256 package window that will trigger interrupt and/or audio muting. Audio muting is controlled by register LNKMOD[3].

The user has the option to use LNKETH-parameter as an interrupt generator that may be used to trigger soft-mute options of external devices such as a DAC.

The LNKETH parameter has been varied in order to illustrate how this affects the experienced range in conditions with and without interference, fading and human body effects.

The sampling rate has been kept at 44.1Ks/s with latency setting of 19.2ms (04) for all tests in this chapter.

Refer to Chapter 2.1.1 for co-existing device specifications and Chapter 2.1.4 for evaluation scale definition.

The tests in this chapter have been conducted with Test Kit 1 (refer to Appendix C for main parameter settings).

*: Whether a corrupt package is audible or not depends on a number of factors such as music characteristics, ambient noise level, timing of the corrupt package, density of corrupt packages etc. Generally, 1-5 corrupt packages within a 256 package interval, is not discernible as noise by the listener.

3.1. Audio muting and LNKETH-parameter setting

3.1.1. Functional description

A low value on LNKETH will result in muting more often (i.e. earlier) than a high LNKETH value. Muting is then preferred to the audible noise caused by a high number of corrupt packages in the datastream.
A higher value of LNKETH will allow a higher amount of audible noise (i.e. corrupted packages) to reach the listener before the audio link is muted.

Figure 18 illustrates the general operating principle of the QoS-engine.

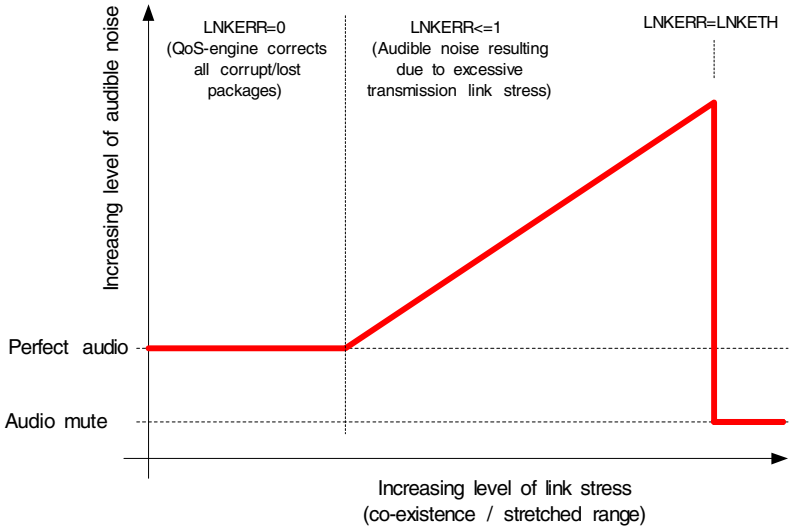

Figure 18 – QoS engine, principle of operation

The above implies that the LNKETH parameter is a *comfort parameter* that should be set as a trade-off between the static noise heard immediately before the audio link is muted, and the average frequency of muting occurring in the given application condition.

3.1.2. Practical implication of LNKETH-setting

Frequent muting is perceived as more annoying to the listener than the occasional noise resulting from a few packets being lost (package errors <5 are hardly discernible and generally not graded as annoying noise).
In scenarios where the RF link is being stressed by fading effects and interference from other systems, the likelihood of having a few packets lost are higher than in scenarios where the RF link is not stressed. This means that if the LNKETH parameter is set too low for the typical application condition, the experienced range might be perceived as shorter than what would be the case if LNKETH was set to a higher value.
That is; few package errors that otherwise would not be detected will cause a distinctive muting audio muting with lower LNKETH-settings.

3.2. Test results

3.2.1. Test R-1; Perception of practical range between ARX/ATX in low noise environment

This test reports the perceived practical range between an nRF24Z1 ARX and ATX with minimal presence of other 2.4GHz activity. The test has been repeated for various LNKETH parameter settings. Results are listed in Table 19.

Noise sources present:

- Low/moderate power WLAN operating at Channel 6, unknown load (WLAN3)

Physical setup:

Test principle is shown in Figure 19. Test panel representatives were asked to walk at slow walking pace carrying the ARX unit away from a stationary ATX positioned 80 cm above ground level. The test panel representatives were to *stop at a distance where the perceived audible noise shifted from 'noticeable' to 'annoying'* (refer to co-existence tests grading scale).

Test location is typical office environment (plaster/sheet metal walls, reinforced concrete floor and support pillars. Ceiling is profiled sheet metal. All external windows are metal tinted). ARX and ATX are within line-of-sight with the exception of minor plaster and glass objects.

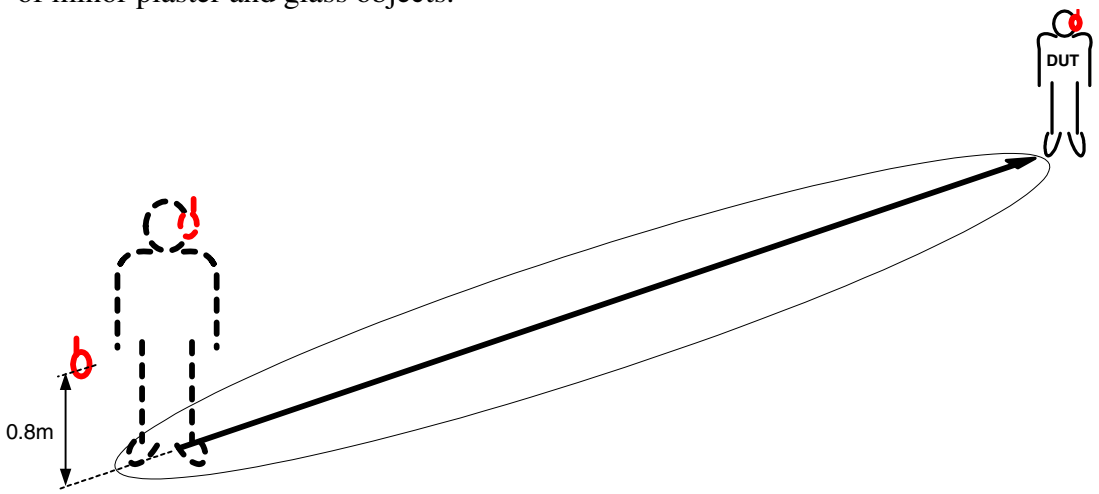

Figure 19 - Test scenario principle (R-1)

LNKETH-setting (decimal value)	Test rep. #1	Test rep. #2	Test rep. #3	Test rep. #4	Average rating
01	27m	27m	28m	26m	27m
18	27m	28m	28m	28m	27.75m
35	33m	29m	28m	28m	29.5m
52	32m	29m	33m	29m	30.75m
70	33m	31m	30m	29m	30.75m

Table 19 – Subjective test results for test R-1

3.2.2. Test R-2; Perception of practical range between ARX/ATX in the presence of WLAN and nRF24Z1 audio streamer activity

This test reports the perceived practical range between an nRF24Z1 ARX and ATX with moderate/high presence of other 2.4GHz activity. The test has been repeated for various LNKETH parameter settings. Results are listed in Table 20.

Noise sources present:

- 1 nRF24Z1 audio streamer kit
- High power 54Mb/s WLAN operating at Channel 6, maximum load (WLAN1)
- Low/moderate power WLAN operating at Channel 6, unknown load (WLAN3)

Physical setup:

Test principle and environment is identical to that of test R-1. The test differs on the account that a WLAN client and PC is positioned 17 meters from the ATX, traffic crossing the test representative path of movement. Likewise, an nRF24Z1 audio streamer is positioned at 10 meters distance from the ATX, as shown in Figure 20.

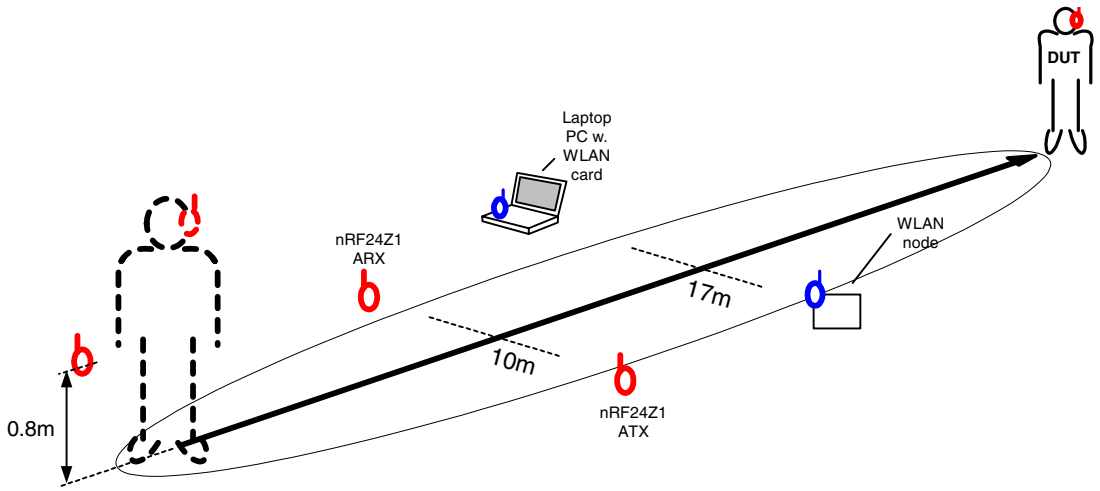

Figure 20 - Test scenario principle (R-2)

LNKETH-setting (decimal value)	Test rep. #1	Test rep. #2	Test rep. #3	Test rep. #4	Average rating
01	21m	22m	21m	21m	21.25m
18	25m	24m	25m	24m	24.5m
35	29m	28m	28m	27m	28m
52	29m	31m	31m	31m	30.5m
70	28m	30m	31m	31m	30m

Table 20 - Subjective test results for test R-2

3.2.3. Test R-3; Perception of audio quality during modulation of the distance between ARX/ATX units

This test reports the perceived audio quality of an nRF24Z1 audio streamer link of which the ARX is stationary while the ATX is moving. The test has been repeated for various LNKETH parameter settings and two different user orientations. Results are listed in Table 21.

Noise sources present:

- Low/moderate power WLAN operating at Channel 6, unknown load (WLAN3)

Physical setup:

Test principle is shown in Figure 21. Test panel representative standing in an upright position with the ARX located above shoulder-height. ATX fixed to the end of a 1.5 meter, non-conductive mechanical pendulum (initial deflection of 45°). The test panel representatives were asked to grade the audio quality while the pendulum was moving.

The test was conducted for two user orientations as shown in the side views in the figure.

Orientation 1: direct line of sight between the ARX and ATX (horizontal distance 0.5m)

Orientation 2: non-direct line of sight between the ARX and ATX (head and upper torso blocking direct propagation path, horizontal distance 0.75m)

Test location is typical office environment (plaster/sheet metal walls, reinforced concrete floor and support pillars. Ceiling is profiled sheet metal. All external windows are metal tinted).

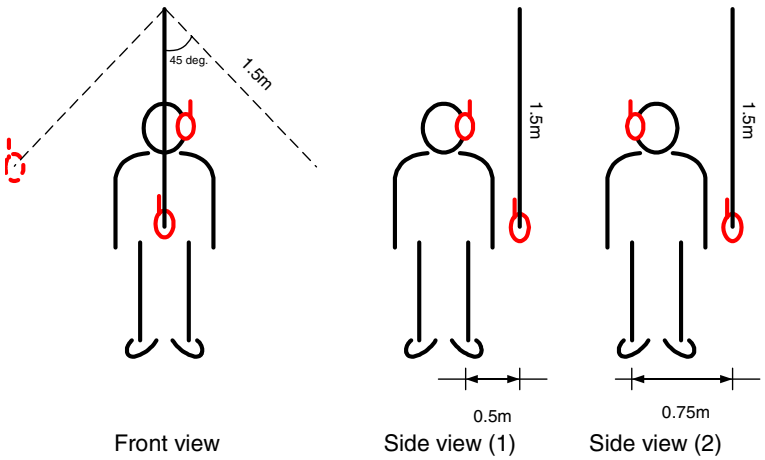

Figure 21 - Test scenario principle (R-3)

LNKETH-setting (decimal value)	0 Flawless/ Inaudible	1 Noticeable when concentrating	2 Slightly noticeable	3 Noticeable	4 Annoying	5 Temporary loss of audio	Average rating
01	4 (4)						0
18	4 (4)						0
35	4 (4)						0
52	4 (4)						0
70	4 (4)						0

Table 21 – Subjective test results for test R-3(User orientation #2 shown in brackets)

4. Discussion

4.1. Scenario I (co-existence)

Implementation of AFH in system firmware results in considerable improvement with regards to immunity to link breakdown in situations with close proximity / high throughput nodes. Test results show a dependency of sampling rate and latency settings with regards to perceived audio quality and link robustness.

All configuration settings used in the test results in a faultless audio link while operating with no or low intensity in-band noise.

As expected, increasing the link headroom by lowering the sampling rate increases the system robustness due to the higher number of packages being available for retransmission. Lowering the sampling rate from 44.1Ks/s to 32Ks/s increases headroom from 6 to 13 packages in each burst, representing more than a doubling of the link headroom capacity. Increasing the latency setting by two, results in two extra retransmission burst being sent within the latency time interval. Thus, increasing the latency setting from 02 to 04 results in approx. 50% increase in overall retransmission headroom. It is therefore expected that increasing the latency setting from 02 to 04 does not result in the same increase in system robustness as would be the case when reducing the sampling rate (whilst keeping the latency setting fixed). Subjective test results for the most extreme coexistence scenarios confirm this.

The high quality / low latency setting 44.1Ks/s and 13.4ms (02) latency show limited performance in moderate to extreme coexistence stress situations. This configuration setting shows acceptable performance in low stress situations such as close proximity to single WLAN nodes or single audio streamer units. Performance is generally better for stationary units, making it more suitable for domestic appliances.

Communication link robustness increases considerably when increasing latency setting and/or reducing sampling rate. The 32Ks/s, 25.8ms (04) setting handles all scenarios with only marginal effect on perceived audio quality for the two most extreme stress situations (D-2 and D-3). These tests represent scenarios where background noise is expected to be considerable, masking imperfections in the reproduced audio stream.

Frequency scans shows a varying degree of off-site WLAN related radiation at the test site originating from WLAN nodes located at premises under the coexistence test lab facilities. This has been listed as the presence of an extra WLAN-node in each test description (WLAN3). As the level of radiation is dependent on node location(s) and node traffic, the variation of radiation over time is considered to influence the test results to some extent.

4.2. Scenario II (range)

The LNKETH parameter value setting seem to have no perceivable effect on experienced audio quality when modulating the t_{st} distance ($\Delta t_{st} \leq t_{st}$). Near human body effects have not been found to affect audio quality in an indoor, low stress scenario (pendulum test, R-3). It is expected that human body effects have larger impact on audio quality/robustness in higher stress level scenarios.

Setting of this parameter should be application specific as the application designer is offered the following trade-off potential;

- high LNKETH setting yield better practical range at the expense of higher amount of audible static noise before audio muting occurs

- low LNKETH setting accelerates muting in the presence of noise, limiting the practical range

Tests indicate that a LNKETH parameter setting in the range of 52 (dec.) yield the longest practical range.

Depending on the application, the user has the option to use LNKETH-parameter as an interrupt generator that may be used to trigger soft-mute options of external devices such as a DAC.

Frequency scans shows a varying degree of off-site WLAN related radiation at the test site originating from WLAN nodes located at premises under the coexistence test lab facilities. This has been listed as the presence of an extra WLAN-node in each test description (WLAN3). As the level of radiation is dependent on node location(s) and node traffic, the variation of radiation over time is considered to influence the test results to some extent.

5. Conclusion

5.1. Scenario I (co-existence)

Tests confirm considerable improvement of robustness to close proximity, multiple in-band interferers after implementation of AFH functionality in the QoS-engine firmware. By increasing latency and/or reducing sampling rate, robustness can be increased in order to cope with the most demanding high stress coexistence environments encountered. The test-panel found noise levels to be perfectly acceptable for a configuration setting of 32 Ks/sec with 25.8ms (04) latency for even the most demanding scenarios.

5.2. Scenario II (range)

LNKETH parameter setting affects the subjective experienced range especially in test scenarios with moderate to high stress level. Tests indicate a potential of boosting practical range in the order of 50% for the moderate/high stress level scenario (vs. LNKETH setting of 01).
The absolute value of range measured in test R-1 and R-2 is *not* to be regarded as a practical value for any given application. Practical range is highly dependent on operating environment, antenna characteristics, ambient RF noise and near human body effects. Normal indoor operating distance is in the 10 meter range.

Appendix A - Definition of terms/glossary

AFH	Adaptive frequency hopping
ATX	Audio transmitter, source of audio
ARX	Audio receiver, recipient of audio
nRF24Z1-kit	nRF24Z1 MegaZig evaluation kit setup for audio streaming of 16-bit uncompressed stereo sound. Latency and sampling rates are listed for each individual test.
Super	Test assistant carrying coexistence equipment related to test
Link headroom	Transmission link headroom of audio streamer application. The amount of corrupt or lost messages that may be retransmitted at any time is dependent on the available headroom. Link headroom is dependent on sampling rate and latency settings.
softstatic	Audible soft static noise caused by corrupt data (faulty data not successfully retransmitted) emerging from the jog-memory at latency timeout. This noise is similar to muffled static noise as heard on LP-records.

Appendix B - Test environment description

Tests have been conducted in a test environment mimicking likely surroundings to application users. Floor is reinforced concrete with semiconductive vinyl surface. Roof is profiled sheet metal supported by reinforced concrete and metal girders, amplifying effect of multipath phenomenon. Surrounding walls are a various mix of glass, steel, plaster, and plywood surfaces. Windows are covered by conductive sun screening (metal tinted).
Furniture consist mostly wood, leather, foam rubber and some metal elements.

Test area floor has been marked with a 0.5 meter mesh, enabling relatively accurate estimation of distances for test personnel.

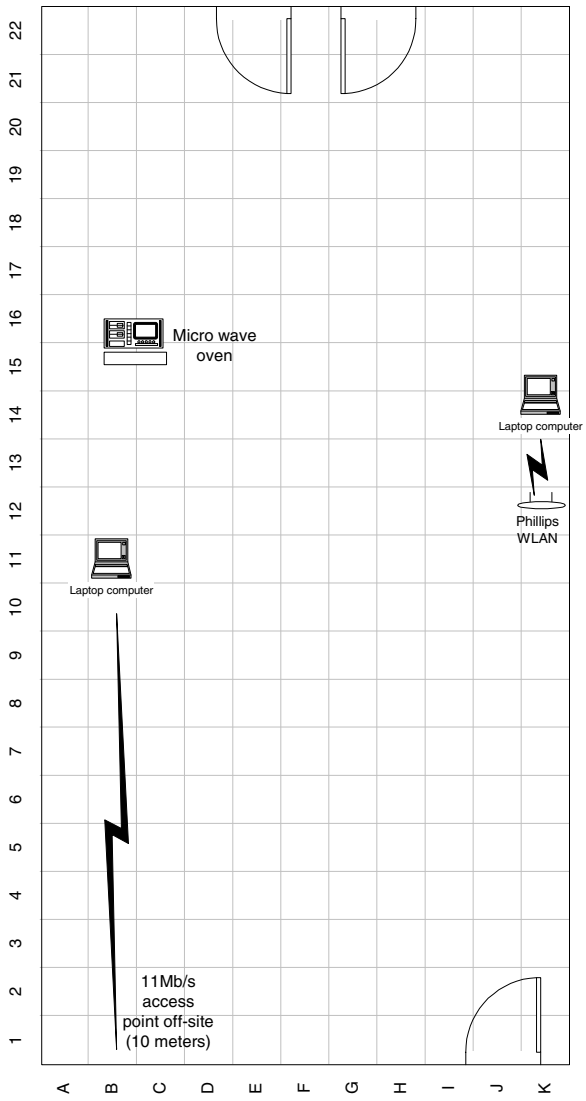

Figure B.1 – Test facility physical layout

Appendix C – nRF24Z1 audio streamer kit frequency hopping allocation tables

Test set 1					
MinFreq (decimal)	4			ATX S/N:	142 990 024
MaxFreq (decimal)	78			ARX S/N:	142 690 050
step (decimal)	22			ADDR:	85 34 12 34 65
Span (decimal)	74				
		Decimal	Hex		
INITIAL (found during link mode)		4			
CH0	26	26	1A		
CH1	48	48	30		
CH2	70	70	46		
CH3	92	16	10		
CH4	38	38	26		
CH5	60	60	3C		
CH6	82	6	06		
CH7	28	28	1C		
CH8	50	50	32		
CH9	72	72	48		
CH10	94	18	12		
CH11	40	40	28		
CH12	62	62	3E		
CH13	84	8	08		
CH14	30	30	1E		
CH15	52	52	34		
CH16	74	74	4A		
CH17	96	20	14		
CH18	42	42	2A		
CH19	64	64	40		
CH20	86	10	0A		
CH21	32	32	20		
CH22	54	54	36		
CH23	76	76	4C		
CH24	98	22	16		
CH25	44	44	2C		
CH26	66	66	42		
CH27	88	12	0C		
CH28	34	34	22		
CH29	56	56	38		
CH30	78	78	4E		
CH31	100	24	18		
CH32	46	46	2E		
CH33	68	68	44		
CH34	90	14	0E		
CH35	36	36	24		
CH36	58	58	3A		
CH37	80	4	04		

Test set 2					
MinFreq (decimal)	4			ATX S/N:	144 820 025
MaxFreq (decimal)	78			ARX S/N:	142 960 019
step (decimal)	26			ADDR:	85 AB 94 34 65
Span (decimal)	74				
		Decimal	Hex		
INITIAL (found during link mode)		4			
CH0	30	30	1E		
CH1	56	56	38		
CH2	82	6	06		
CH3	32	32	20		
CH4	58	58	3A		
CH5	84	8	08		
CH6	34	34	22		
CH7	60	60	3C		
CH8	86	10	0A		
CH9	36	36	24		
CH10	62	62	3E		
CH11	88	12	0C		
CH12	38	38	26		
CH13	64	64	40		
CH14	90	14	0E		
CH15	40	40	28		
CH16	66	66	42		
CH17	92	16	10		
CH18	42	42	2A		
CH19	68	68	44		
CH20	94	18	12		
CH21	44	44	2C		
CH22	70	70	46		
CH23	96	20	14		
CH24	46	46	2E		
CH25	72	72	48		
CH26	98	22	16		
CH27	48	48	30		
CH28	74	74	4A		
CH29	100	24	18		
CH30	50	50	32		
CH31	76	76	4C		
CH32	102	26	1A		
CH33	52	52	34		
CH34	78	78	4E		
CH35	104	28	1C		
CH36	54	54	36		
CH37	80	4	04		

Test set 3					
MinFreq (decimal)	4			ATX S/N:	144 820 147
MaxFreq (decimal)	78			ARX S/N:	144 790 060
step (decimal)	30			ADDR:	85 83 C1 86 22
Span (decimal)	74				
		Decimal	Hex		
INITIAL (found during link mode)		4			
CH0	34	34	22		
CH1	64	64	40		
CH2	94	18	12		
CH3	48	48	30		
CH4	78	78	4E		
CH5	108	32	20		
CH6	62	62	3E		
CH7	92	16	10		
CH8	46	46	2E		
CH9	76	76	4C		
CH10	106	30	1E		
CH11	60	60	3C		
CH12	90	14	0E		
CH13	44	44	2C		
CH14	74	74	4A		
CH15	104	28	1C		
CH16	58	58	3A		
CH17	88	12	0C		
CH18	42	42	2A		
CH19	72	72	48		
CH20	102	26	1A		
CH21	56	56	38		
CH22	86	10	0A		
CH23	40	40	28		
CH24	70	70	46		
CH25	100	24	18		
CH26	54	54	36		
CH27	84	8	08		
CH28	38	38	26		
CH29	68	68	44		
CH30	98	22	16		
CH31	52	52	34		
CH32	82	6	06		
CH33	36	36	24		
CH34	66	66	42		
CH35	96	20	14		
CH36	50	50	32		
CH37	80	4	04		

Test set 4					
MinFreq (decimal)	4			ATX S/N:	144 820 036
MaxFreq (decimal)	78			ARX S/N:	144 700 035
step (decimal)	34			ADDR:	85 2B 39 CC 83
Span (decimal)	74				
		Decimal	Hex		
INITIAL (found during link mode)		4			
CH0	38	38	26		
CH1	72	72	48		
CH2	106	30	1E		
CH3	64	64	40		
CH4	98	22	16		
CH5	56	56	38		
CH6	90	14	0E		
CH7	48	48	30		
CH8	82	6	06		
CH9	40	40	28		
CH10	74	74	4A		
CH11	108	32	20		
CH12	66	66	42		
CH13	100	24	18		
CH14	58	58	3A		
CH15	92	16	10		
CH16	50	50	32		
CH17	84	8	08		
CH18	42	42	2A		
CH19	76	76	4C		
CH20	110	34	22		
CH21	68	68	44		
CH22	102	26	1A		
CH23	60	60	3C		
CH24	94	18	12		
CH25	52	52	34		
CH26	86	10	0A		
CH27	44	44	2C		
CH28	78	78	4E		
CH29	112	36	24		
CH30	70	70	46		
CH31	104	28	1C		
CH32	62	62	3E		
CH33	96	20	14		
CH34	54	54	36		
CH35	88	12	0C		
CH36	46	46	2E		
CH37	80	4	04		

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