WECODEC

the westbury community development centre

Final Report of a DRM Trial in the FM-Band

Westbury, Johannesburg, South Africa

V2.51

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Document History

Version	Date	Item changed/added
0.1	05 June 2017	Template prepared from license application, research, strategy and regulatory documentation
0.2	09 June 2017	Changed/added: Structure, objectives, timelines, systems, methodology
0.3	12 June 2017	Changed: Structure; Added: Results
0.4	13 June 2017	Added: Contributors, Copyright
0.5	22 June 2017	Added: Drive-by measurements, propagation Maps, and explanations
1.0	30 June 2017	Touch-ups
1.4	07 July 2017	About WECODEC and Project Partners, final touch-ups and release
2.0	15 April 2018	Added measurements in North Johannesburg/Gauteng
2.1	22 April 2018	Added Title Picture, added content, touch-ups
2.4	23 April 2018	Added Content in chapters Objectives, Reasons, Benefits, final touch-ups
2.5	15 May 2018	Touch-ups after review with project partners

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Project Partners:

The Westbury Community

The Westbury Youth

Thembeka & Associates

BluLemon, Edenvale, South Africa

BBC World Service, London, UK

Fraunhofer IIS, Erlangen, Germany

STARWAVES, Switzerland

The DRM Consortium

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1. Executive Summary

The Westbury Community Development Centre Trust (WECODEC), license holder of Kofifi FM 97.2, a community radio station in Westbury, South-West Johannesburg, with support from the BBC World Service, Fraunhofer Institute for Integrated Circuits, and others, initiated a trial broadcast project to evaluate DRM Digital Radio Mondiale in the VHF Bands (also known as Mode E or DRM+).

A 2-fold trial frequency spectrum license was issued by ICASA for Johannesburg on 101.25 MHz and Carnarvon on 64.0 MHz and became effective on 03 March 2017 for a period of 8 months in which the Johannesburg trial was conducted. An extension has been applied for to test transmissions in Carnarvon in the extended FM-Band.

Mobile measurements have taken place in 8 radial directions as well as various additional mobile measurement excursions with both professional and (pre-) consumer receiver equipment. The main technical objectives of the trial – acquiring evidence of no interference with adjacent FM transmissions and evaluation of the propagation characteristics of the signal – have successfully been achieved. This final report contains all propagation maps and measurement results for the Johannesburg trial. A separate report will be compiled for the Carnarvon trial once concluded.

Apart from the technical part, this trial also looks at spectrum efficiency and evaluates the socio-economic benefits for the Westbury community and South Africa and its broadcasters and listeners.

For the Johannesburg transmission we were using a Nautel 2.5 kW transmitter operating at 175 W and 275 W resulting in an estimated ERP of 500-1000 W on our stacked 4 vertical dipole antenna located at Rahima Moosa Hospital in Coronationville with an approximate antenna height of 70 m above ground level. Although mobile reception is still impacted by prematurity of receivers without an appropriate AGC mechanism, audio decoding was possible at almost all predicted areas and beyond and showed a similar or better behaviour than FM audio reception of the analogue signal that is transmitted from the same site depending on the terrain.

Power consumption per service is much lower than FM: 12x for mobile and 30x for fixed reception.

Both **adjacent frequencies** RSG Pretoria on 101 MHz and RSG Brixton on 101.5 MHz **were not interfered by our transmissions**. Our frequency (101.25 MHz) is part of dead frequency spectrum that cannot be used for analogue FM but it is perfectly suitable for DRM: Hence it was demonstrated that the **existing dead FM spectrum can accommodate** a large number – only **in Joburg around 50**(!) – **additional DRM radio programs** without impacting or need of restacking any existing FM services.

The other way around it was also demonstrated that RSG's **adjacent transmission** on 101.5 MHz transmitting at 33 kW ERP (18 dB stronger) **did not impact the reception of our signal** even at difficult indoor scenarios. Correlation between predictions and real reception was not impacted by diverse exposure to the adjacent transmissions. Consequently, a **separation of 250 kHz between an FM and a DRM transmission in the FM Band is sufficient** in case of mixed spectrum utilization.

Along 3 audio programmes using the latest xHE-AAC codec, various text and data services including Journaline were broadcasted and successfully decoded with both professional and consumer receivers. Bit rates as low as 16 kbps per audio service provided good stereo quality and could proof that **this technology is the most spectrum efficient solution currently in the market** that will benefit the communities, have a huge impact in the licensing framework and will create jobs in South Africa.

2. Introduction

DRM (Digital Radio Mondiale) is a digital radio standard, initiated by the DRM consortium in 1998 and later adopted by ITU. The consortium developed this digital transmission system for the AM-Band, i.e. for long-, medium- and short waves (up to 30 MHz, DRM Mode A-D) and launched the system worldwide. The extension of the DRM system family to upper frequency bands from 30MHz up to 254 MHz (also called DRM or DRM Mode E) is standardized under ETSI ES 201980 V3.1.1 (2009-02-16) and ITU-R Rec. BS.1660. DRM is a spectrum efficient system with a bit rate capacity in Mode E up to 186 kbps at only 96 kHz bandwidth. The COFDM modulation techniques combined with the appropriate use of a guard interval enables single frequency network (SFN) operation, and robust mobile reception up to 300 km/h also in multipath environments.

Data services, multiplexing and signalling schemes are the same as in the earlier established part of the DRM standard. In Mode E, a wide range of possible data rates from 37 to 186 kbit/s allows for flexible use of the mux with respect to the number and type of programs (audio, data, video) adjusted to the broadcasters' requirements and preferences. Up to four (typically three) radio programmes with excellent sound quality or 5.1 surround sound can be combined in a single transmission. Also several kinds of data services can be transmitted including DRM text messages, Journaline advanced text, Slideshow images, EPG, traffic information, etc. Most services are also standardised in DAB+ so DRM can be perfectly combined with existing AM/FM/DAB+ networks and received seamlessly. The DRM System is an open standard and due to its small bandwidth it fits well into the European/African AM and FM raster.

3. Co-existence of DRM and FM in VHF Band II: Johannesburg Example

One of the main objectives of the development of DRM in the VHF Bands was the possibility of a close placement of DRM signal to an FM signal so that it can be flexibly configured depending on the existing use of spectrum. In this way, DRM may be introduced into the FM frequency bands.

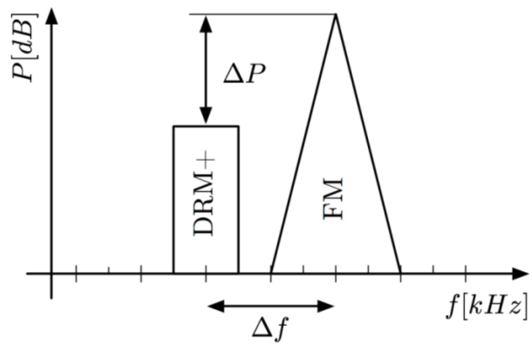


Figure1: Example configuration for DRM robustness mode E and FM signal

Figure A1-1 illustrates how the DRM transmission can be placed closely above or below the existing FM transmission (**as demonstrated DRM needs only 10% of the power of a FM transmission** so ΔP is naturally already at a >10dB advantage). To guarantee the respective protection levels and audio quality of the FM transmission, the carrier frequency distance Δf and the power level difference ΔP of the FM and the DRM transmissions have to be planned accordingly. Δf can be chosen according to a 50 kHz channel raster. Δf >= 150 kHz is recommended. ΔP can be varied flexibly; however, a ΔP > 20dB is recommended for the minimum Δf = 150kHz according to previous evaluations.

Looking at the heavily congested FM spectrum in Johannesburg, a proof of DRM not interfering with adjacent FM transmissions, would demonstrate the feasibility of the standard.

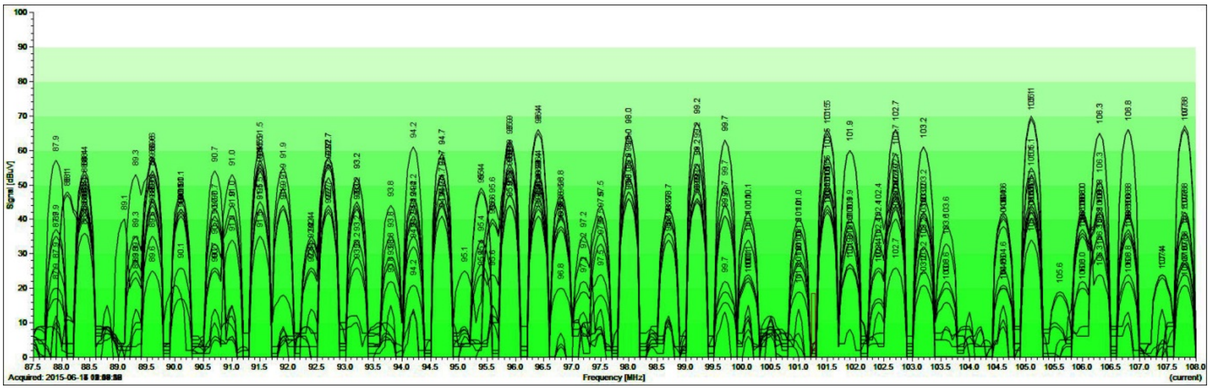


Figure 2: Overlay of Scans of the FM Spectrum in various parts of Johannesburg

Figure A4-1 confirms that there would be no space for another FM transmission in Johannesburg except for perhaps one or two low-power radio stations with a very limited coverage area.

However, if one gap as the one that we have identified for our trial would work for DRM without interference in both ways, it would proof that there will be suddenly plenty of available digital spectrum in the FM Band, namely 16 allocations (marked in red) as per the below figure:

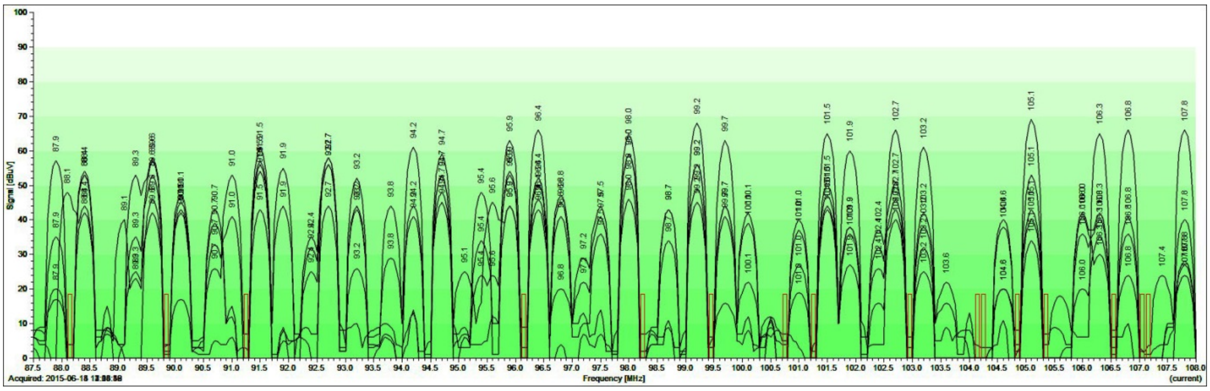
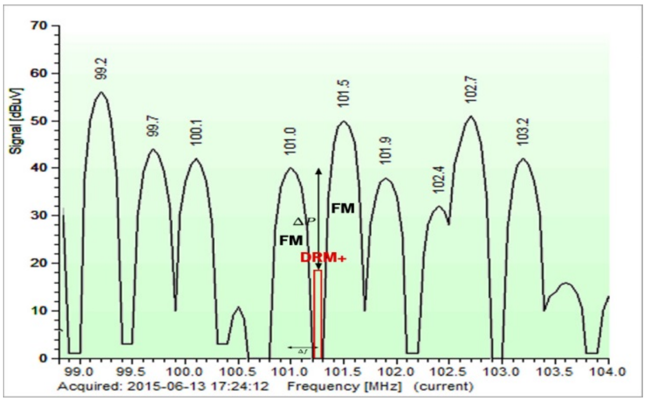


Figure 3: Possible DRM+ Allocations in the FM Band in Johannesburg

Considering at least 3 sound programmes per DRM signal in the FM-Band, in this scenario up to **48 additional sound programmes could be added to the current FM spectrum in Johannesburg**. If going down to 200kHz@-10dB this number would even increase a lot more.



As a good candidate for such a frequency we have identified the frequency 101.25 MHz as a possible candidate. It is situated between 101.0 MHz (RSG Pretoria, 33 kW ERP, distance: 56 km) and 101.5 MHz (RSG Johannesburg, 38 kW, 3 km distance) with a delta f of each 250 kHz as shown in figure A4-4:

Figure 4: Our DRM+ allocation for the trial

None of the intermediate frequencies (101.2 - 101.4 MHz) were used elsewhere within a radius of 160 km. And as Kofifi FM 97.2 was already transmitting from Rahima Moosa Hospital, Coronationville, we decided to co-locate the trial DRM transmitter at the same place. This allowed us also to precisely compare the coverage of the FM and DRM transmissions, utilize the same antenna system (with a combiner) and other advantages such as site security, power, air-conditioning etc.

4. Reasons for the Trial

The DoC and DTPS, as well as ICASA, SABS, and SADIBA, were looking at the two digital radio standards DAB and DRM. Both DAB and DAB+ had been tested by Sentech since 2006 and DRM in the AM Band (DRM30) has been tested by Radio Pulpit in 2014/2015 whereas **DRM+ had never been tested on the African continent yet**. Due to the assumed advantages and socio-economic benefits (see below) of the system, a DRM VHF trial was therefore highly recommended. This was also raised at the SADC BDM Conference on 17 March 2016 in Maseru and the CRASA Conference in June 2016.

By its compact design and tiny bandwidth allocation, it is believed that DRM is a perfect technology to be used for community radio. This is why WECODEC as a community radio station was keen to undertake the trial and to confirm that also from its technical and economic capacity a community radio station will be able to implement, operate and control such digital sound broadcasting service all on its own – if necessary. The benefits for the community, besides better sound quality, are much lower operating costs (less power consumption, less maintenance on lower power transmission equipment, less replacement costs in case of damage or loss), multilingual programs, free digital information systems (Journaline: comparable with social media but free of data charge) and content development programs that would benefit the youth. As currently many community radio initiatives are blocked by moratorium, DRM in VHF could be a quick intervention opening this channel again.

Although VHF Band III spectrum was allocated to most subscribers of the GE-06 conference also for digital radio, at that time the demand on digital dividend spectrum was not foreseeable. This is why most countries, specifically those who adopted DVB-T2 at a later stage, made lots of significant changes to their GE-06 spectrum allocations with the aim to free frequency spectrum to be used for IMT broadband services. However, the demand on such spectrum is still much higher than the amount of available spectrum can cover. This is why more and more countries consider utilizing the entire UHF Band for IMT broadband in the future to ensure universal access to information to every citizen. In this case DTT also will have to find a new accommodation so this potentially could force DTT to be moved back into VHF Band III. Consequently, as DAB+ requires spectrum in Band III, South Africa would benefit from a Digital Radio system that does not block VHF Band III.

Then again, DRM can also be operated in the Extended FM Band (part of VHF Band I) which is the only spectrum allowed for broadcasting in or close to the SKA. At present, South Africa has not yet come up with a solution to serve the already underprivileged communities in the Karoo with universal access to information – DTT is not allowed and broadband still very scarce. DRM could be the perfect intervention therefore the second location in Carnarvon close to the SKA has been selected for this trial.

Technically, this trial gave results with regards to coverage (4QAM and 16QAM) compared to FM, in both urban and rural environments. Also we got evidence that there was no interference between DRM and FM in a real live broadcasting environment. Another aim was the test of DRM receivers and giving an opportunity to the local industry to develop own receivers and test with our signal.

5. Timeline of the Trial so far

- April 2015 The idea of undertaking a DRM+ trial in Johannesburg was discussed at the SADIBA Digital Broadcasting Now Workshop in Johannesburg
- June 2015 Negotiations between DRM, BBC and WECODEC started
- September 2015 The intended project was presented to an international audience at IBC
- December 2015 An MoU was signed between BBC and WECODEC to undertake the trial
- April 2016 The trial equipment was sent from BBC to WECODEC and WECODEC submitted a trial license application to ICASA
- May 2016 The equipment was installed at our FM transmitter site in Coronationville
- June 2016 The need for the trial was also confirmed at the 2017 CRASA workshop
- August 2016 Presentations were held by WECODEC at ICASA for further explanations
- September 2016 Thembeka and Johannes undertook a travel to 4 destinations in Europe to verify the feasibility DRM and its benefits for South Africa
- October 2016 Tk and JvW presented a report with its finding of the Europe trip to ICASA
- January 2016 Lee was assigned as project manager to support the trial activities
- February 2017 The trial license was issued by ICASA becoming effective on 1 March 2017
- 10 March 2017 The transmission officially started in presence of WECODEC team and ICASA staff members. First objective – no interference towards adjacent channels – was demonstrated and verified;
- 22 March 2017 The trial project was presented at the German DRM Forum in Bonn;
- April-May 2017 Mobile measurements were taken; various consumer receiver setups were tested and software improved as consequence of the trial; trial was presented at the DRM Consortium General Assembly in Zurich;
- June-July 2017 Localization of Journaline data services; further tests with consumer receivers were performed; an interim report was produced and submitted; the monitoring receiver needed to be shipped for repairs;
- September 2017 An extension for the license to conclude with the Carnarvon trial was submitted to ICASA;
- October 2017 Monitoring receiver came back and drive tests measurements concluded;
- December 2017 End of the technical evaluation of the FM Band trial in Johannesburg;
- April 2017 This final report is published.

6. Objectives of the Trial

The objectives of the trial in details are:

- To verify that DRM if operated in FM Band will not interfere with existing FM transmissions;
- To evaluate if FM transmissions adjacent to a DRM signal have an impact on the DRM signal;
- To compare the real DRM signal propagation with prediction calculations;
- To confirm proposed benefits of the DRM system in the VHF Bands, in particular:
    - Spectrum efficiency and power savings compared to FM;
    - Sound quality – specifically of the new audio codec xHE-AAC;
    - Showcasing data including educational services with specific focus on Journaline;
    - Evaluation of receivers that are available and can be used by consumers;
    - Real effect of DRM in the communities in terms of youth and woman participation;

- The effects of DRM for Community Radio Stations in the FM Band and how to potentially share this Band with both Public and Commercial Broadcasters;
- To analyse effects on the Licencing Framework of DRM in the VHF Bands not only for community but also for public/commercial broadcasters;

- To compare different robustness modes (4QAM vs 16QAM);
- To analyse DRM vs FM propagation characteristics and verify official planning parameters.

7. Our Transmission System for the Trial

As loan from the BBC, WECODEC received a complete DRM transmission/broadcast chain containing:

- 1x RFmondial DRM Content Server (based on Fraunhofer technology) for audio/data encoding and multiplexing;
- 1x RFmondial A/D Interface;
- 1x RFmondial DRM Modulator for the VHF Band;
- 1x Nautel Exciter/Transmitter;
- 1x Nautel 2.5kW Power Amplifier;

and the RF-SE monitoring receiver by RFmondial. In our first configuration we installed the system with the receiver to setup and test the functionality on a dummy load (picture: May 2016).

Later we had to remove the monitoring receiver as we needed it as receiver for our mobile measurements.

2 months later, also the satellite dish and receiver to receive BBC World Service as another audio source for the trial was installed. The final setup is as follows:

← FM Power Transmitter for Kofifi FM 97.2

← FM Exciter for Kofifi FM 97.2

← STL Receiver for both Kofifi FM 97.2 and DRM
← RDS Encoder for Kofifi FM 97.2
← BBC C-Band Receiver

← DVD Player for third DRM Audio source

← Content Server for DRM System
← DRM Modulator
← Audio A/D Converter

← DRM Exciter

← DRM Power Transmitter

(Front view of transmission system).

Back view of the transmitter rack and the 4-dipole antenna system with BBC C-Band reception dish:

The transmission chain and equipment in detail:

STL Receiver Channel 1	BS Electronics, Cape Town, South Africa
C-Band Receiver Channel 2	XDS PRO-40, X -Digital Systems, San Diego, CA, USA
DVD Player Channel 3	SINOTEC, Midrand, South Africa
Connectivity STL to A/D converter:	Balanced Stereo Audio over 2x XLR
A/D Converter:	RFmondial, Germany
Connectivity to Content Server:	UDP over IP over Ethernet
Content Server	RFmondial, Germany
Connectivity to DRM Modulator	MDI over IP over Ethernet
DRM Modulator	RFmondial, Germany
Connectivity to VHF Band II Exciter	Baseband over AES/EBU over XLR
VHF Band II Exciter	Nautel, Canada
VHF Power Transmitter	Nautel 2500, Canada
Connectivity to Combiner	Coaxial 7/8' EIA to 7/8' EIA
Combiner	97.2 MHz FM / 101.25 MHz DRM 7/8' EIA to 1 5/8' flange
Lightning Protector	BS Electronics, Cape Town, South Africa – 3x 7/16' DIN
4-way Antenna Splitter	RF Industries, Alberton – 7/16' DIN to 4x N-Type
4x VHF Band II Antennas	RF Industries, Alberton, South Africa
Internet connectivity	iBurst

Technical Transmission Specifications:

RMS Power Range	64 - 2500 W RMS
RMS Typical Power	175 W RMS
Antenna Gain	6 dBd
Cable/splitter loss	approximately 1.4 dB
Typical ERP	500 W - 1000 W
Transmission Frequency	101.25 MHz
Modulation; Bandwidth	DRM Mode E; 96 kHz

Antenna System and Location:

Antenna system	4-stack vertical dipole
Co-ordinates	27E58’20’’ / 27S11’23’’
Physical address	Rahima Moosa (Coronation) Hospital, Fuel Road, Westbury
Antenna height	60 m
Antenna height above sea level	1720 m
Polarization	Vertical
Beam width	Omni-directional

DRM Parameters:

DRM Mode	E
Modulation	4 QAM / 16 QAM (Typical: 4 QAM)
Protection Level (from 0 to 3)	1 (code rate 0.33)
Bitrate	49680 bps (typical)
Services	1. Audio: KOFIFI DRM 101.25, xHE-AAC mono, 14320 bps 2. Audio: BBC World Service, xHE-AAC mono, 12320 bps 3. Audio: (various), HE-AACv2 parametric stereo, 19360 bps 4. Data Services including Journaline Demo: 3680 bps

License Details:

License Number	001/Trial/DRM+/WECODEC/Nov2016
Issued on	02 February 2017
To	Westbury Community Development Centre Trust
Effective from	01 March 2017
Valid until	31 October 2017
Signal Distributor	BluLemon
Geographic Coverage Area	Westbury, South of Johannesburg, Sophiatown and surrounding areas within the City of Johannesburg Metropolitan (and in Carnarvon in the Northern Cape) as set out in the attached technical specifications in Schedule B2 of the license (Appendix)
Designation of Emission	96K0X7EXF
Frequency Stability	2 kHz
Spurious Emissions	6 0dB / 1 mW

8. Our Receiving Units and Setups for the Trial

As part of the loan equipment provided by BBC World Service, an RFmondial DRM Monitoring Receiver was dispatched to WECODEC together with the first lot of broadcast equipment in April 2016. This receiver was used to setup and test the transmission equipment on a dummy load (provided by Carlos Rebelo) prior to real field trials. Once the system was initialized and considered functional, the receiver was removed from the transmission site and prepared for installation in our measurement vehicle. As a replacement we have equipped the transmitter site with a RTL-SDR based USB receiver operated on a PC with the open source software SDR Sharp.

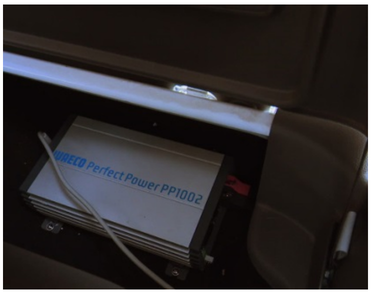
Besides this professional receiver, various low-cost consumer devices (to operate in conjunction with PC's, laptops, tablets or smart phones) have been acquired and are being tested in this trial.

8.1 Our Drive-By Measurement Vehicle

Contributed by Kofifi TV, WECODEC is using a Volkswagen Caddy for the drive-by measurements.

Sent in for preparations

Car antenna



DC/AC Inverter to supply 230V

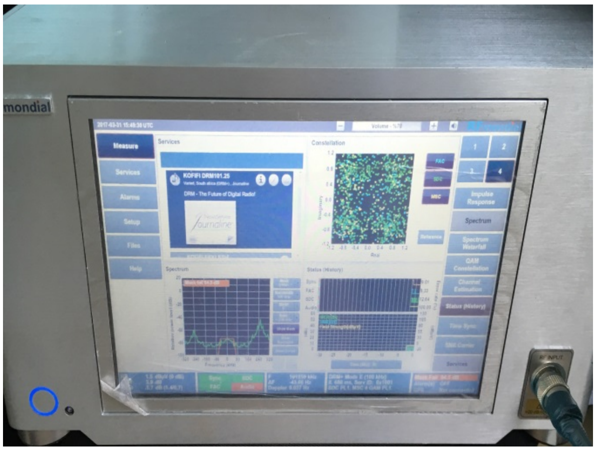
Magnet Antenna

The car was equipped with a generic FM car antenna to simulate real-life reception conditions. As some equipment including the RFmondial monitoring receiver operates at 230V current, we also had to equip the car with a DC/AC inverter.

For accurate field strengths and SNR/MER measurements a Kathrein magnet antenna was used as reference.

8.2 RF Mondial Monitoring Receiver

Today, the RFmondial RF-SE12 is the world's only DRM VHF Band capable calibrated reference monitoring receiver. It is built in a 6U 19 inch aluminium case with integrated LCD touch screen but can be fully controlled via a Flash® capable browser interface. As there is currently no compatible Flash version available for iOS or Android, we had to acquire a Windows 10 tablet computer.



The RF Mondiale receiver original display

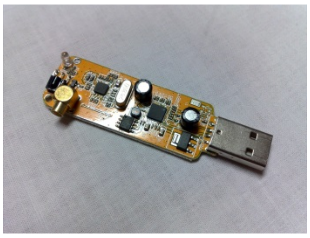
The receiver controlled by our Prestigio tablet

8.3 STL-SDR Receivers

As there was a delay of the delivery of the "Titus II", a DRM capable consumer receiver, WECODEC decided to investigate the possibility of using so-called "RTL-SDR" receivers for our trial.

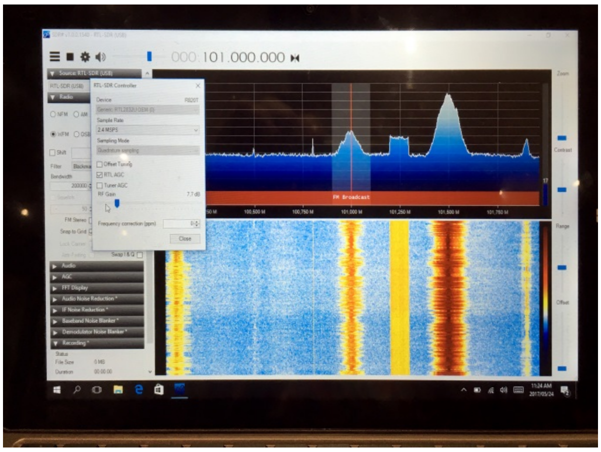
RTL-SDR is a very cheap software defined radio that uses a 10 US$ (R150) DVB-T TV tuner dongle based on the Realtek RTL2832U chipset. With the combined efforts of Antti Palosaari, Eric Fry and Osmocom it was found that the signal I/Q data could be accessed directly, which allowed the DVB-T

TV tuner to be converted into a wideband software defined radio via a new software driver. As common applications also include FM radio, tuner chipsets used in such DVB-T dongles are also capable of tuning into the FM Band. Typical tuner chipsets are the Elonics E4000, Fitipower FC0012/13, or Rafael Micro R820T/2.

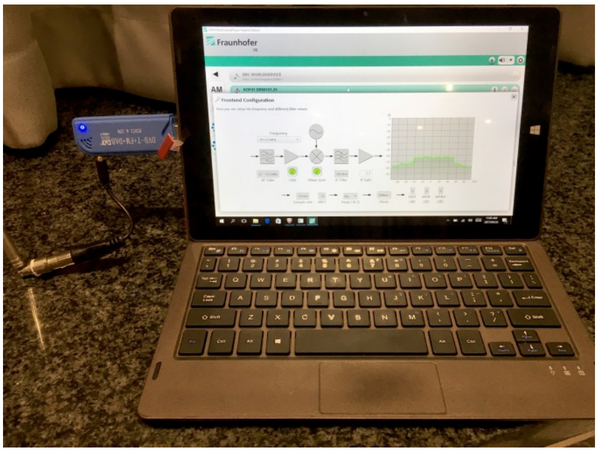


A typical DVB-T USB-Dongle.

The RTL-SDR solution can work with various software programs including the functionality of playing FM radio or display the spectrum. Fraunhofer IIS in Erlangen/Germany has developed a digital radio receiver software called ‘MultimediaPlayer Radio App’ which is capable of decoding a DRM signal from an RTL-SDR dongle on any Windows PC, laptop or tablet. This solution allowed us to start testing consumer suitable DRM scenarios for the community and elsewhere.



“SDR-Sharp” showing the spectrum and our signal



Fraunhofer Multimediaplayer App decoding our signal

<u>All measurement equipment and tools in detail:</u>

Vehicle	Volkswagen Caddy
Car Antenna	Standard car whip antenna fitted by Soundwaves
Inverter	Perfect Power PP1002, by WAECO, Germany
Reference Antenna	K 510 351 cut to 75cm, 50Ω, by Kathrein, Germany
Monitoring Receiver	RFmondial RF-SE12 – DRM+ version
GPS Receiver	NL-402U by NAVILOCK, attached to the monitoring receiver
Tablet (used for remote control of RF-mondial receiver as well as SDR receiver)	MULTIPAD VISCONTE V 3G by Prestigio, Russia (sourced in South Africa)
RTL-SDR Receivers	1. DVB-T Stick, with FC0012 tuner by Trekstor, China 2. DVB-T Stick, with R820T2 tuner, no-name, China
RTL-SDR Software	1. SDR-Sharp by Youssef TOUIL, V. 1.0.0.1540 2. Drivers: Zadig by Peter Batard (GPLv3), V. 2.2.689 3. Multimediaplayer App by Fraunhofer IIS, Germany 4. RTL-TCP Rev. e3e6ee23 by Osmocom, Germany

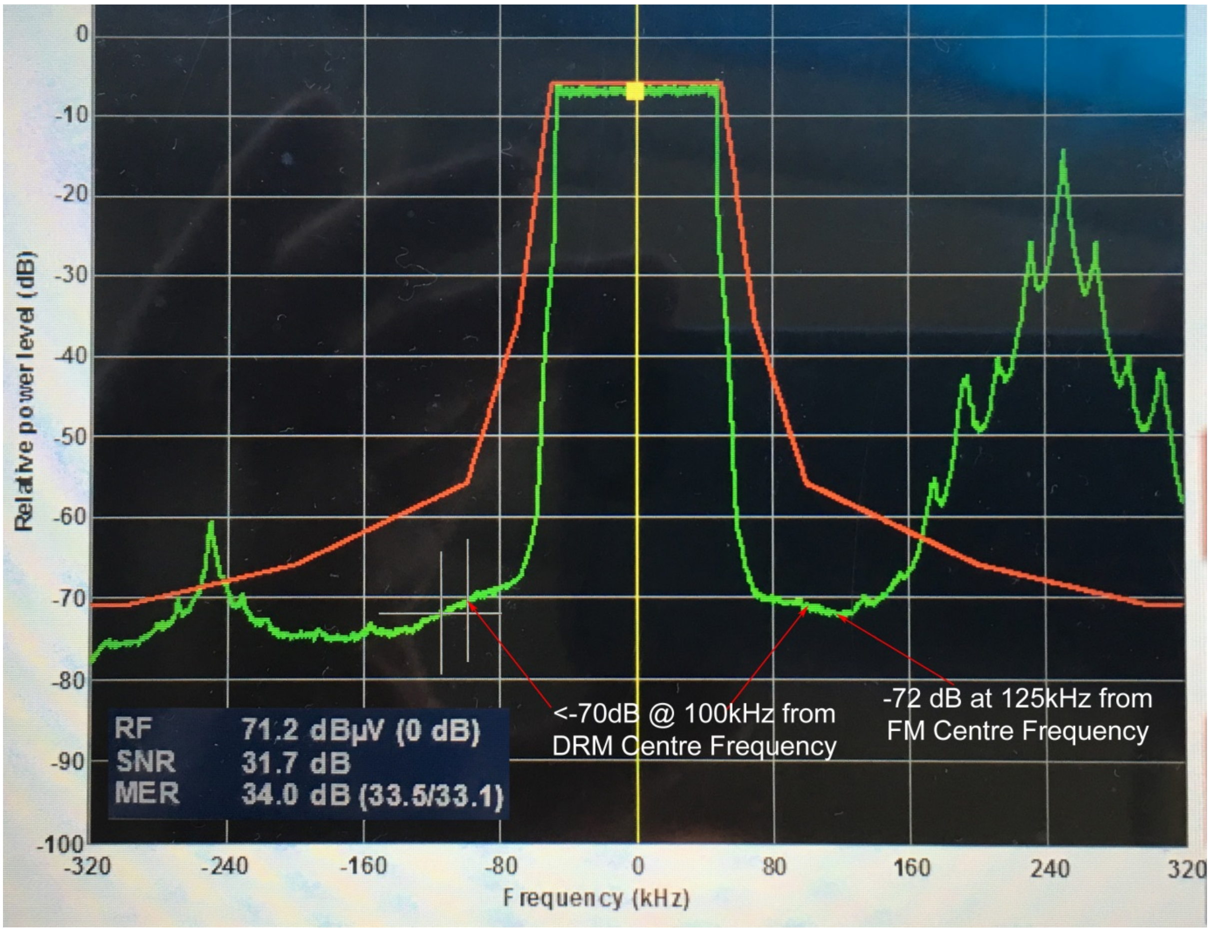
9. Methodology and Results

Phase Zero

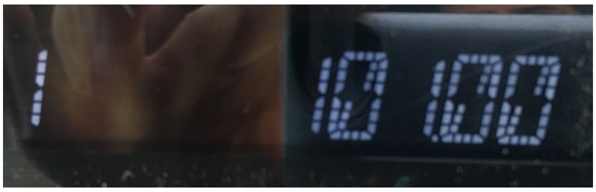
Our first objective as mentioned earlier was to proof that no harmful interference to existing FM transmissions would occur from our DRM transmissions. It was assumed that the highest possibility of such interference would be noticeable in close distance to our transmitter site. We therefore measured field strength and spectrum mask conformity right in front of the transmitter site as well as tuned into both adjacent channels with different FM receivers and listened if the audio quality was impacted as well as tested and confirmed that RDS information was not impacted either.

Further measurements within 2.5 km of the transmitter were done and at locations where one or both adjacent signals were weak due to terrain or other reasons, the DRM transmitter was remotely switched off via TeamViewer access to identify if the impact of the FM signal was caused or partly caused by the DRM transmission. These tests were done within the first week of operation to ensure that no harmful interference was emitted from our trial.

With regards to the visual test, in front of the transmitter site with a field strength of 71.2 dBµV (80 dBµV/m: antenna factor=8.2 @ 101.25 MHz / 50Ω) the DRM signal was clearly within the limits of the ITU conform spectrum mask that proposes the signal to be at a relative power level of-56dB at +-100 kHz from the centre frequency (our signal was <-70dB on both sides). At the physical end point of the FM signal at +-125 kHz where the stronger adjacent signal at 101.5 MHz came down to -72dB which was not exceeded by our DRM signal either:



Audio was then measured with JVC, Pioneer, and Jeep car radios:



No interference caused by the DRM transmission was audible to both adjacent FM channels. Audio/Video recordings have been captured and are available on the attached DVD.

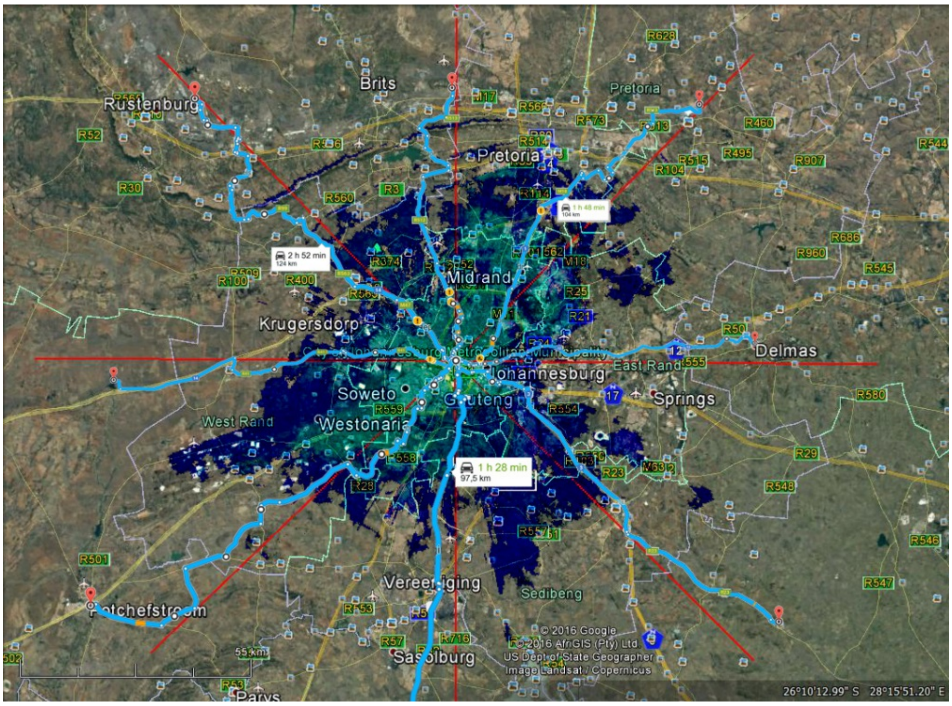
To verify at a weak adjacent transmission signal which we found on RSG 101 MHz close to Westdene Dam at 2.3km distance from the transmitter, the vehicle was stopped in that position and the DRM transmitter was remotely switched off. There was no change to the RSG FM audio signal noticeable.

These tests were undertaken with our measurement vehicle VW Caddy with its built-in Pioneer radio and were repeated with Honda Brio with built-in JVC radio as well as a Jeep Wrangler with its built-in Jeep car-hifi system. All tests confirmed that no harmful interference to the adjacent FM channels were evolving from our DRM transmissions.

In coordination with ICASA it was planned at a later stage (Carnarvon) to repeat this test at modified DRM frequencies closer to the adjacent channels as at another trial in Indonesia it was demonstrated that even at a Δf of only 150 kHz no interference to FM transmissions were noticed.

<u>Phase One</u>

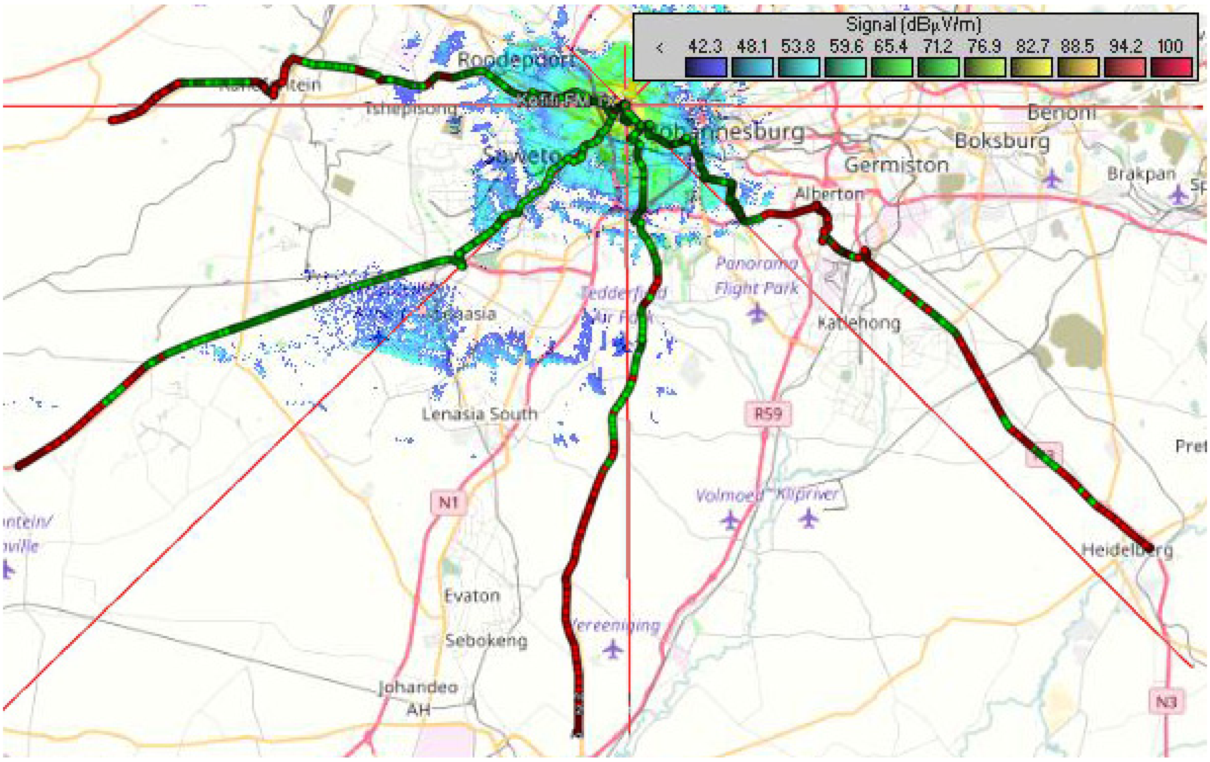
Within the first 2 months, drive-by measurements were conducted with our vehicle using the RFmondial Monitoring Receiver and the Kathrein antenna, at a height of 1835 mm from the ground. For these measurements initially 8 radial routes from the transmitter site in N, NE, E, SE, S, SW, W and NW directions have been planned.



Possible planned routes vs maximum estimated coverage prediction

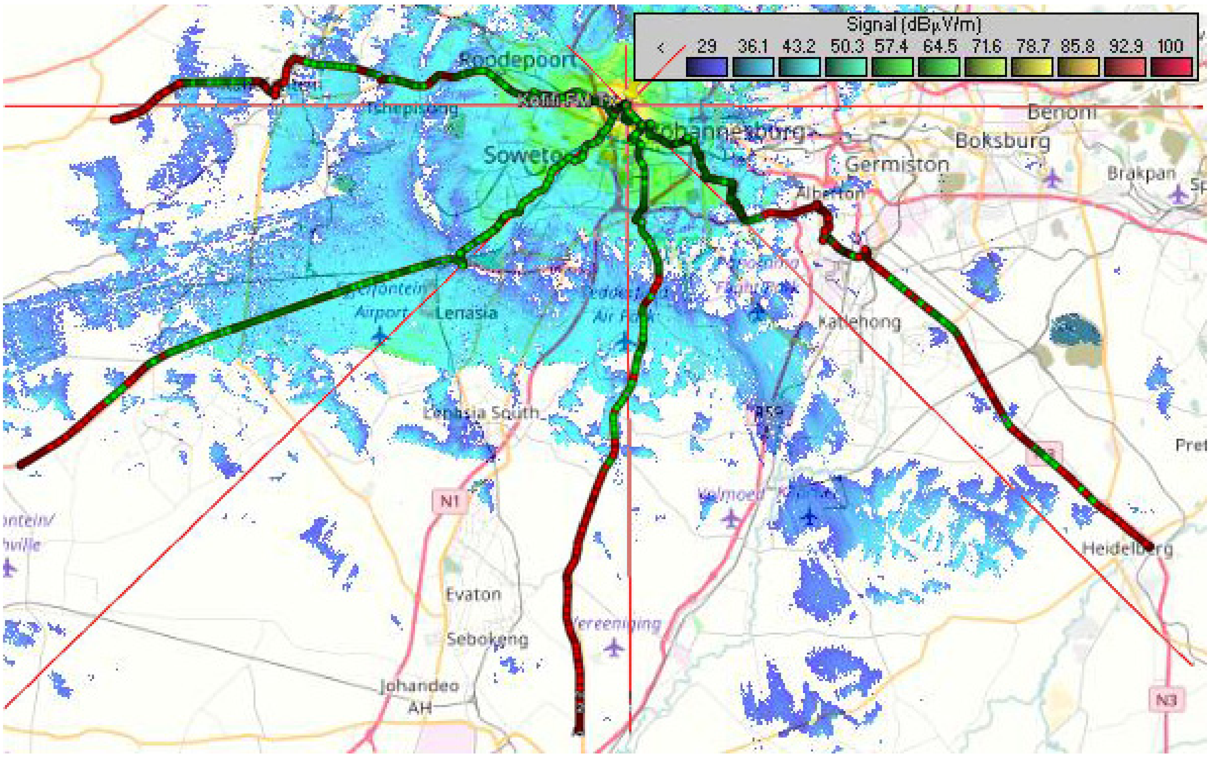
Measurements were conducted by driving outwards on each radial with the all service channels configured on our standard modulation setting (4 QAM) up to the point where complete audio failure occurred plus 5 km. Once audio failure detection was confirmed, the same route was measured in the opposite direction back to the transmitter, with the MSC configured to the higher modulation setting (16 QAM). This measurement sequence was undertaken for 4 of the planned radial routes (SE, S, SW, and W) but thereafter the monitoring receiver became faulty and needed to be shipped for repairs. The remaining 4 routes were examined in October 2017 after the receiver had been returned. The transmitter was configured to transmit a DRM signal at 175 W RMS (500 W ERP) during the initial 4 drives and 275 W RMS with improved cable loss (1000 W ERP) for the second 4 drives. During such measurements the built-in car-hifi system as a second receiver was tuned to the co-located FM transmission on 97.2 MHz in order to have a permanent comparison between the analogue and digital signals originating from the same site. This was to verify if signal losses are specific to the DRM signal or affected both signals consequent to terrain characteristics or interferences impacting the whole band. It was recorded that almost in every situation there was a correlation between the FM audio and the DRM MER with a non-relevant count of abnormalities.

According to ITU-R BS.2214-1 (07/2015) *(Planning parameters for terrestrial digital sound broadcasting systems in VHF Bands)*, the minimum field strength for mobile reception at a location probability of 99% is defined as 42.27 dBµV/m for 4 QAM and 1/3 FEC and 49.57 dBµV/m for 16 QAM and 1/2 FEC. However, already the results from our first 4 radial mobile drive-by measurements demonstrate a comfortable overhead according to those parameters and there is not a single spot of predicted coverage that was not measured error-free:



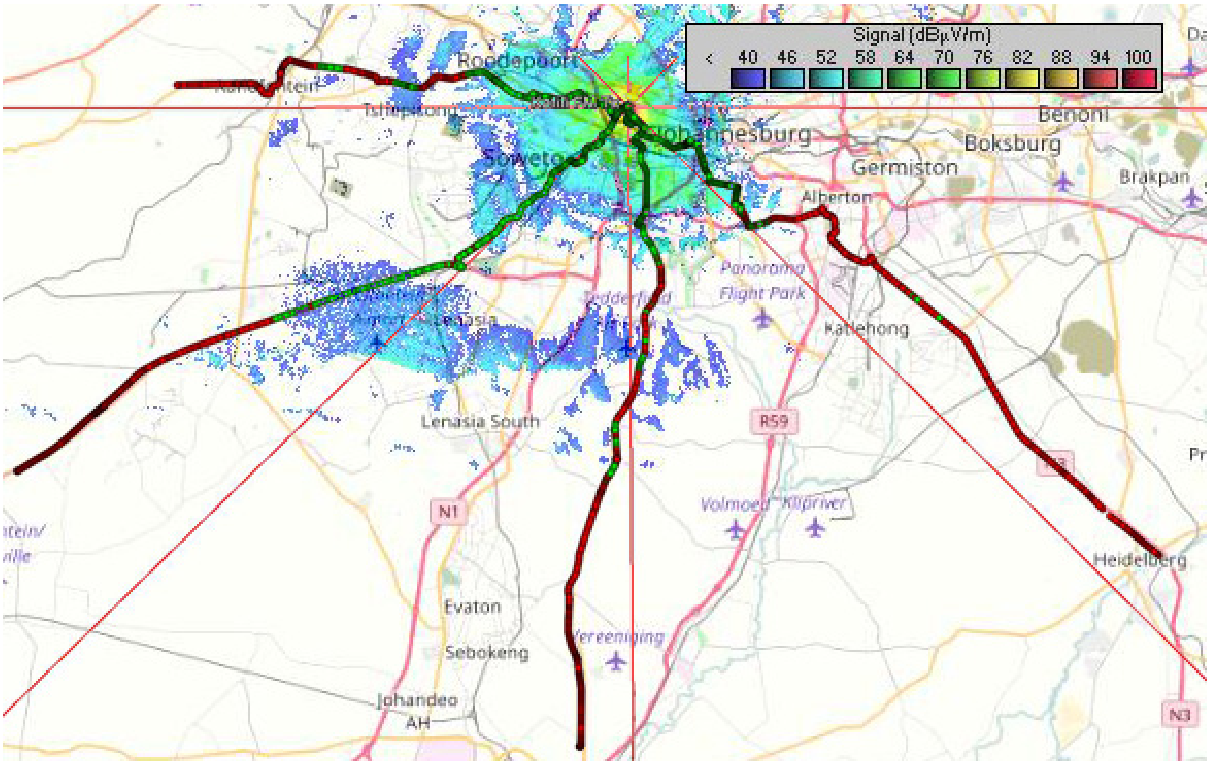
Drive-by mobile measurements at 4 QAM and 1/3 FEC against coverage prediction at 99% location probability and a threshold of 42.27 dBµV/m

The measurements show an average overhead of roundabout 13 dB that can cater for worse real reception conditions such as poor quality aerials and receivers or man-made noise interference.



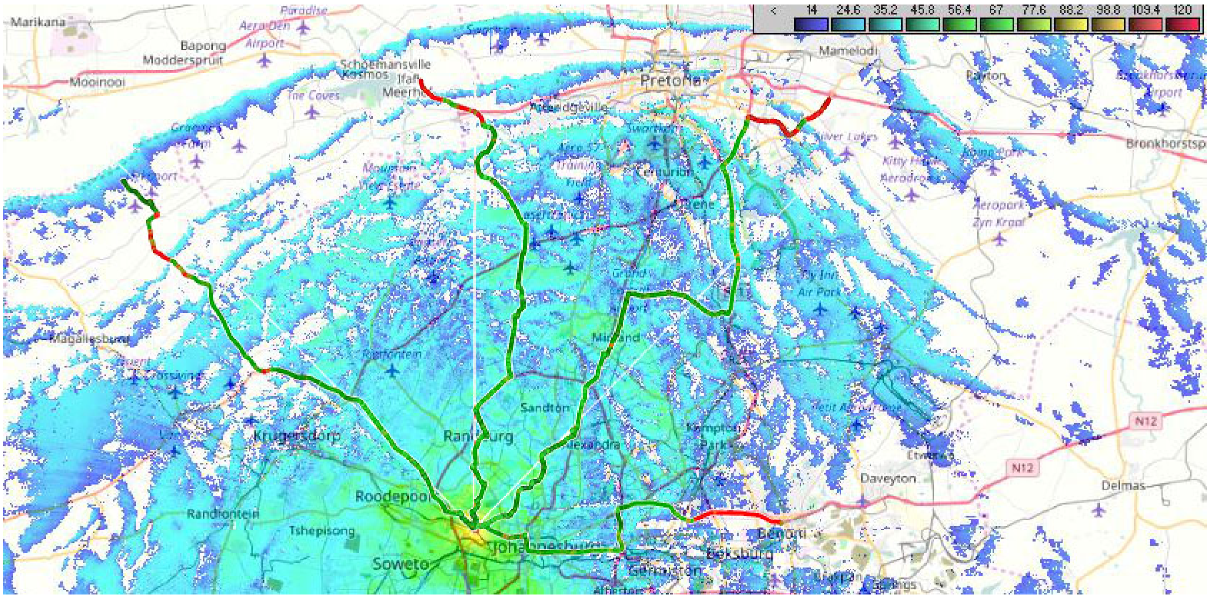
Drive-by mobile measurements at 4QAM and 1/3 FEC against coverage prediction at 99% location probability and a threshold of 29 dBµV/m

The Drive-by mobile measurements with 16 QAM and 1/3FEC show the expected higher sensitivity as reception was at 100% only a 40dBµV/m threshold. As planning parameters of 49.47 dBµV/m are for 1/2 FEC and supposed to be lower for 1/3 FEC, the overhead is lower (between 6 and 8 dBµV/m).



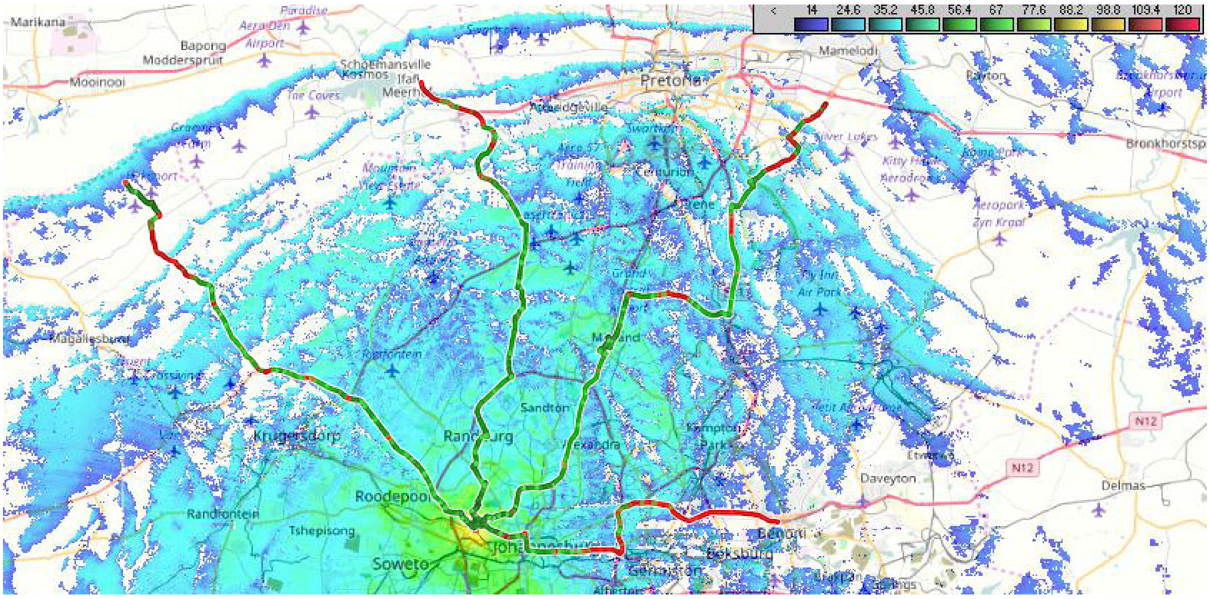
Drive-by mobile measurements at 16 QAM and 1/3 FEC against coverage prediction at 99% location probability and a threshold of 40 dBµV/m

The results from the second 4 radial mobile drive-by measurements demonstrate an amazing overhead compared to the planning parameters – an overlap with predicted values are as low as in the range of 9 dBµV/m for 4 QAM (planning parameters: 42.27 dBµV/m, overhead: 33 dB!):



Drive-by mobile measurements at 4 QAM and 1/3 FEC against coverage prediction at 99% location probability and a threshold of 9 dBµV/m

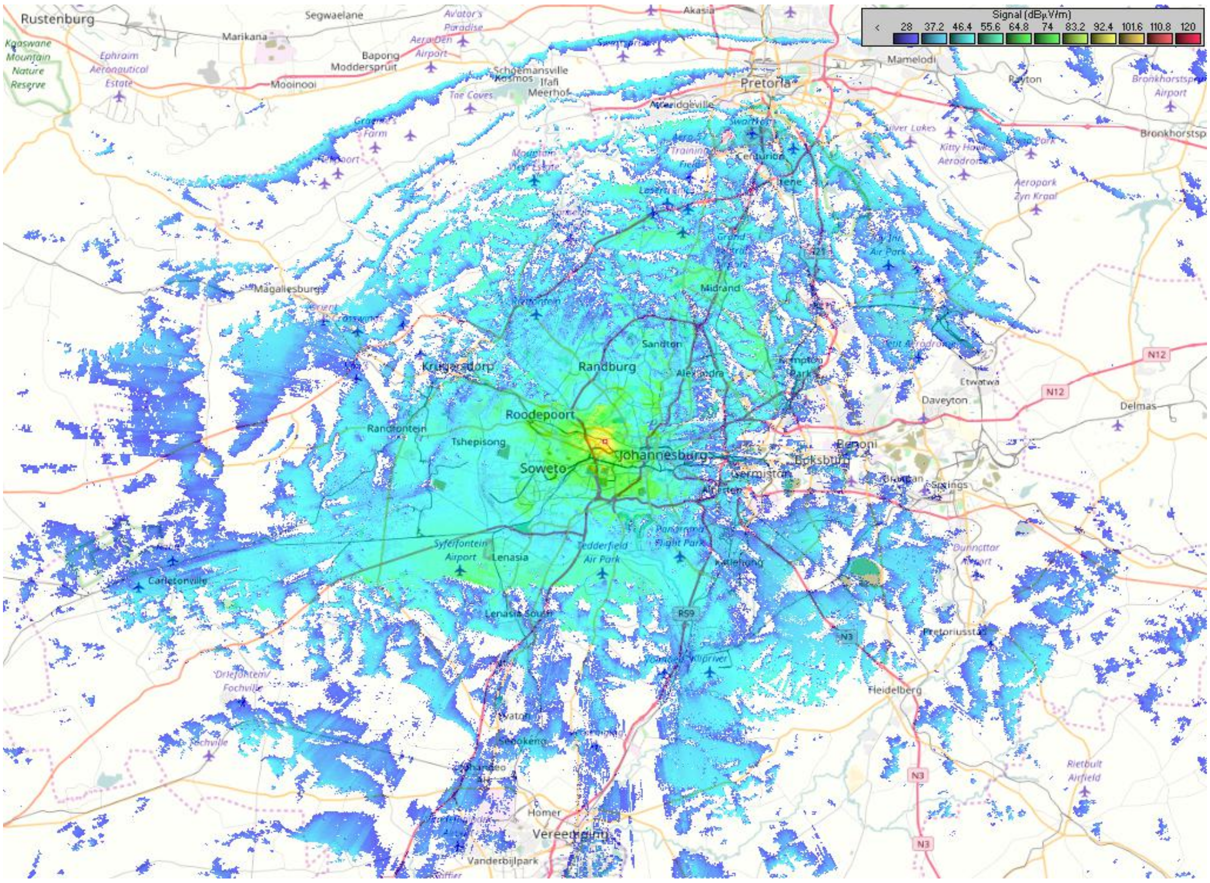
The parameters for the 16 QAM measurement were this time set to 1/2 FEC to be able to measure against ITU planning parameters that are for 16 QAM only published with 1/3 FEC. The 16 QAM drive-by mobile measurements show reception was present already at a 14 dBµV/m threshold. Against the planning parameters (49.47 dBµV/m at 1/2 FEC) the overhead is now even at 35 dB):



Drive-by mobile measurements at 16 QAM and 1/2 FEC against coverage prediction at 99% location probability and a threshold of 14 dBµV/m

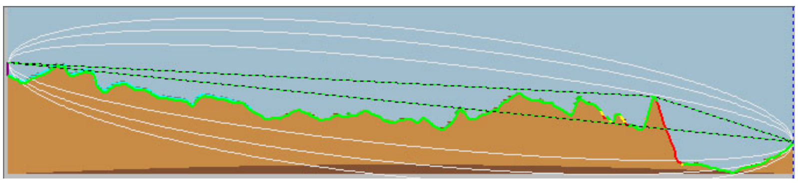
This measurement shows that an increase of only 3 dB at the transmitter side results in far better reception (around 20 dB) probably by overcoming noise at a critical level. However, the predictions are done with 99% location probability which is recommended for mobile digital radio reception.

An additional reason for the increased reception levels might have been the fact that the monitoring receiver that just came from repairs might have had a better performance.



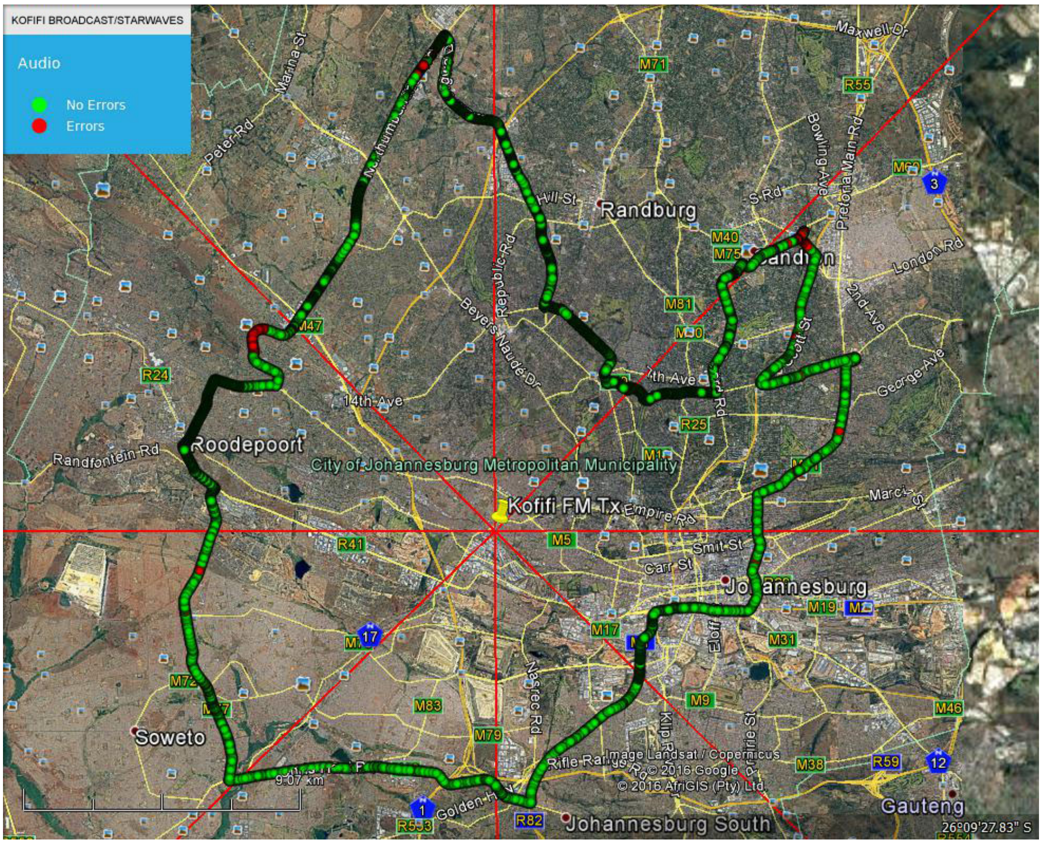
If calculating with lower location probabilities the predictions are getting closer to the real figures: This map shows predictions for 20 dBµV/m but with a location probability of 90% instead of 99%.

To determine optimal planning parameters, we would recommend undertaking further investigations what the most appropriate location and time probability values would be for DRM in VHF, also compared to FM. These values are nowhere to find in the current literature or documentation.



At this spot 55km away from the transmitter site and behind Hekport mountains (no line of sight at all) the reception was still clear and showed a field strength of 28.1 dbµV/m at an SNR of 9 dB and MER of 8.3dB. Fixed reception was even possible with 16QAM.

Measurements were also taken randomly at various routes on a daily routine in order to understand strengths and weaknesses of the system such as vulnerability to specific terrain or interference. Also during these measurements the car-hifi system was tuned to 97.2 MHz for comparison purposes.



A map resulting from a round trip in an average distance of 10 km around the transmitter site. The signal was blocked behind Noorde-krans hill where also no FM signal was audible.

Services were monitored and measured on all the planned and random routes. Whenever measurement incidents (e.g. loss of audio, decode-ability, recovery of audio etc.) were experienced the coordinates, measurement parameters and incident details were logged and noted.

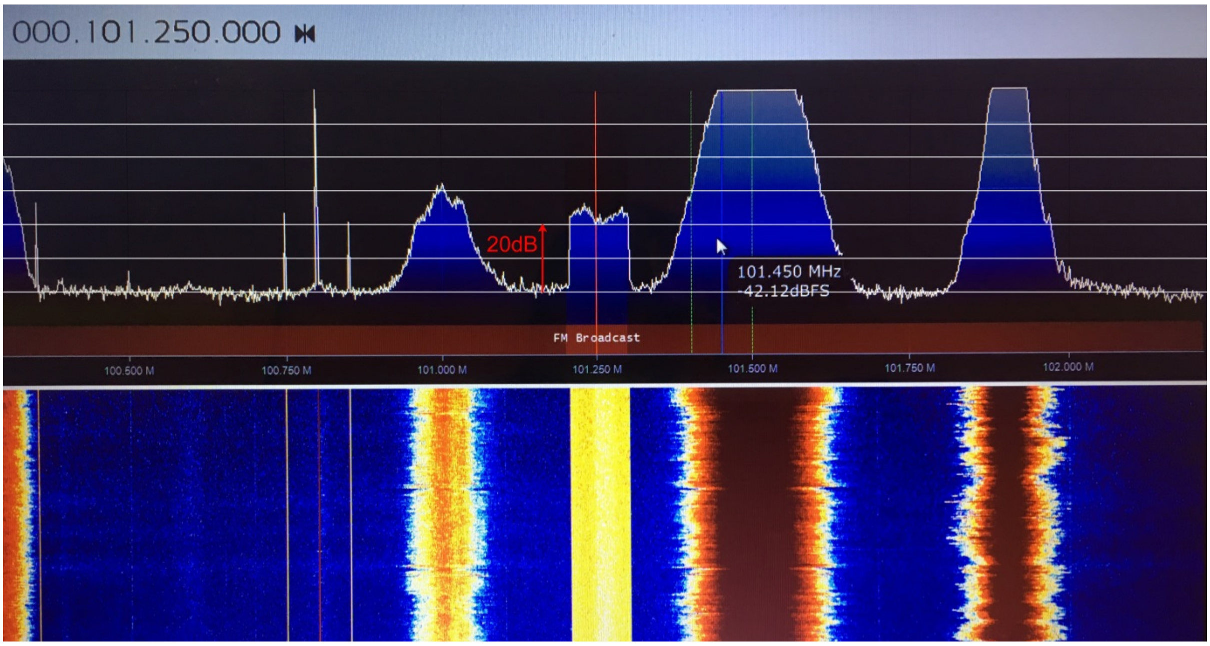
Phase Two

In the second phase we included a few consumer receivers and let community members and other stakeholders experience the functionality of the DRM broadcasts. Thereafter we conducted a brief survey amongst the trialists. This should help to evaluate the usefulness of the DRM system including data services in a practical environment. Without any exception it can be reported that all individuals participating on the trial were deeply impressed by the capability of the system.

For this purpose a number of RTL-SDR receiver dongles were used at various customers' locations and connected to their existing PC's, notebooks or Windows™ tablets and Fraunhofer's Multimedia-Player App was installed for system evaluation.

In preparation for this test, various RTL-SDR based receiver solutions have been tested in cooperation with Fraunhofer Institute and RFmondial in the second week of May 2017 in Hannover, Germany, where a live VHF DRM signal is present at 95.2 MHz. For the drive-by tests in Hannover with 3 different RTL-SDR receivers, a software that specifically coded by Fraunhofer for this test was used to capture signal information. The findings of these tests in Hannover helped to improve the Fraunhofer Multimediaplayer App so that it could be used in our Johannesburg trial.

Then a few mobile and fixed tests have been undertaken in Johannesburg with two different RTL-SDR based receiver sets. As AGC functionality still needs to be improved, the *mobile reception capabilities* of such solutions are still limited and so far only function reliably within a relatively close distance to the transmitter (3-5km). However, at *fixed locations* with the possibility of manually tuning the input gain to an optimal level, the results so far are very close to the results from the RFmondial monitoring receiver. Even in critical indoor locations with poor FM reception a crystal clear reception of the DRM signal was possible as shown in this screenshot:



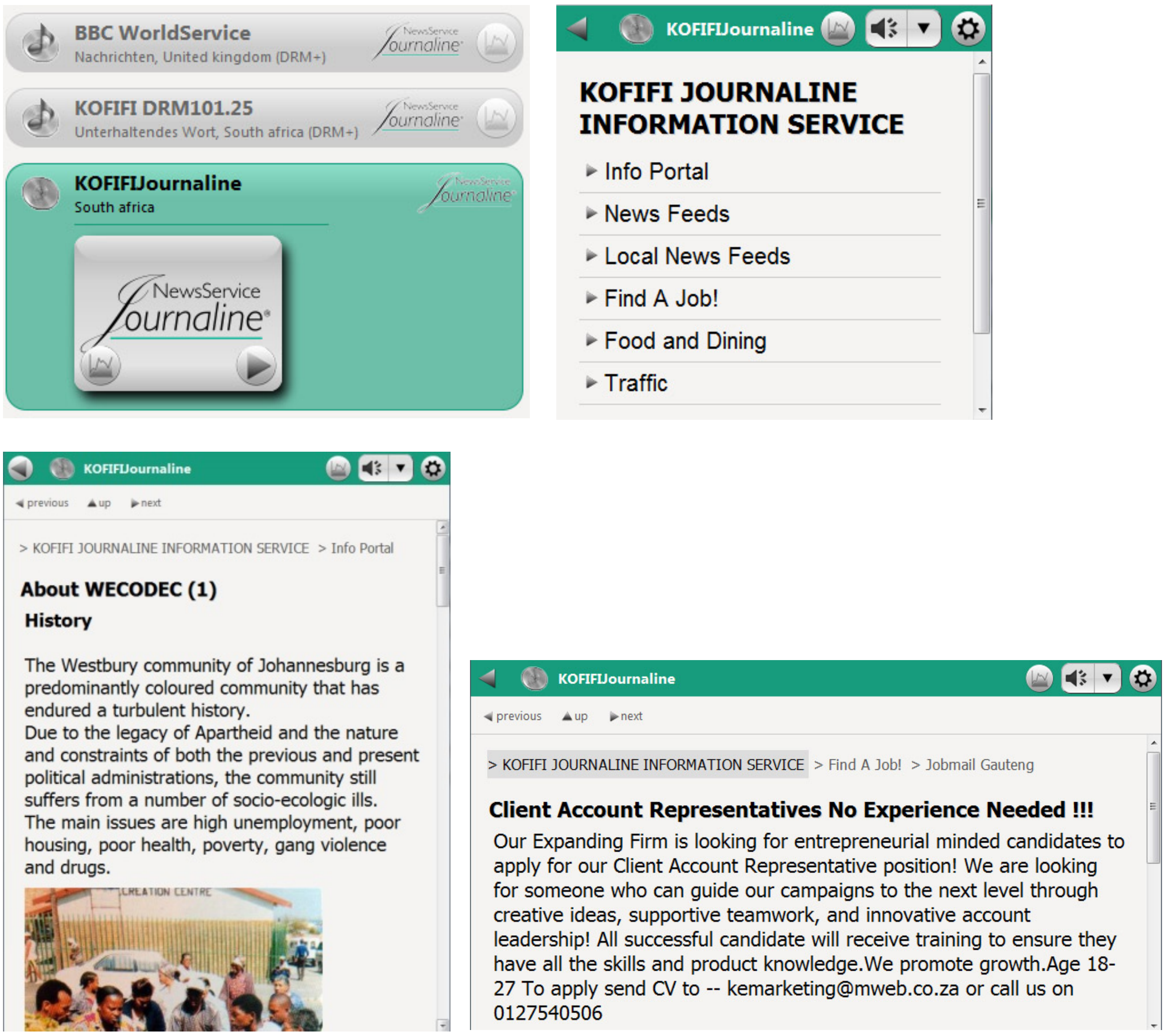
SDRSharp with RTL Dongle and small whip antenna at critical indoor location: SNR>20dB.

As a next step WECODEC has even built its own prototype of a DRM capable multi-standard digital receiver that was able to receive our DRM transmission as well as the DAB+ transmission that was broadcasted on Channel 13F at 50 kW ERP from Brixton Tower. With this receiver we were able to demonstrate that **job creation in the electronic industry is possible at community level**. The 100% community hand-made receiver prototype is still available at WECODEC for verification.

With this receiver it is also possible to directly compare the performance of DRM versus DAB+.

Our community-built DRM/DAB Multi-Standard Digital Receiver with DRM, DAB+ and FM function (DRM30 and AM were still under development), demonstrated and awarded in September 2017 at IBC in Amsterdam.

Also some live hyper-text information (updated automatically every 60 minutes from Internet sources) was integrated with the Journaline service. This included an Info Portal with information about WECODEC, Kofifi FM and other stakeholders, DRM, Government and country information, National and local News including lifestyle and sports, as well as various Job Portals (**"Find a job via Digital Radio"**) including a skills portal and more – **as free digital information service without data costs to the consumer**, either on the radio's display or a smart device connecting to the radio.



Screenshots of the WECODEC/Kofifi Journaline Information Service

This trial was the first time that a totally free-to-air digital information service was broadcasted by a community in South Africa. It was evidence that Universal Access to information is possible without the usage of broadband internet and expensive airtime data whilst improving skills development in the community and creating jobs in the ICT sector in line with the National Development Plan (NDP), the Electronic Communications Act (ECA), PFMA, and BBBEE Acts.

10. Future Option: DRM in the Extended FM Band (Outlook)

A number of countries, including some of BRICS countries such as Brazil and China have plans to extend the FM Band to lower frequencies – down to 76 or even 64MHz (the Extended FM Band) as a logical consequence as higher frequency spectrum is needed for other purposes. According to the National Radio Frequency Plan 2013 of South Africa, published in Government Gazette 36336, parts of this spectrum (also known as VHF Band I, 47-68MHz) are even still allocated for broadcasting:

ITU Region 1 allocations and footnotes	South African allocations and footnotes	Typical Applications	Comments
47-68 MHz BROADCASTING	**47-50 MHz** BROADCASTING LAND MOBILE 5.164	CT0 Cordless Telephones MTX (49.67 – 49.97 MHz)	Paired with 46.61 – 46.97 MHz. Radio Frequency Spectrum Regulations (Annex B) (GG. No. 34172, 31 March 2011).
	50-54 MHz AMATEUR 5.169	Wireless microphones (53 – 54 MHz)	Radio Frequency Spectrum Regulations (Annex I) (GG. No. 34172, 31 March 2011) Radio Frequency Spectrum Regulations (Annex B) (GG. No. 34172, 31 March 2011)
5.162A 5.163 5.164 5.165 5.169 5.171	**54-68 MHz** BROADCASTING FIXED 5.171 MOBILE except aeronautical mobile 5.171	Government Services Model control (54.45 – 54.55 MHz) Single Frequency Mobile (54 – 54.325 MHz) Mobile 1 BTX (54.325 – 54.45 MHz) Mobile 2 BTX (55.45 – 56.85 MHz) Single Frequency Mobile (56.85 – 58.5 MHz) Mobile 2 MTX (58.5 – 59.9 MHz) Mobile 1 MTX (59.9 – 60.025 MHz) Sport Stadium Communications (62.8 – 62.85 MHz) National Emergency Alarm Radio (NEAR) (66 – 68 MHz)	Radio Frequency Spectrum Regulations (Annex B) (GG. No. 34172, 31 March 2011) Paired with 59.9 – 60.025 MHz Paired with 58.5 – 59.9 MHz Paired with 55.45 – 56.85 MHz Paired with 54.325 – 54.45 MHz

Extract from SA National Frequency Plan of South Africa

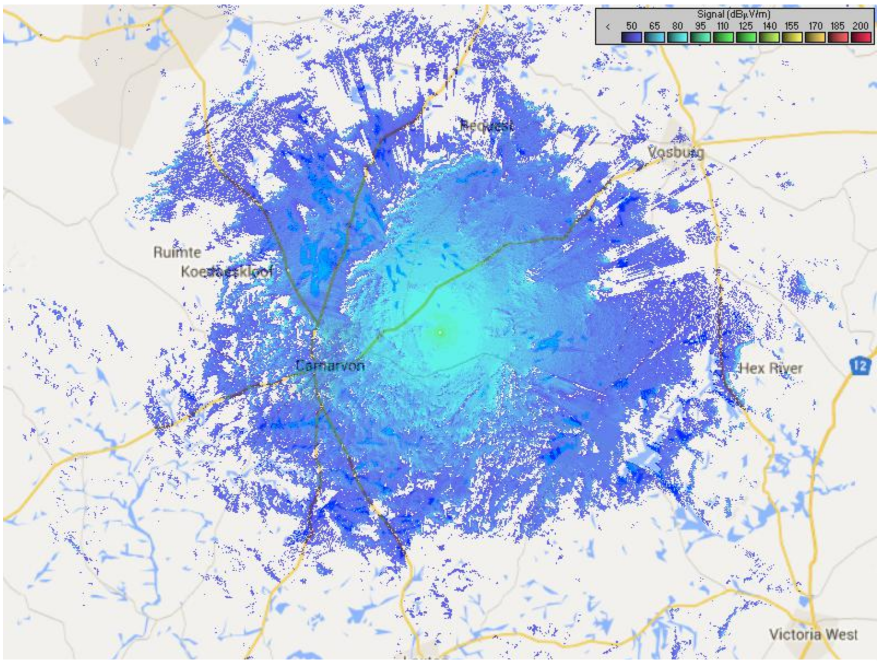
Specifically, frequency spectrum between 63 and 66 MHz is only assigned for broadcast services and could be considered as a potential FM Band extension spectrum for digital sound broadcasting.

The ECC (Electronic Communications Committee within the European Conference of Postal and Telecommunications Administrations (CEPT)) has also looked at its Report 117, *"MANAGING THE TRANSITION TO DIGITAL SOUND BROADCASTING IN THE FREQUENCY BANDS BELOW 80 MHz"*, Athens, February 2008 and revised Gothenburg, September 2010, at the use of the lower frequency broadcast bands – below 80 MHz – for digital broadcasting to national, local and community audiences. Included are the LF, MF, 26 MHz (HF) bands and VHF Band I.

DRM has been developed to operate within this spectrum and has been approved by ITU. As in the Northern Cape close to the SKA area (besides half of the FM Band) it actually is the only radio frequency spectrum that is permitted to carry broadcast signals to the marginalized communities in that area which otherwise would remain disconnected from Universal Access to information, we have chosen this area for our Extended FM Band trial.

Sentech is currently operating an FM sound broadcast from Carnarvon/Wildeperdeberg but only broadcasting 3 radio stations which are KFM, RSG and SAFM. Extending the FM Band by opening up only 1 MHz of spectrum (e.g. 64 – 65 MHz) would provide space for 30 additional radio channels plus 10 independent data services such as traffic and weather information; news, health and educational Journaline services, or even basic news and even educational video services based on diveemo video. **These could also include detailed weather information and forecasts for farmers in the area.** It could also accommodate an emergency warning system and in the future replace the analogue NEAR system vacating even more spectrum for future usage such as digital radio or mobile TV. **Extending the FM Band such as planned in Brazil, it could accommodate over 330 radio programs!**

Due to possible sky-wave interference, broadcasting within Band I but should be above 63 MHz which is known as the “magical split” from where no sky-wave propagation has been discovered. Therefore we have applied for and granted the frequency of 64.0 MHz which is central in the proposed future Digital Radio Band of 63 - 66 MHz. The transmitter will be located at Sentech’s Carnarvon site (22°22'29''S/30°54'14''E). The sub-project that we call “Digital Karoo” will be done in co-operation with Sentech, Ulwazi FM and Radio Gamkaland (the two closest community radio stations in the area). As Band I has not been in use for broadcasting for a long time sourcing adequate equipment was a greater challenge than expected. At least, we have managed to source a suitable transmitter as well as a content server license and have finalized the design of an affordable full equipment chain. However, the trial in the Karoo will commence as a separate project and start after publishing this report.



Predicted Coverage Map of the Karoo-DRM+ Multiplex

11. Benefits

Many benefits as described below are mandatory by the Object of the ECA (Section 2):

<u>Efficient usage of spectrum as a national resource</u>

Since the initial efforts of introducing digital broadcasting in the 1980’s, the world has experienced numerous “revolutions” of information technology. Even the digitization plans from the ITU Geneva conference in 2006 had to be revised as radio frequency spectrum has become one of the most relevant natural resources on earth and different stakeholders are claiming utilization of the same.

This is a big challenge for both policy makers and regulators as they have to protect the interest of the public as well as provide an optimal environment for economic growth. Obviously these challenges are different for each country and economy due to their individual developments of the ICT sector and many other parameters. E.g. terrestrial television spectrum is less relevant in countries that have national cable coverage. But their economic viability is also dependent on general factors such as population density and terrain properties. In conclusion it can be said that in each economy, the most efficient utilization of radio frequency spectrum is paramount because all economies worldwide requires radio frequency spectrum for ICT in order to efficiently deliver universal access of information to the citizens. Wasteful usage of spectrum will have a negative impact on this requirement, the growth of the sector, and consequently the entire GDP as such. In this light, the approach of DRM to fit into the existing FM Band spectrum will allow for the most efficient usage of that spectrum instead of occupying new spectrum bands (as DAB+ does) that could be used more efficiently for other applications such as moving DTT into VHF Band III and release the UHF Band for ICT broadband.

With regards to an extension of the FM Band, a review of Band I utilization by digital radio is long overdue. It has not been used for analogue television broadcasting for reasons that are specific to disadvantages that analogue broadcasting develops in those bands (e.g. the frequency/signal bandwidth ratio is very low) but would now be overcome by the advantages of the digital signals. The ECC of 2008 concluded: *"The greater quality and versatility of the DRM+ system would suggest that this was the preferred option for Band I. Band I is not at present, formally available for DRM+ (or DRM30) transmissions although individual administrations could give the relevant authorisation. With this in mind there are a number of regulatory instruments that would have to be put in place before widespread deployment. It is proposed that the CEPT considers revising the ERC Report 25 (the ECA Table) in the part 47-68 MHz to permit the introduction of digital sound broadcasting in this part of the spectrum (Band I)"*.

<u>Job Creation and Stimulation of the South African Consumer Electronics Industry</u>

- The immediate presence of digital radio signals will open a new market for digital radio receivers
- Designed and produced in South Africa (Proudly South African)
- New product lines can also be exported to other markets within SADC, Africa and the world.
- This will bring innovation to the industry
- BBBEE-manufactures will benefit economically
- South African enterprises can play an important role in the international rollout of DRM receivers serving markets such as India, Indonesia, or Russia.

<u>Job Creation and uplift of media industry</u>

DRM will allow for the kick-off of digital radio without further delay as spectrum is already available. This means that jobs can be created immediately within the media industry which will also stimulate the sector, specifically within the community radio sector where numerous initiatives are lined up for consideration but cannot be helped yet due to lack of analogue spectrum.

<u>Skills Development</u>

The project will enable skills development in the very new field of digital radio. Through our community radio station we will encourage community members to participate on this pioneering project and divergent in the science and technology area of which the government has been encouraging and is in line with the governance policy in the science and technology sector. The newly empowered people from the community will in future be able to operate in other areas such as the Northern Cape where there is a specific demand for DRM+.

<u>Research and Development</u>

- Thus in the Westbury area creating a snowball effect, South Africa will be recognised as pioneer conducting this first DRM+ trial on the African continent.

- In the Northern Cape, South Africa will be able to demonstrate that it has been able to develop an answer to the special requirement on universal access to information versus spectrum usage restrictions in the Square Kilometre Array (SKA) area.
- Creating a platform for Research and Development in the Digital Sound Broadcasting domain
- Thus adding to South Africa innovation – case study in the cellular industry (pay as go)
- This allows for innovation in the Sentech Lab – DTT/DAB/DRM
- This will have an impact for South Africa/Africa/ Globally

<u>Better Signal Quality and additional programmes</u>

Citizens will benefit from a better signal and audio quality and improve their access to information. Additional sound and multimedia services will open opportunities for new educational programmes, interactive services (e.g. employment service), weather and traffic information, emergency warning systems and many other benefits for the citizens and communities.

<u>Content Development – via Journaline</u>

- More content development – youth and women participation
- University Radio upliftment and more content by university students creating a robust platform for an information repository
- Educational purposes in rural areas
- Health sector – e.g. Health information outbreaks will help in sending out information to communities
- Weather Sector – e.g. Flash Floods, Droughts
- Accessibility for Persons with Disabilities.
- Universal Access – No costly airtime-data required
- Receive information without data- Benefit Rural Development in Education and Health

<u>Accessibility for Persons Living with Disabilities</u>

- Journaline allows for all to participate
- Allows for text , pictures, text reading
- Allows for Braille
- Emergency Warning System - Receiver will react even if turned off in the case of emergency and inform audible and visually

12. About WECODEC

The Westbury community of Johannesburg is a previously disadvantaged community that has endured a turbulent history. Due to the legacy of apartheid and the nature and constraints of both the previous and present political administrations, the community still suffers from a number of socio-economic ills. The main issues are high unemployment, poor housing, poor health, poverty, gang violence and drugs.

Within Westbury, a number of small self-help groups have risen to combat the effects of the social ills. A major catalyst force for change is the Westbury Community Development Centre (WECODEC). Spearheaded by a of young people – many of who were key role players in gang activities – the formation of WECODEC in 1998 became a turning point in the history of the Westbury and surrounding communities.

In the same year, WECODEC negotiated the first reconciliation between the rival gangs. This has resulted in a significant drop in violent crime. The team began to initiate self-sustaining projects designed to achieve the collective aims of poverty alleviation, skills development and social upliftment.

Today, the centre hosts a number of activities and resources including computer training, upgrading and maintenance, an internet-enabled resource centre, a library, a crèche, women's groups and prayer groups. WECODEC has become a beacon of inspiration for the community and now plays a critical role in representing the community both within and externally to all strata and society.

Through persistent effort, the team behind WECODEC has secured support and recognition from Government ministers, the private and NGO sector. Journalist and writer, Dr Don Mattera has been instrumental in the development of the project. As a leading figure in the struggle against apartheid, his personal commitment to the development of Westbury has inspired the hearts and minds of the community.

In pursuing its objectives WECODEC established a community radio station, **Kofifi FM 97.2**, in order to enhance its vision and purpose and is now broadcasting on air since 2012. The radio station is one of the few who are self-providing signal distribution via an SMME company due to its natural affinity to innovation and technology. Due to this interest, WECODEC recruited Mr Johannes von Weyssenhoff, an engineer and technical consultant from Germany on a skills transfer purpose who has then – inspired by WECODEC's work for the community – developed his passion for inventing and promoting technologies for community broadcasting including a solution for broadcasting community television in the L-Band. This solution was then worldwide firstly tested within the Westbury community and in early 2015 the idea was born to undertake WECODEC DRM trial in the FM Band (DRM+) to evaluate its benefits for community radio in South Africa. WECODEC then also received assistance from Ms Thembeka Khaka (Thembeka&Associates) for licensing, compliance and regulatory affairs who was of great help retrieving the license and maintain relationship with ICASA.

The successful launch of the community radio station has enabled WECODEC to establish and attract other strategic partners within and external to the community. A number of companies have been established out of this key strategic partnership which has then also enabled the radio station to grow exponentially. This symbiotic effect of the activities of a community radio station as NGO and enterprise development resulting in job creation and skills development within the community has been recognised as a ground-breaking community upliftment model. It has brought to life various business platforms, key strategic partnerships, and opportunities for the community.

The organization also renders community services such as feeding schemes, vegetable gardens and partnerships with local primary and senior secondary schools, as well as counselling. The collective organisations have established relationships with the local CPF's (Community Policing Forums) and with local and provincial government departments, as well as with MICT Seta for training and development of young entrants into the media industry, with a strong focus on youth and women with skills programmes, internships and learnerships currently being in place.

13. Project Partners

About BBC World Service

Founded on 18th October 1922, The British Broadcasting Corporation is a British public service broadcasting statutory corporation. Its main responsibility is to provide impartial public service broadcasting in the United Kingdom, the Channel Islands, and the Isle of Man. Outside the UK, the BBC World Service has provided services by direct broadcasting and re-transmission contracts on radio since the inauguration of the BBC Empire Service on 19 December 1932. More recently the BBC World Service has expanded its services to television and online.

About Fraunhofer IIS

The Fraunhofer-Gesellschaft is the leading organization for applied research in Europe. Its research activities are conducted by 72 institutes and research units at locations throughout Germany. The Fraunhofer-Gesellschaft employs a staff of more than 25,000, who work with an annual research budget totaling 2.3 billion euros. Of this sum, almost 2 billion euros is generated through contract research. Around 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. International collaborations with excellent research partners and innovative companies around the world ensure direct access to regions of the greatest importance to present and future scientific progress and economic development.

The Fraunhofer Institute for Integrated Circuits IIS is one of the world's leading application-oriented research institutions for microelectronic and IT system solutions and services. It ranks first among all Fraunhofer Institutes in size. With the creation of mp3 and the co-development of AAC, Fraunhofer IIS has reached worldwide recognition.

About Blulemon

BluLemon (Pty) Ltd was founded in 2005 by Mr. Russel Jones and has their head office in Edenvale, South Africa, has a level 4 BBBEE rating, and contributes towards social development programmes and skills development. BluLemon is wholly South African owned, using local expertise and suppliers, and has extensive experience in international trade. Blulemon's equipment and installations can be found all over the African continent, from Nigeria to the Kenya and other Southern African countries. BluLemon is a licensed Signal Distributor by ICASA. Besides Sentech BluLemon is the only ECNS license holder who serves community broadcasters as signal distributor in South Africa.

14. Acknowledgements

This project has been possible by a concerted teamwork of many enthusiastic believers in this technology and its relevance and benefits specifically to marginalized communities in South Africa and Africa. In this section we would like to express our acknowledgement to individuals and organizations that have contributed to make this wonderful project happen.

Special thanks to:

The people and leaders of the Westbury Community – special thanks to Dr Stephen Mncube, Dr Don Mattera and Joseph Cotty;

The WECODEC project team directed by Chairman and Community Leader Pastor Peter Faver, Johannes von Weyssenhoff (engineering and technology) and Thembeka Khaka (strategy; regulatory and compliance; policy); Lee Tsomo (Project Management), as well as Clinton Adams and David Boer (field technicians);

Khomotso Motsepe, Emeka D. Okawkwu, and their team at ICASA for their interest in innovation and cooperation during the preparation and operation of the trial;

Mothibi Ramusi for strategic advice and mentoring with compliance matters;

BBC World Service for contributing broadcast equipment –thanks to Nigel Fry and Robert Webber;

Fraunhofer Institute for Integrated Circuits for contributing Multimediaplayer software and Journaline support – thanks to Alex Zink, Thomas Dettbarn, Guido Leisker and Martin Speitel;

The DRM Consortium Project Office and members for their assistance in initiating this trial and hosting WECODEC in Europe –thanks to Ruxandra Obreja, Olaf Korte, Matthias Stoll and Albert Waal;

Carlos Rebelo for helping with RF installations;

Ryan Miller of SoundWaves for contributing a car radio antenna and preparing our vehicle;

GlobeCast for contributing additional equipment;

Russel Jones for contributing Electronic Communications Network Services;

Dr. Hanns and Brigitte von Weyssenhoff for their boundless support.

15. Glossary

A/D	Analogue-to-Digital
AGC	Automatic Gain Control
AM	Amplitude Modulation
BBC	British Broadcasting Corporation
BDM	Broadcast Digital Migration
CEPT	European Conference of Postal and Telecommunications Administrations

CF	Correction Factor
COFDM	Coded Orthogonal Frequency Division Multiplexing
CRASA	Communications Regulators Association of Southern Africa
CTB	Communications Technology Broadcasting
DAB+	Digital Audio Broadcasting
D.F.	Dipole Factor
dB	Decibel
dBµV/m	dB-microvolt per meter
Δf (delta-f)	Frequency spacing
ΔP (delta-P)	Power difference
DoC	Department of Communications
DRM	Digital Radio Mondiale
DRM30	Digital Radio Mondiale for broadcast frequencies below 30MHz
DRM+	Digital Radio Mondiale for broadcast frequencies above 30MHz
DTPS	Department of Telecommunications and Postal Services
EBU	European Broadcasting Union
ECA	Electronic Communications Act of South Africa
ECC	Electronic Communications Committee within CEPT
EEP	Equal Error Protection
EPG	Electronic Program Guide
ERC	European Radiocommunications Committee
ERP	Effective Radiated Power
ETSI	European Telecommunications Standards Institute
Extended FM Band	Spectrum potentially between 64 (China) or 76 (Brazil) and 108MHz
FAC	Fast Access Channel
FM	Frequency Modulation
FS	Field Strength

HASL	Height Above Sea Level
HE-AAC	High Efficiency Advanced Audio Codec
IBC	International Broadcast Convention (in Amsterdam, The Netherlands)
ICASA	Independent Communications Authority of South Africa
ICT	Information and Communication Technology
ISO	International Standard for Standardization
ITU	International Telecommunications Union
kHz	Kilo Hertz
kW	Kilo-Watt
L-Band	Frequency Band 1.452-1.492 GHz
MER	Modulation Error Ratio
MF	Medium Frequency
MOT	Multimedia Object Transfer (Picture Slideshow format in DAB/DRM)
µV	mikro-Volt
MHz	Mega Hertz
MPEG	Motion Picture Engineering Group
MSC	Main Service Channel
MW	Medium Wave
QAM	Quadrature Amplitude Modulation
RCSI	Receiver Status and Control Interface
RF	Radio Frequency
RSG	Radio Sonder Grense
RTL-SDR	Realtek 2832U based software defined radio
SABC	South African Broadcasting Corporation
SABS	South African Bureau of Standards
SADIBA	South African Digital Broadcasting Association
SDC	Service Description Channel

SDR	Software Defined Radio
SFN	Single Frequency Network
SKA	Square Kilometre Array (located in the Northern Cape, South Africa)
S/N	Signal-to-Noise Ratio
SW	Short Wave
TPEG	Transport Protocol Experts Group (a data protocol suite for traffic and travel related information used in digital broadcasting)
UHF	Ultra-High Frequency
UHF Band	Frequency Band 470-870MHz
V/m	Volts per meter
VHF	Very High Frequency
VHF Band I	Frequency Band 47-68MHz
VHF Band II	Frequency Band 87.5-108MHz (same as FM Band)
VHF Band III	Frequency Band 174-254MHz (in South Africa)
VSWR	Voltage Standing Wave Ratio
xHE-AAC	Extended High Efficiency Advanced Audio Codec

Authorized: ______________________ Westbury, 23 April 2018

Pastor Peter Faver (Chairman WECODEC) Place, Date

Authorized: ______________________ Sandton,23 April 2018

Thembeka Khaka (Regulatory and Compliance) Place, Date

Authorized: ______________________ Hannover, 23 April 2018

Johannes von Weyssenhoff (Technical Lead) Place, Date