TRAINING PROJECT LABORATORY REPORT

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

This is a report for training project laboratory in electrical engineering info-communication BSc course. This laboratory consist of two parts, both will be covered by this report. The first part is circuit realization and measurements around a radio direction finder receiver. The second part is measurements, calculation and software tools realization in Space technology laboratory.

1 PART1 – RADIO DIRECTION FINDER RECEIVER

From week 1 to 7 I was working on the radio direction finder receiver. Our task is to realize the circuit following the schematic. The printed circuit board(PCB) is prepared in advance.

1.1 Components

SURFACE MOUNTED COMPONENTS All resistors, capacitors, inductors and transistor are packaged using surface mount technology(SMT). Which makes them tricky to hand solder on the board. When to much soldering is applied a short circuit could happen between pads underness components. A multimeter is very useful for troubleshooting.

THROUGH HOLD COMPONENTS Audio jack, potentiometer and crystal oscillator are through hold components which provided a firm connection to the PCB.

1.2 Circuit design

The circuit is designed in KiCad

1. The radio receiver:
   The main blocks:
   - 9 turns from 210 cm CuZ copper wire as antenna,
   - radiofrequency (RF) amplifier,
   - RF band pass filter,
   - bipolar junction transistor (BJT) based mixer,
   - local oscillator,
   - audio frequency low pass filter,
   - audio amplifier.
2. The test transmitter:
   Collpitts type oscillator, where the quartz frequency is some 100 Hz different from the receiver local oscillator frequency, in order to make audio signal and it can be heard.

1.2.1 *Schematic*

The schematic diagram of the receiver is in Fig. 1.

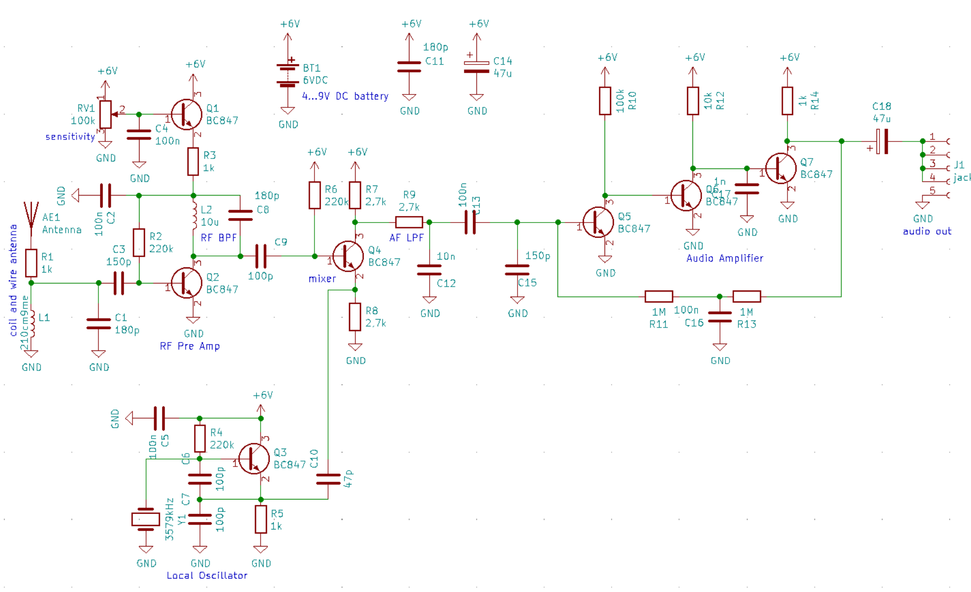


Figure 1: Schematic

1.2.2 *Printed Circuit Board*

The designed PCB can be seen in Fig. 2. There are THT and SMD type components.

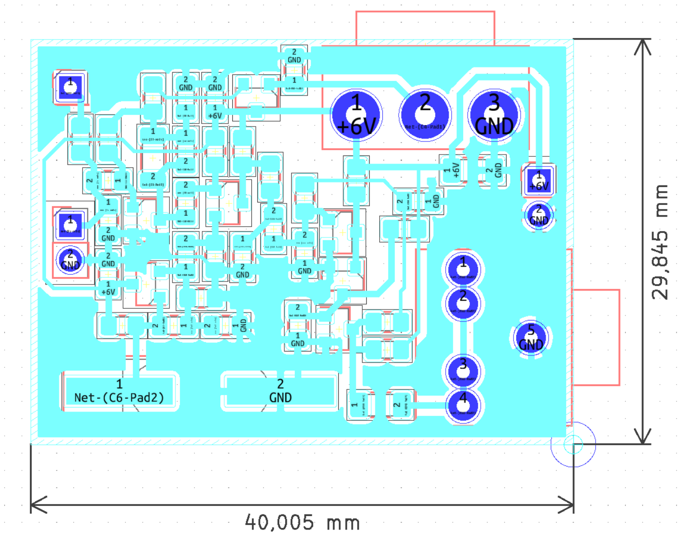


Figure 2: PCB

1.2.3 *Component placement*

The components with its reference is in Fig. 3.

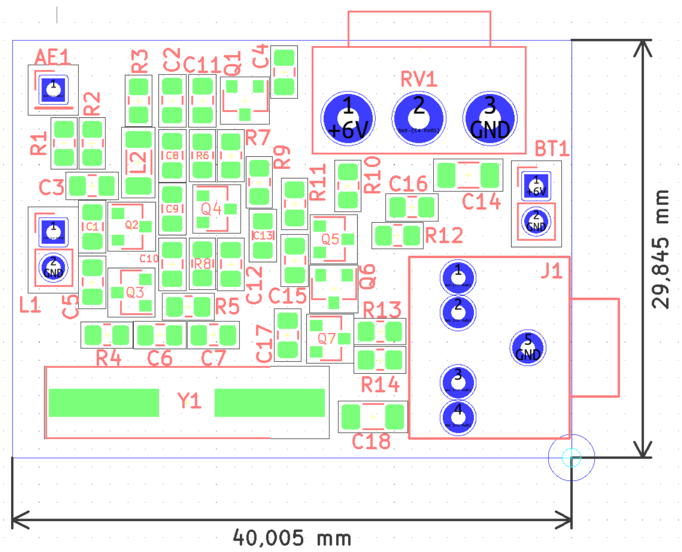


Figure 3: Components Placement

1.3 Measurements

The task is to measure the following parameters of the realized circuit and make test and measurement report based on the measurement results.

1. Bias DC voltages to the reference GND point on all pins of all semiconductors.
2. Voltage curve in time of the local oscillator output (emitter): peak-to-peak voltage and frequency.
3. Receiver audio (time domain) output signal on the AF output connector: variable resistor low, middle, high position: peak-to-peak voltage, frequency, curve. During this measurement, a single test transmitter will be run near to the receiver.

1.3.1 *Bias DC voltage of transistors*

DC voltage is measured reference to ground. And potentiometer is set to a low position during measurements.

Transistor	Voltage
Q1	807mV
Q2	72.4mV
Q3	2.79V
Q4	1.94V
Q5	96.5mV
Q6	97.2mV
Q7	96.9mV

Table 1: Transistor voltage measurement

1.3.2 Voltage curve in time domain of the local oscillator output

In this measurement 10x probe gain is used. I used the quick measure function on the oscilloscope.

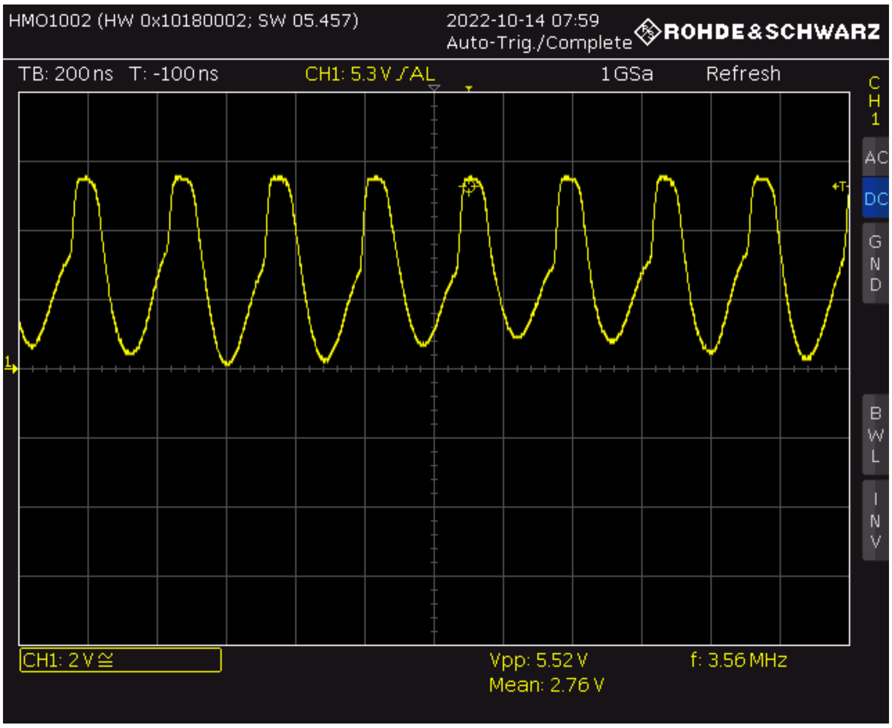
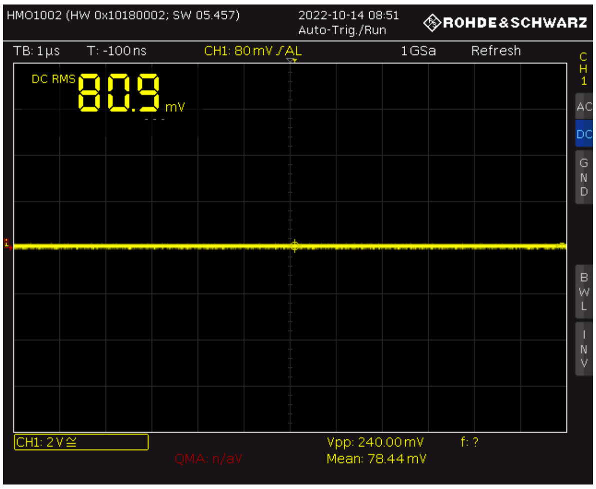


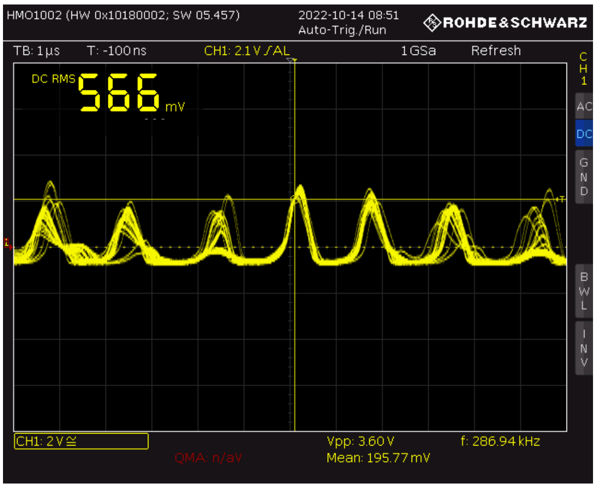
Figure 4: local oscillator output

From the schematic 1 we can see that a crystal oscillator with 3.579MHz frequency is used. Our measurement result matches this value within 0.5% of error.

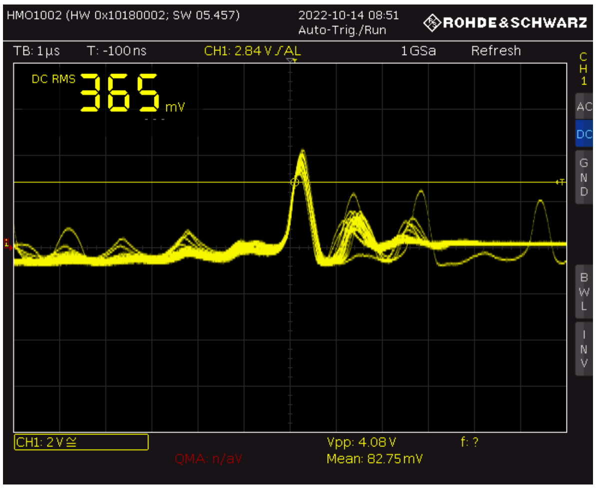
1.3.3 Receiver audio (time domain) output signal



(a) Low



(b) Mid



(c) High

Figure 5: Receiver audio output signal in time domain

2 PART2 – 58GHZ ATTENUATION

From 8 to 14 week I worked for Space technology laboratory supervised by Dr. László Csurgai-Horváth. Our topic is to research about oxygen and rain attenuation on 58GHz radio signal.

2.1 Introduction on 58GHz band

Signal around 60Ghz band has a unique advantage. Around this frequency signal propagation is effected by oxygen molecule in the air. This phenomenon is called oxygen attenuation. Because such phenomenon, signal can not propagate for long distance. In urban area where high bandwidth communication is required this property can increse frequency reuse rate which will conserve frequency band resource.

2.2 Experiment setup

Two antennas are placed on the roof of building V1 and building E. An indoor unite was set in the laboratory for data logging.

GEOMETRY Geolocation of antennas are measured using GPS coordinate where distance and elevation angle can be calculated. GPS coordinates are:

- Building V1 antenna: 47.476647, 19.056420, 123.2m
- building E antenna: 47.477423, 19.057490, 146.8m

From above data we calculated distance $d = 118.0m$ and elevation angle $\theta = 11.537°$

HARDWARE SPECIFICATION Testing divices are consist of indoor and outdoor units. Both manufactured by Nokia Network. Hardware specification are defined in the user manual of these units [1]

- Frequency: 57.725GHz
- Polarization: vertical
- Antenna gain: 34dB
- Transmitter output power: 5dBm

2.3 Calculations

FREE SPACE LOSS Free space loss is the loss when signal travels through open space with no other attenuation. This can be calculated using following equation [2]

$$a_{sz}^{[dB]} = 32.44 + 20\log f^{[MHz]} + 20\log d^{[km]} - G_{TX}^{[dB]} - G_{RX}^{[dB]} \quad (1)$$

Where:

- a_{sz} is free space loss in dB
- f is radio frequency in MHz
- d is distance between transmitter and receiver in km
- G_{TX} is transistor antenna gain in dB
- G_{RX} is receiver antenna gain in dB

OXYGEN ATTENUATION Oxygen attenuation or Atmospheric attenuation is the effect of signal propagation due to gas in the atmosphere. The following figure is given in ITU-R P.676 [3] which demonstrate signal attenuation with different frequency. A peak at around 60GHz is clearly visiable which is casued by oxygen molecule in the air.

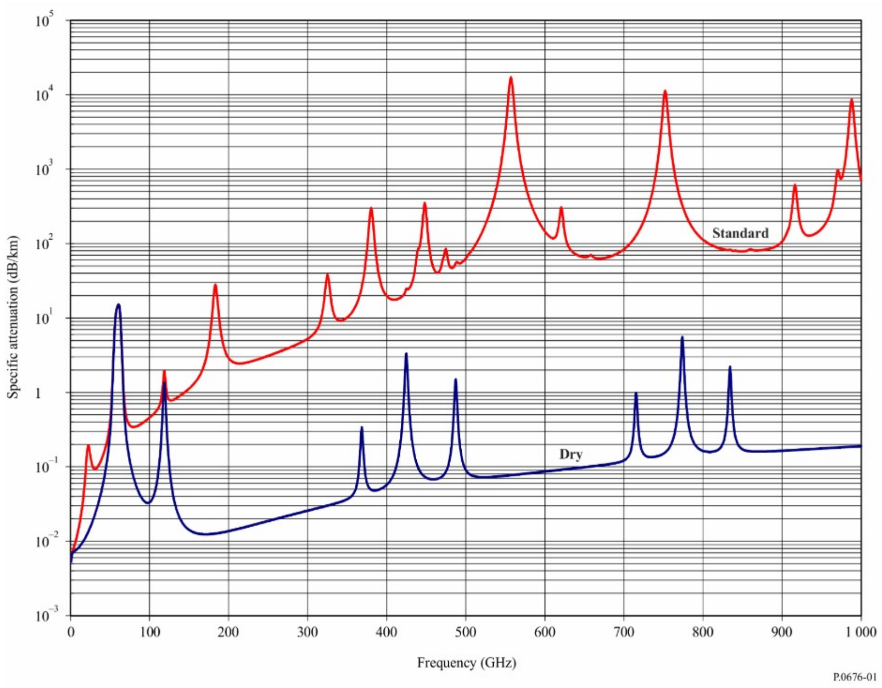


Figure 6: Atmospheric attenuation

The calculation of oxygen attenuation can be quite complex, but for the purpose of estimation, the software program Matlab offers a built-in function `gaspl` that can be used.

```
L = gaspl(range,freq,T,P,den)
```

arguments:

- range: Signal path length in multimeters
- freq: Signal frequency in Hz
- T: Ambient temperature in degrees Celsius
- P: Dry air pressure in Pa
- den: Water vapor density or absolute humidity in g/m^3

RAIN ATTENUATION Rain attenuation is our main research direction. We want to measure how rain will effect signal propagation on this particular frequency. The specific attenuation γ_R (dB/km) is obtained from the rain rate R (mm/h) using the following equation:

$$\gamma_R = kR^{\alpha} \tag{2}$$

Where:

- f: frequency(GHz)
- k: either k_H or k_V
- α: either α_H or α_V

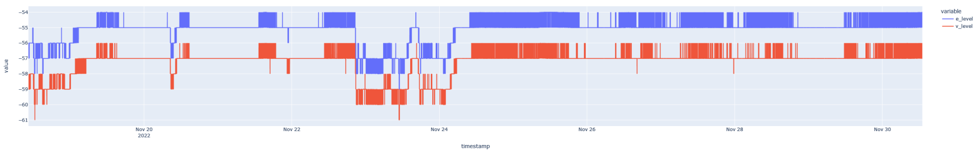
Values for the constants k and α is given in the ITU-R P.838 [4]

Frequency	k_H	α_H	k_V	α_V
58GHz	0.8226	0.7731	0.8129	0.7552

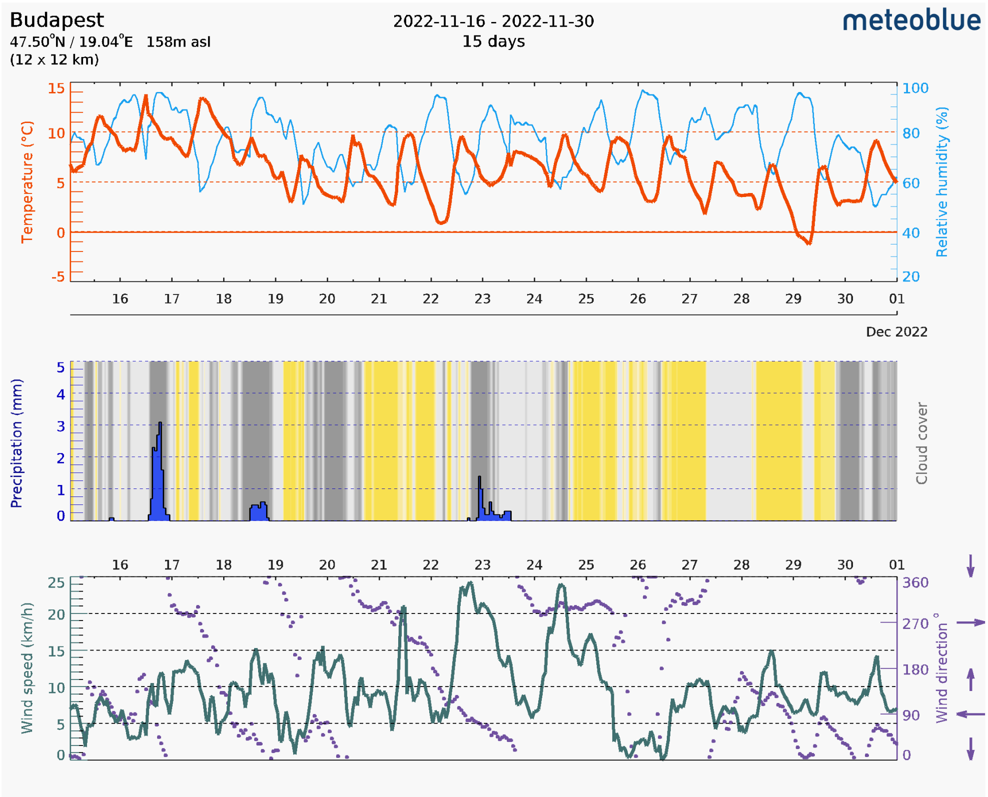
Table 2: Frequency-dependent coefficients for estimating specific rain attenuation

2.4 Measurement result

We can observe the change of signal level by ploting the signal level over the span of 15 days.



(a) Signal level



(b) Weather data

Figure 7: Signal level compared to weather data from 16Nov to 30Nov

Figure 7.a shows the signal level from 16 Nov to 30 Nov. Unfortunately some data are missing because of the unreliable data logging software.

Figure 7.b is the historical weather level. [5]

We can observe a clear corelation between signal level and precipitation.

2.5 Data processing

The measurement for this experement happens in a span of several monthes to cover different weather condition. Significant amount of data is generated during this process. As a result it is crucial to save and process the data in a safe and efficient way. I created two program for data processing. One is running on the data logging computer in the laboratory and the other is running on a cloud server for data visualisation.

2.5.1 Data collection

The measurement data is generated by Nokia HopperManager. A management software designed to work in pair with our equipments. The measurement logs are in text file format and is designed to be human readable. Here is a example of HopperManager log file:

```
    Measurements logged at : 14:40:24 27-10-2022

Unit                              MC Name          Value     Time
*****************************************************************

OU1A:MetroHopper: Radio InterfacRx level           -57 dBm   14:40:21 27-10-2022
Flexbus 1 far-end: OU1A:MetroHopRx level           -54 dBm   14:40:21 27-10-2022
```

I wrote a python program that extract 3 data fields from the log using regex. The signal level of both receiver and a timestamp. The program then upload these data to a database. This program also support batch uploading. User can sepcify a directory which contains logfiles and the program will automatically upload all the files.

The following regex pattern is used to match 3 data fields from a logfile.

```
(?:InterfacRx.+)(-\d{2})(?:\sdBm\s{3})(\d{2}:\d{2}:\d{2}\s\d{2}-\d{2}-\d{4})(?:\n.+\s)(-\d{2})
```

2.5.2 Data visualisation

I also created a webapp running on Oracle cloud using a lowcode development library called Dash. User can select a time range on the website and the webapp will fetch the data from database then plot a graph.

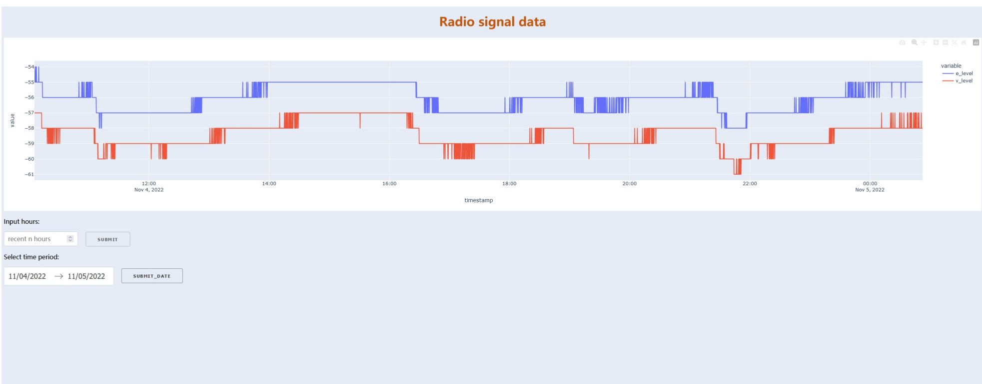


Figure 8: A screenshot of webapp

The webapp is available at this ip address: `http://152.70.177.227:8080/`

2.5.3 *Data storage*

Oracle Cloud Autonomous Database is used to store all the measurement data. This assures that in an event of a power loss all data will be preserved.

Considering data security reasons, both programs are configured as dedicated database user who are granted with necessary permition only.

2.6 Outlook

MEASUREMENT RESOLUTION The resolution of measurements is only 1dBm and data logging interval is 10 second. Both of these are limitations of HopperManager. It is possible to increse the resolution to 0.1 dBm and shorten the interval by using the built-in scripting tool. But the scripting language is a proprietory standard of Nokia with very limited documentation.

DATA COLLECTION SOFTWARE My original design is to let the program running continuously to achive realtime data uploading. But since logfiles generated by the script tool is different from current file format it requires further development to be compatible with newer format.

Also it will be ideal if the data collection software can monitor the system thread of HopperManager and report automatically in the event of software crash. The report can be done by using Webhook which can be easily integrated into Microsoft Teams.

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[1] Nokia Network Oy. *Nokia MetroHopper Radio Product Description*. C33512.09.

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