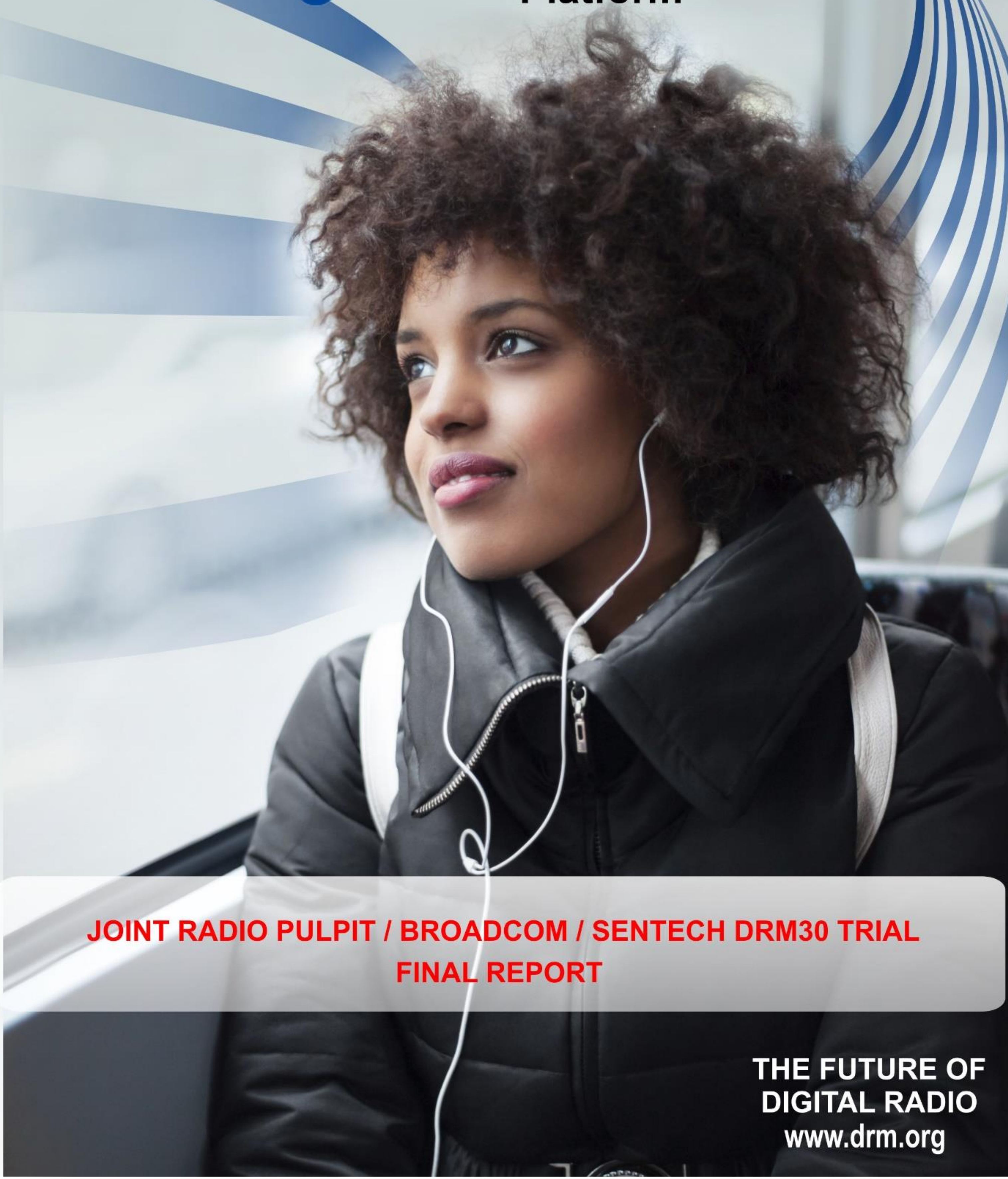
drm

Southern African Platform



JOINT RADIO PULPIT / BROADCOM / SENTECH DRM30 TRIAL FINAL REPORT

THE FUTURE OF DIGITAL RADIO

www.drm.org

EXECUTIVE SUMMARY

Radio Pulpit initiated a DRM30 trial broadcast with support from Broadcom International cc and Sentech Ltd. The DRM test transmission was conducted in Pretoria South Arica during the period September 2014 up to October 2015.

DRM Measurements were conducted successfully on 1440 kHz using a 10 kW DRM30 transmitter.

Two low profile antennas were used in the trial and both were capable to provide good signal coverage. Performance differences between the antennas highlighted the importance of the AM antenna as part of the DRM station design.

Field strength measurement indicated that the propagated ground-wave does not radiate equally in all horizontal directions due to ground conductivity, nature of the topographical terrain, man-made noise etc.

The DRM30 coverage performance is not only a factor or received signal strength but is also a factor of the signal to noise ratio in the reception area

Modulation configuration selection had a direct impact on signal coverage area and data throughput. The 16QAM modulation configuration setting provided a more robust signal resulting in a larger signal coverage area compared to the 64QAM modulated signal which provided a higher data rate and a smaller signal coverage area.

The DRM30 signal performed better than the analogue AM signal with regard to coverage area for the same transmitter power.

DRM30 demonstrated a substantial reduction in energy consumption compared to analogue AM broadcast to cover the same area.

DRM30 demonstrated improved spectrum usage in that in our study DRM30 was capable of transmitting two good audio services on the same AM frequency and bandwidth.

Added to the audio service text messages and a Journaline service were also transmitted which was seen on the receiver end; demonstrating the added value offered by DRM30 in addition to the normal audio program being broadcasted.

The report contains the measurement results and the findings on the Radio Pulpit DRM30 Trial.

TABLE OF CONTENTS Page No.

I ABBREVIATIONS, ACRONYMS AND DEFINITIONS

Abbreviations & Acronyms	Description
AM	Amplitude Modulation
CF	Correction Factor
CTB	Communications Technology Broadcasting
DAB+	Digital Audio Broadcasting
D.F.	Dipole Factor
dB	Decibel
dBµV/m	dB-microvolt per meter
DRM	Digital Radio Mondiale
DRM30	Digital Radio Mondiale for broadcast frequencies below 30MHz
EBU	European Broadcasting Union
EEP	Equal Error Protection
FAC	Fast Access Channel
FS	Field Strength
HASL	Height Above Sea Level
ICASA	Independent Communications Authority of South Africa
IDWM	ITU Digitized World Map
ISO	International Standard for Standardization
ITU	International Telecommunications Union
kHz	Kilo Hertz
kW	Kilo-Watt
MF	Medium Frequency
MHz	Mega Hertz
MSC	Main Service Channel
MW	Medium Wave
QAM	Quadrature Amplitude Modulation
RCSI	Receiver Status and Control Interface
RF	Radio Frequency
SDC	Service Description Channel
S/N	S/N
SW	Short Wave
V/m	Volts per meter
VSWR	Voltage Standing Wave Ratio

II RELEVANT AND APPLICABLE DOCUMENTS

Document No	Description	Location
ETSI ES 201 980	Digital Radio Mondiale (DRM); System Specification	ETSI
ETSI TS 102 349	Digital Radio Mondiale (DRM); Receiver Status and Control Interface (RSCI)	ETSI
ITU-R BS.1615-1	"Planning parameters" for digital sound broadcasting at frequencies below 30 MHz	ITU
ITU-R P.1321	Propagation Factors Affecting Systems Using Digital Modulation Techniques at LF and MF	ITU
ITU-R P.368-7	Ground-wave Propagation Curves for Frequencies Between 10 kHz and 30 MHz	ITU
ITU-R P.1147-2	Prediction of sky-wave field strength at frequencies between about 150 and 1 700 kHz	ITU
ITU-R P.1321	Propagation Factors Affecting Systems Using Digital Modulation Techniques at LF and MF	ITU
ITU-R P.832-2	World Atlas of Ground Conductivities	ITU
EBU-Tech 3330	Technical Bases For DRM Services Coverage Planning	EBU
ITU-R BS.703	Characteristics of AM sound broadcasting reference receivers for planning purposes	ITU

III CONTRIBUTION

This document has been compiled as a joint effort between Radio Pulpit, Sentech Ltd. and Broadcom International who all contributed resources, time and effort in order to establish the DRM trial broadcast and to execute the test and measurement program.

Special thanks to Dr. Roelf Petersen (Radio Pulpit) and Jaco van Heerden (Radio Pulpit), Chris and Heinrich Joubert (Broadcom), Benjamin Hendricks (Sentech), Johan Koegelenberg (Sentech), Marius Venter (Sentech), Johan Minnie (Sentech), Dave Dodd (Sentech), Anina De Haas (Sentech) for their contribution and efforts.

IV DOCUMENT CHANGE HISTORY

Revision No	Description of Change	Date of Issue	Issued By
V1.03	Final Report	2016-06-13	Radio Pulpit / Broadcom / Sentech

V NON-DISCLOSURE OF INFORMATION

1. INTRODUCTION

This report contains the measurement results and the findings on the Radio Pulpit DRM30 Trial. Measurements were conducted successfully on the 10 kW DRM30 transmitter.

Herewith follows a brief list of events in chronological order as it relates to the DRM trial:

- Radio Pulpit was granted the DRM trial license mid-April 2014;
- The DRM transmitter site which included the Broadcom was prepared and operational May 2014;
- First DRM broadcast in South Africa went on-air the 1st of June 2014;
- DRM technical configuration set-up was completed at the end of August 2014;
- DRM broadcast with normal program content started on the 1st of September 2014;
- The delivery of the DRM test equipment was delayed and arrived during January 2015;
- Radio Pulpit requested a 6 months extension of the trial license early in February 2015;
- Antenna and DRM performance tests using the Broadcom low-profile antenna were completed at the end of March 2015, herein after referred to as phase 1 and 2 measurement test exercises;
- Radio Pulpit was granted an extension for the DRM trial up to the 16th of October 2015;
- Antenna and DRM performance tests using the KinStar low-profile antenna were completed at the beginning of October 2015, herein after referred to as the phase 3 and 4 measurement test exercises;

  This report contains the results and findings for tests performed during all measurement exercise test phases (1 to 4). The measurement exercises were conducted by using the following main transmitter station components:

- DRM30 transmitter;
- Broadcom low-profile antenna;
- KinStar low-profile antenna.

2. BACKGROUND INFORMATION

DRM30 is a broadcasting system designed as an improvement of current analogue Amplitude Modulated (AM) radio broadcast systems.

The DRM30 broadcasting system was designed to be a high quality digital replacement or co-existing system for analogue radio broadcast systems in the AM frequency band (long wave, medium wave and short wave). In terms of spectrum allocations, channel plan and impact on existing listeners, the technology requires minimal additional regulatory intervention as it was designed to operate in the same frequency bands and channel arrangements as the existing analogue services. Impact on existing AM listeners will therefore be minimal as the technology was also designed to operate in simulcast mode which allows the transmission of both digital and analogue services from the same transmitter on the same frequency channel. Unlike analogue radio services, digital radio broadcasting technologies allow more efficient utilization of the frequency bands, e.g. DRM30, DRM+ and DAB+. Additional services and value added services can also be provided without the requirement of additional frequency spectrum due to the digital based design of the system.

In this regard the technology should prove to be efficient, effective in spectrum usage with the capability to incorporate additional services providing an innovative platform for both the listeners and broadcasters. Compatibility of the DRM30 digital service with existing analogue services should also assist interested broadcasters to phase-in the conversion from analogue to digital broadcasting. This would also allow the spread of the required investment over a period of time with limited impact on existing services and budget constraints.

Radio Pulpit obtained a temporary DRM broadcasting license from the Independent Communications Authority of South Africa (ICASA) to undertake a DRM30 trial project to broadcast on the DRM30 standard covering the greater Pretoria area and the northern parts of Johannesburg. The Radio Pulpit DRM30 trial was conducted in collaboration between Radio Pulpit, Sentech and Broadcom International cc.

The trial consisted of four measurement phases:

- Test Phase 1 - Evaluation of Broadcom Antenna;
- Test Phase 2 - DRM30 Signal Coverage Evaluation - Broadcom Antenna;
- Test Phase 3 - Evaluation of KinStar Antenna;
- Test Phase 4 - DRM30 Signal Coverage Evaluation - KinStar Antenna;

3. OBJECTIVES

The main objectives of the DRM30 measurement trial are listed as follow:

- Confirm the potential benefits of the DRM30 technology as a radio broadcast platform;
- Evaluation of actual coverage versus predicted coverage (for both Ground and Sky-wave propagation modes);
- Evaluation of two different low-profile AM antenna systems (herein after referred to as the Broadcom & KinStar antennas respectively);
- Obtain sufficient measurement data for analysis to assist in reaching a conclusion on the overall performance of the technology;
- Determine if, how and where the technology could be applied to benefit broadcasters;
- Evaluation of available commercial radio receivers in both fixed and mobile conditions.

4. POTENTIAL BENEFITS OF THE DRM30 TECHNOLOGY

Potential benefits of the DRM30 technology in the MW broadcast band are as follow:

- Exploit some unique signal propagation qualities which are only available in the MW frequency band, more specific wide area coverage and sky-wave propagation;
- Allows select-ability between various capacity and robustness modes for optimum performance, depending on the broadcaster's requirements with regard to area coverage and audio quality;
- Enhanced audio compression which improves efficient utilization of the digital channel;
- Good audio quality;
- Ability to enhance listener's experience;
- Provide additional features, such as Electronic Program Guide, Journaline, News Feeds and Slideshow (pictures);
- Emergency Warning Feature (EWF);
- Single-Frequency-Network (SFN) operation which allows more efficient use of limited spectrum;
- Hand-over capability between different radio platforms or networks (between DRM, DAB+ and FM);
- Capability to operate in current existing analogue Medium Wave (MW) frequency bands;
- Capability to operate in simulcast mode (i.e. broadcasting analogue and digital simultaneously).

5. TECHNICAL INFORMATION ON DRM30 SYSTEM

5.1. TRANSMITTER

The transmitter used to broadcast the MW signal was the Ampegon M2W 25 kW DRM transmitter which was configured according to the basic technical specifications listed in **Table 1**. Antenna input current was measured and the transmitter output power was adjusted to 10kW at the input point to the antenna.

Transmitter Specifications		
No	**Description**	**Value**
1	Transmitter Power	10 kWatt (mean) DRM
2	Transmit Frequency	1.44 MHz
3	Frequency Band	MF
4	Modulation	DRM - Mode A
5	Bandwidth	9kHz

Table 1: Transmitter Specifications

Picture 1: Ampegon M2W 25kW DRM Transmitter

5.2. BROADCOM ANTENNA SYSTEM

The Broadcom antenna (**picture 2**) is a short (24 meters) folded monopole antenna designed by Broadcom which consisted of a capacitive top loading and a diamond-shaped feed skirt to increase the frequency bandwidth capability required for DRM30 operation.

The antenna was tuned to resonance and impedance matched to 50 Ohms before connecting it directly to the RF feeder without any additional tuning elements.

The basic antenna specifications are listed in **table 2**.

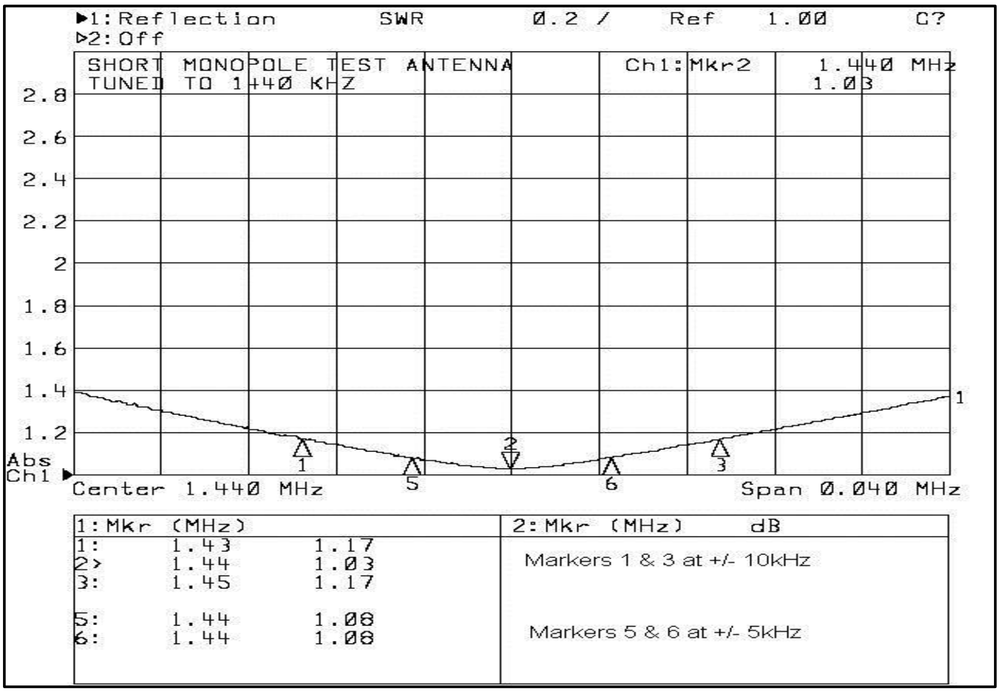
Broadcom Antenna Specifications		
No	**Description**	**Value**
1	Manufacturer	Broadcom
2	Installer	Broadcom
3	Type	Mast Radiator
4	Input Impedance	48.8Ω - j0.1
5	VSWR	1.08:1 at ±5 kHz
6	VSWR	1.17:1 at ±10 kHz
7	Height	24m
8	Beam Width	360°
9	Polarisation	Vertical

Table 2: Broadcom Antenna Specifications

Measured Broadcom Antenna Radio Frequency (RF) response is graphically presented in **graph 1**.

Broadcom's low-profile MF antenna system was used for antenna directivity measurements as well as signal coverage measurements (**phase 1** and **2**).

Picture 2: Broadcom Short Vertical Antenna



Graph 1: Measured Broadcom Antenna RF Response

5.3. KINSTAR ANTENNA SYSTEM

The KinStar antenna (**picture 3**) is a new reduced height antenna designed by Star-H Corporation and manufactured by Kintronic Laboratories and consists of four horizontal and vertical radiating wires. The lengths and arrangements of the wires were designed by computer optimization methods to provide the best compromise between reduced antenna height, antenna gain and frequency bandwidth. Total height of the KinStar antenna used in this trial was 20 meters.

An ATU (Antenna Tuning Unit) also formed part of the antenna system to match the antenna's input impedance to the transmitter's output impedance.

Basic antenna specifications of the KinStar low-profile MF antenna system are listed in **table 3**.

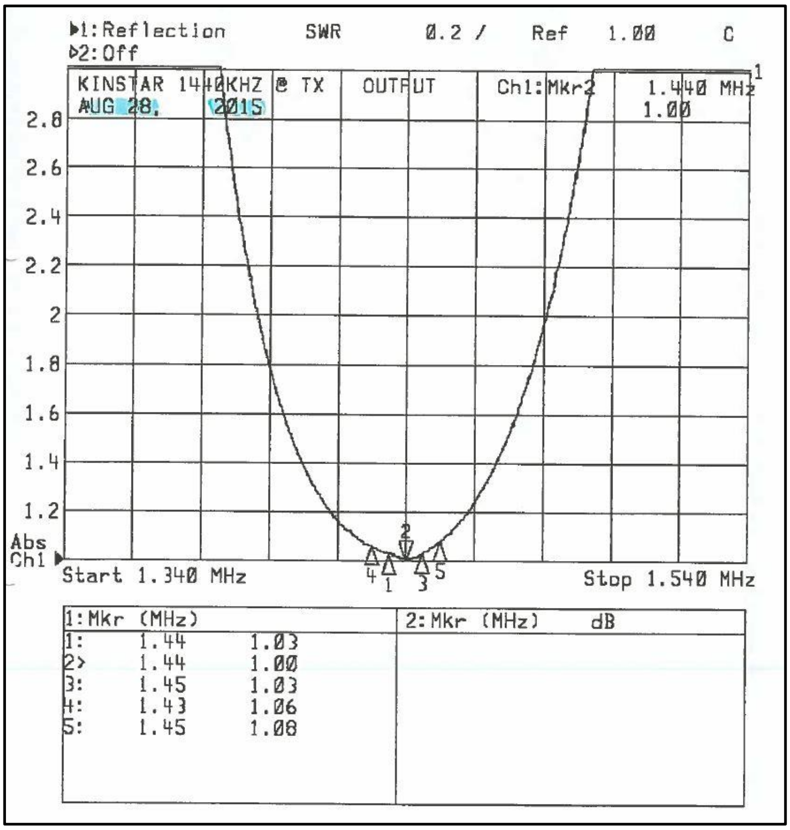
KinStar Antenna Specifications		
No	**Description**	**Value**
1	Manufacturer	Kintronic Labs
2	Installer	CTB
3	Type	Mast Radiator
4	Input Impedance	50Ω + j0
5	VSWR	1.03:1 at ±5 kHz
6	VSWR	1.08:1 at ±10 kHz
7	Height	20m
8	Beam Width	360°
9	Polarisation	Vertical

Table 3: KinStar Antenna Specifications

Measured Kinstar antenna Radio Frequency (RF) Response is graphically presented in **graph 2.**

Antenna directivity measurements as well as signal coverage measurements were conducted on the KinStar low-profile MF antenna system (**phase 3** and **4**).

Picture 3: KinStar low profile antenna.



Graph 2: Measured KinStar Antenna RF Response

6. MEASUREMENTS

6.1. INITIATION OF MEASUREMENT EXERCISE

Radio Pulpit and Broadcom International established a DRM30 trial broadcast platform and Sentech agreed to participate in the DRM30 trial by providing an alternative antenna (KinStar), as well as support in terms of conducting measurement exercises with the main objective to determine the functional capacity and capability of the DRM30 technology.

An alternative antenna was purchased from Kintronic Laboratories and installed by CTB (Communications Technology Broadcasting) in the later stage of the DRM30 trial. This antenna was constructed on the exact same location as the previous antenna (previous Broadcom antenna was dismantled).

Measurements exercises were planned in different phases (Phase 1 to 4) and scheduled accordingly.

Phase 1 measurement exercise focused on the Broadcom antenna's performance which was scheduled over a period of two days and conducted from the 17th to the 18th of September 2014. A preliminary measurement report for phase 1 was completed on the 30th of September 2014 of which the findings are also included in this report.

Phase 2 measurement exercise focused on DRM signal coverage measurement of the signal broadcasted using the Broadcom antenna was scheduled over a period of eight days and conducted from the 16th to the 26th of March 2015. Measurement data was analysed and the results and findings were also compiled in this report.

Phase 3 measurement exercise focused on the KinStar antenna performance which was scheduled over a period of three days and conducted from the 15th to the 17th of September 2015. Measurement data was analysed and the results and findings also compiled in this report.

Phase 4 measurement exercise focused on DRM signal coverage measurement of the signal broadcasted using the KinStar antenna was scheduled over a period of eight days, conducted from the 22th of September 2015 to the 2nd of October 2015. Measurement data was analysed and the results and findings were also compiled in this report.

Additional measurements were also conducted on the KinStar antenna which focused on the analogue AM signal coverage which was also scheduled over a period of two days and conducted from the 5th to the 6th of October 2015. Analysis and findings are also compiled in this report.

6.2. MEASUREMENT TOOLS

Various measurement tools were used to conduct the required measurements and are listed below:

- Input current to the antenna system was measured with a Delta Electronics Peak RF Meter and used to calculate the input power to the antenna system;
- Antenna input impedance was measured by using a Hewlett-Packard (HP) RF Network Analyzer (8712B);
- Static measurements were conducted at fixed pre-determined locations using the Photomac (PI 4100), Fraunhofer (DT700) and RF Mondiale DRM Monitoring Receiver (RF-SE12) measurement tools;
- Drive-By measurements were conducted using a RF Mondiale DRM Monitoring Receiver (RF-SE 12);
- Antenna Tuning Unit (ATU) measurements were conducted using HP Network Analyzer (8712B) and HP Communication Test Set Hewlett Packard measurement tools (VSWR measurements).

Details of measurement tools used are tabled in **table 4**.

Measurement Tools			
No	**Description**	**Manufacturer / Supplier**	**Model / Code**
1	Peak RF current meter	Delta Electronics	TCT-1
2	RF Network Analyzer	Hewlett-Packard	8712B
3	Active Rod Antenna	Rohde & Schwarz	R&S®HE010E
4	Bias Unit	Rohde & Schwarz	R&S®IN600
5	DRM Monitoring Receiver RF-SE	RFmondial	Model RF-SE12
6	DRM30 Domestic Receiver	NewStar	DR-111
7	DRM30 Domestic Receiver	Himalaya	DRM2009
8	DRM30 Domestic Receiver	Morphy Richards	27024
9	DRM30 Domestic Receiver	Uniwave	Di-Wave 100
10	Communication Test Set	Hewlett-Packard	8920A

Table 4: Measurement Tools

6.3. MEASUREMENT METHOD

Measurements were conducted on planned locations and routes which consisted of both static measurements as well as Drive-By measurements. Static measurement results were mainly used to determine antenna performance and Drive-By measurement results used to conduct signal coverage verification. Static measurements on the routes were identified based on incident findings (e.g. Audio loss, audio recovery etc.)

Only the static point measurement method was used to conduct basic antenna performance measurements. Measurements were conducted at a height of approximately 1.5 meters above ground level and consisted of one measurement per static point. Measurements were conducted at distances of 0.5km, 1km, 2km and 5km from the transmitter station in 8 main predetermined radial directions (0º, 45º, 90º, 135º, 180º, 225º, 270º and 315º). The transmitter was configured to provide an analogue pilot signal during the antenna measurement exercises.

Drive-By measurements were conducted at a height of two meters at a measurement sampling rate of four measurements per second at a maximum speed of 90 km/h. These measurements were conducted on eight pre-planned radial routes over a period of eight days. Measurements were conducted by driving outwards on each radial with the MSC (Main Service Channel) configured on a lower modulation setting (16QAM) up to the point where complete audio failure occurred. Once audio failure detection was confirmed, the same route was measured in the opposite direction back to the transmitter, with the MSC configured to a higher modulation setting (64QAM). This measurement sequence was repeated for all eight planned radial routes. The transmitter was configured to transmit a DRM30 signal during the coverage measurement exercises.

Static measurements were conducted at fixed locations on the planned routes by using the Drive-By measurement tool. These static measurement points were either located at pre-identified measurement test point locations (e.g. major towns), or incident point locations (where audio failure or recovery occurred) identified during the Drive-By measurement exercise. Static measurements were conducted at a height of approximately two meters above ground level at predetermined and incident locations.

Limited analogue AM measurements were also conducted for comparison purposes between analogue (AM) and digital (DRM30). Drive-By and static measurements for AM and DRM30 comparison purposes were conducted only on the northern and southern radial routes.

Services were monitored and measured on all the planned 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.

6.4. MEASUREMENT DATA

Drive-By measurement data measured by the DRM Monitoring Receiver (RF-SE12) was logged, downloaded and converted to the appropriate format for coverage and statistical analysis purposes.

6.5. MEASURED PARAMETERS

DRM30 parameters measured are listed in recommendation ETSI ES 201 980. Receiver Profile A was chosen, which include parameters like time, GPS coordinates, RF level etc.

6.6. DRM30 CONFIGURATION PARAMETERS

Configuration parameters used for the DRM30 16QAM, 64QAM and Analogue Modulation (AM) configuration settings are provided in **table 5**, **6** and **7** below:

Robustness mode	DRM Mode A, Long interleave
RF Spectrum occupancy	9 kHz
FAC Mode	4 QAM
SDC Mode	4 QAM
MSC Mode	16 QAM
DRM Channel	12400 bps;
MSC Protection	EEP [0.5]
Audio coding	AAC (mono), Sampling Rate, 24kbps
Data services	Journaline enabled, PRBS enabled

Table 5: DRM30 16QAM Parameter Configuration

Robustness mode	DRM Mode A, Long interleave
RF Spectrum occupancy	9 kHz
FAC Mode	4 QAM
SDC Mode	4 QAM
MSC Mode	64 QAM
DRM Channel	18000 bps
MSC Protection	EEP [0.5]
Audio coding	AAC (mono), Sampling rate 24kbps
Data services	Journaline enabled, PRBS enabled

Table 6: DRM30 64QAM Parameter Configuration

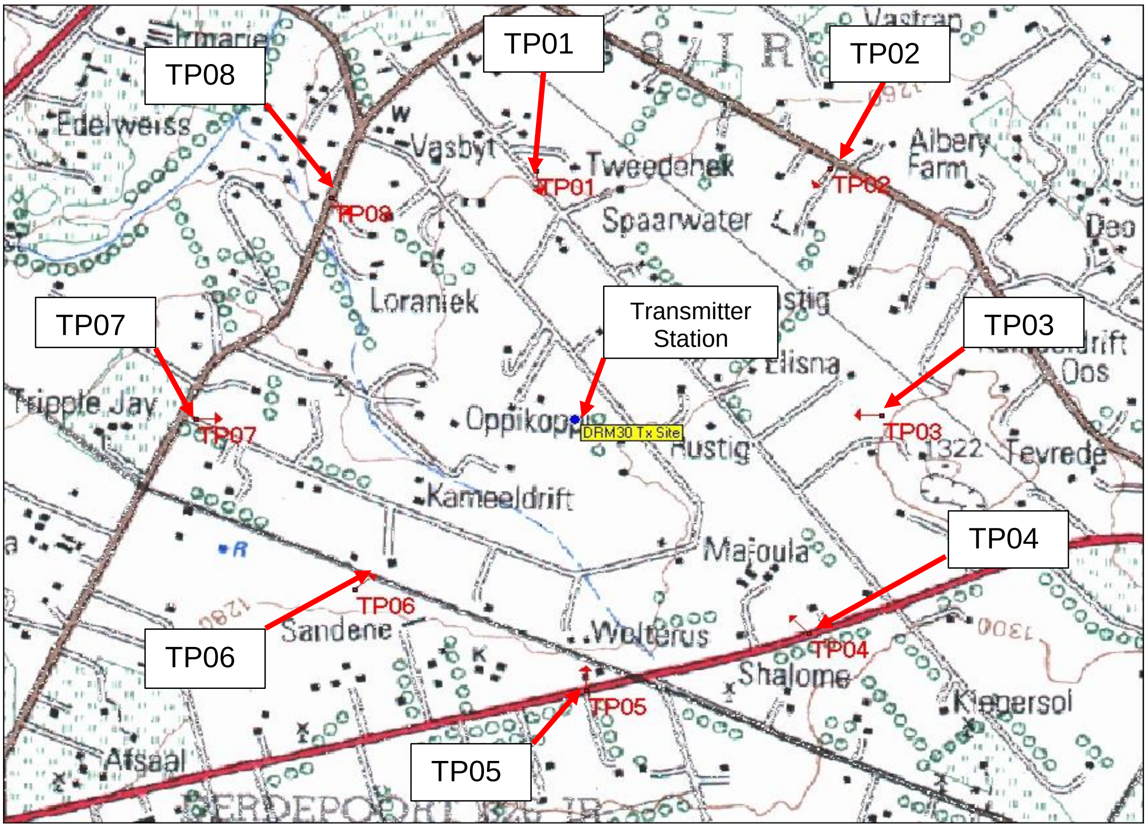
Output power	10 kW
Modulation	Amplitude Modulation (double sidebands)
Bandwidth	9 kHz

Table 7: AM Parameter Configuration

6.7. ANTENNA MEASUREMENT TEST POINTS

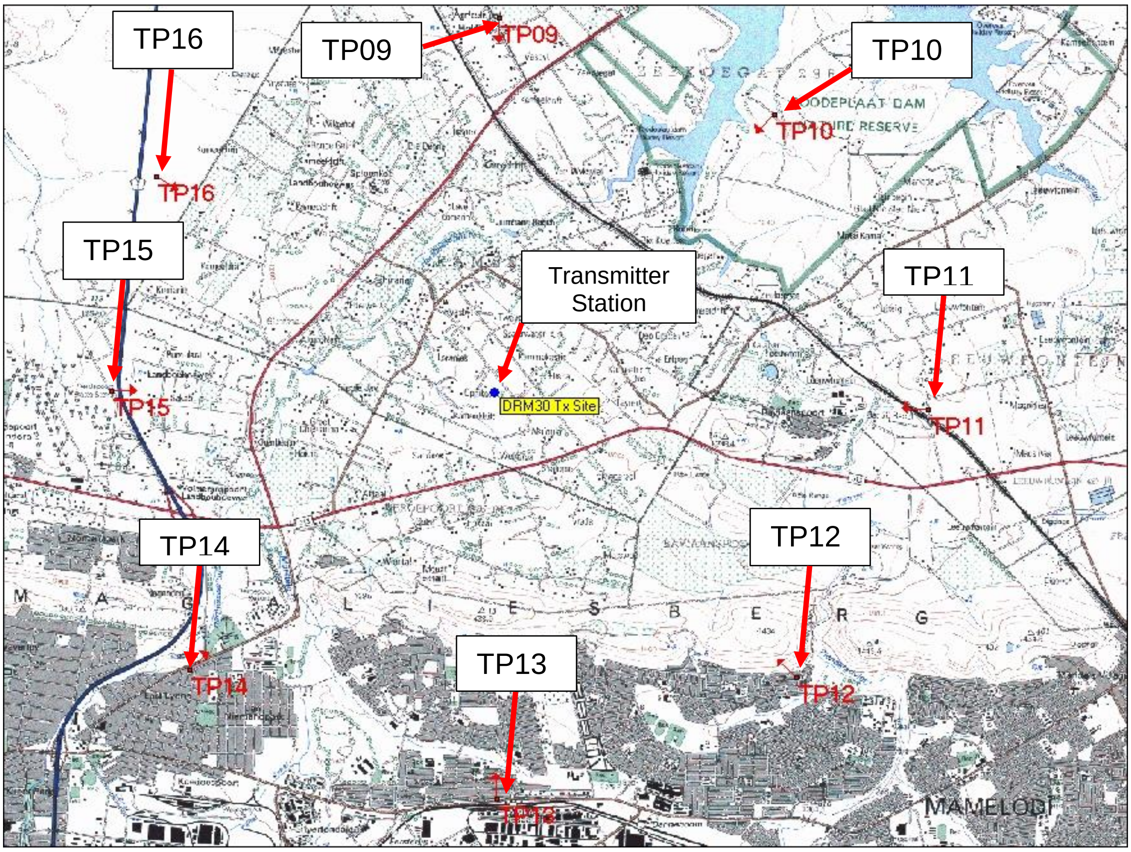
Static measurement test points were identified and planned for the antenna measurement exercise. The number of test points identified consisted of 32 measurement test points around the transmitter station which were located in eight different radial directions (0º, 45º, 90º, 135º, 180º, 225º, 270º and 315º), at four different distances (0.5km, 1km, 2km and 5km) from the antenna.

Test points are indicated on **maps 1 to 8**. The details of each test point are tabled in **table 16** in **annexure A.**

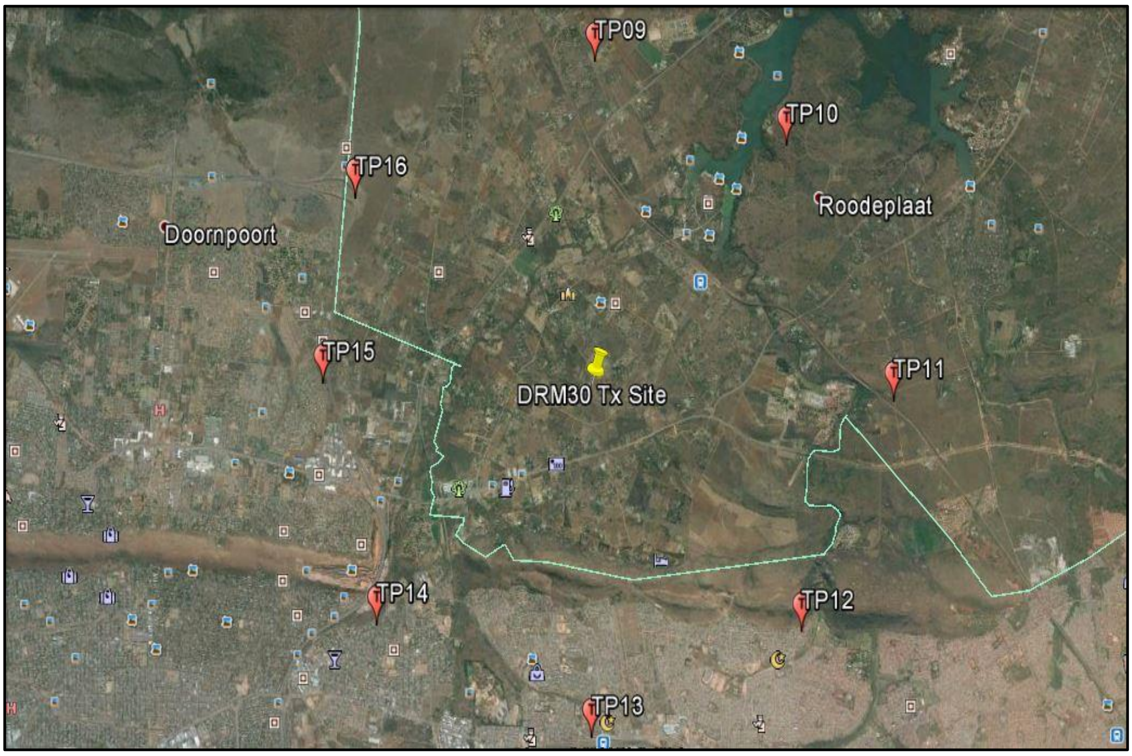


Map 1: Test points (TP01 to TP08) in 8 radial directions located at a distance of 1km from the transmitter site. (ATDI ICS Telecom map)

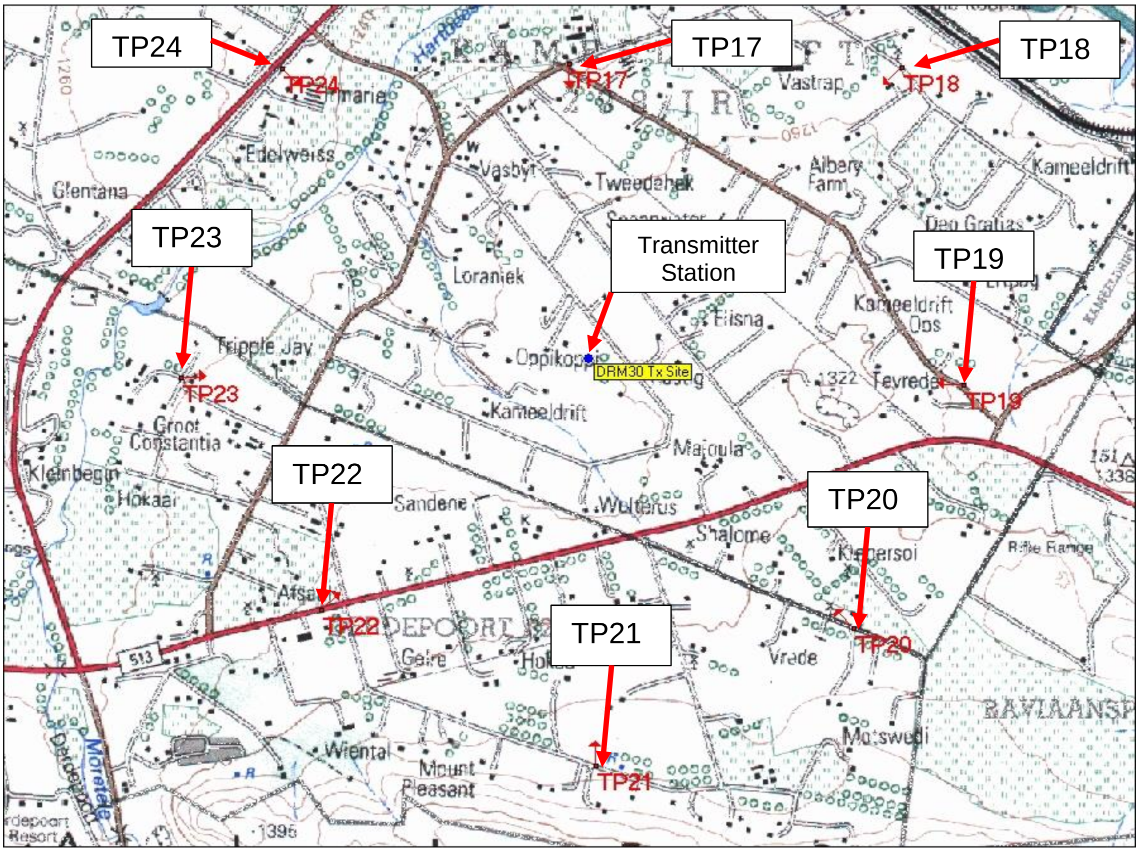
Map 2: Test points (TP01 to TP08) in 8 radial directions located at a distance of 1km from the transmitter site. (Google Earth Map)



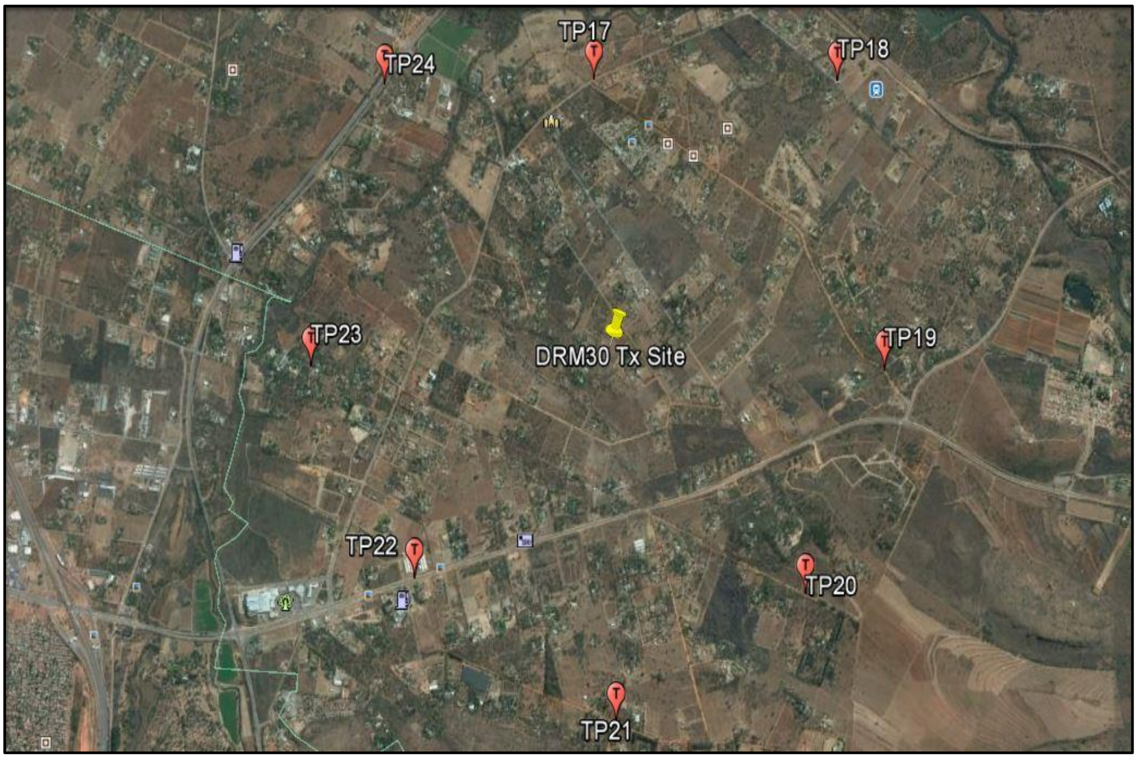
Map 3: Test points (TP09 to TP16) in 8 radial directions located at a distance of 5km from the transmitter site. (ATDI ICS Telecom map)



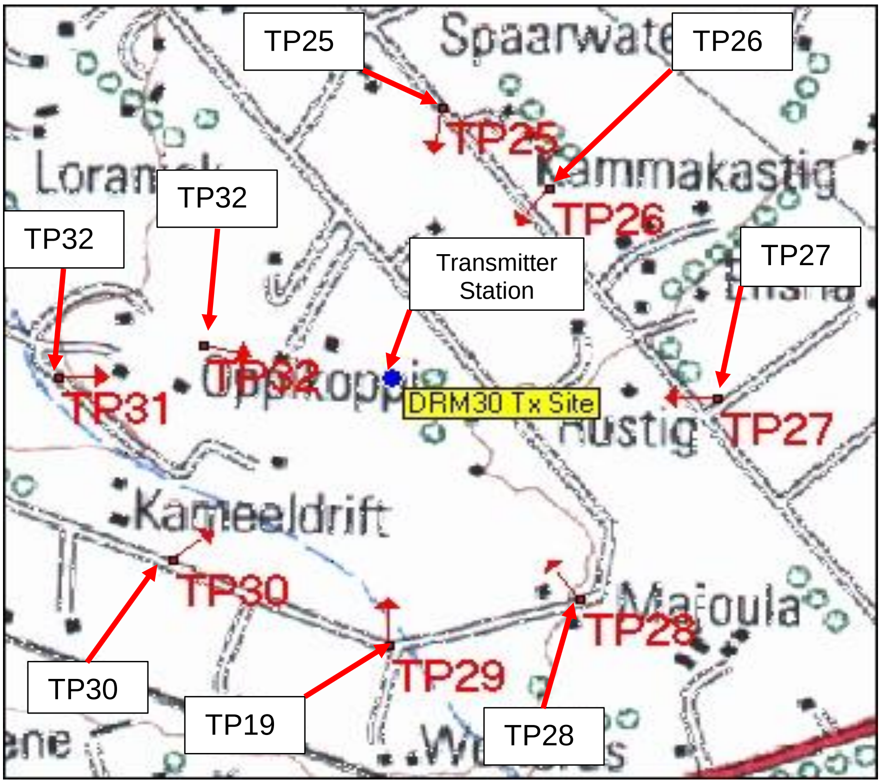
Map 4: Test points (TP09 to TP16) in 8 radial directions located at a distance of 5km from the transmitter site. (Google Earth Map)



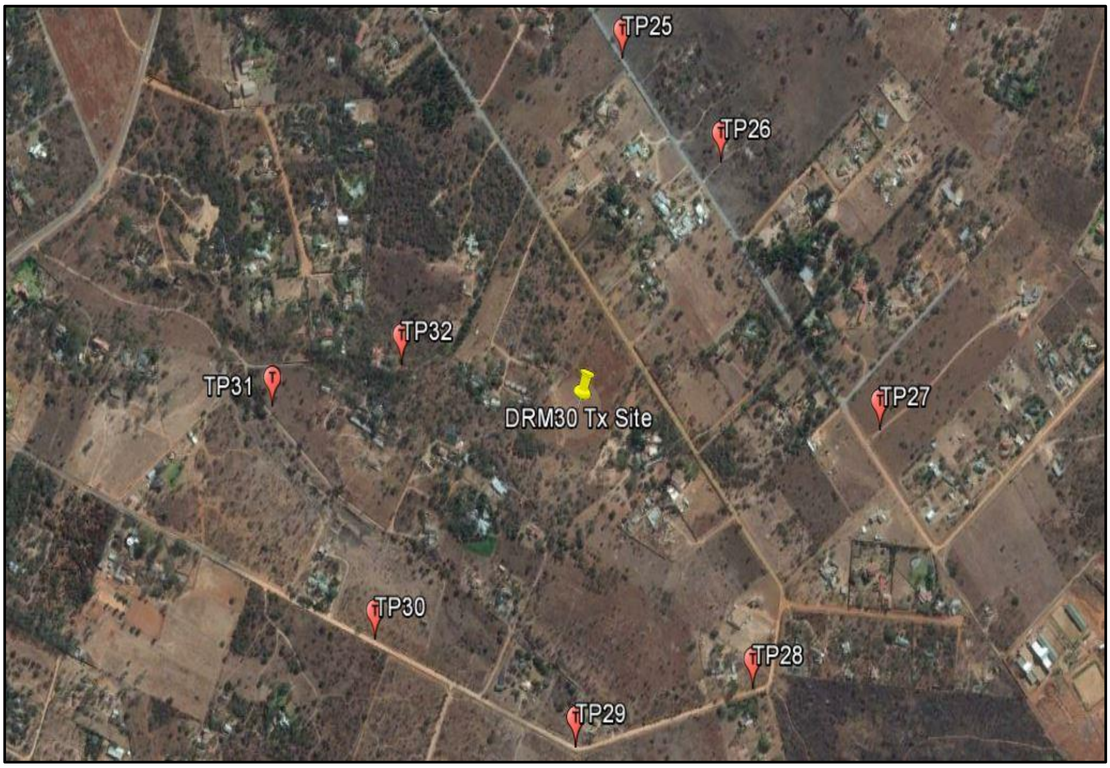
Map 5: Test points (TP17 to TP24) in 8 radial directions located at a distance of 2km from the transmitter site. (ATDI ICS Telecom map)



Map 6: Test points (TP17 to TP24) in 8 radial directions located at a distance of 2km from the transmitter site. (Google Earth Map)



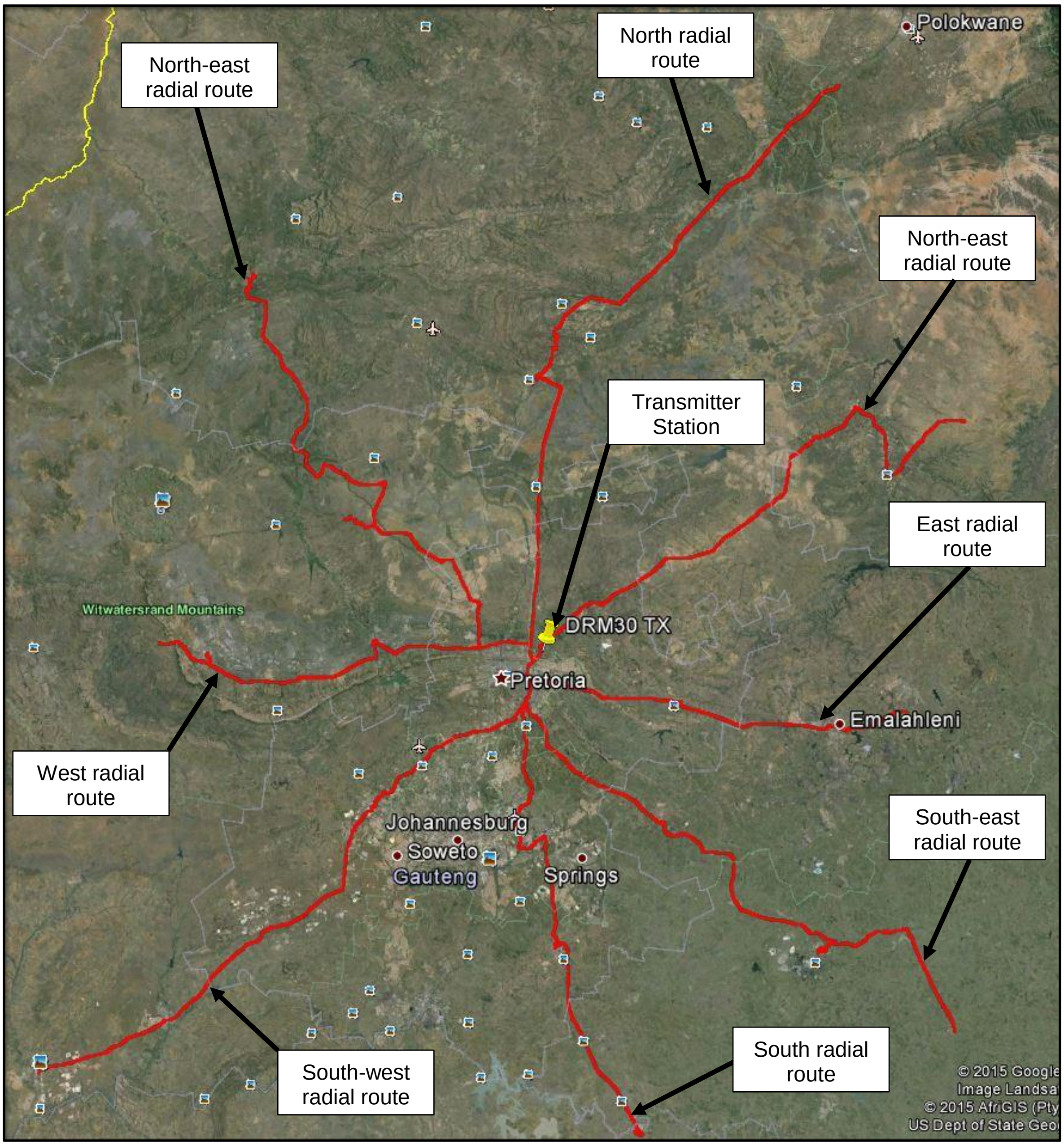
Map 7: Test points (TP25 to TP32) in 8 radial directions located at a distance of 0.5km from the transmitter site. (ATDI ICS Telecom map)



Map 8: Test points (TP25 to TP32) in 8 radial directions located at a distance of 0.5km from the transmitter site. (Google Earth Map)

6.8. DRIVE-BY MEASUREMENT ROUTES

Eight Drive-By measurement routes were planned for the coverage measurement exercise inside and outside the predicted coverage area indicated in **map 9**. The main objective for selecting these routes was to determine the maximum area covered and also to measure and monitor the signal quality within the coverage area. The four main radial routes were measured first (north, east, south and west), followed by the remaining four routes (north-east, south-east, south-west and north-west). Details on the various measurement routes are tabled in **table 8** on **page 24**.



Map 9: Drive-by measurement routes in eight radial directions.

Drive-by Measurement Routes			
Route No.	**Dates measured**	**Description**	**Objective**
1	2015/03/16 2015/09/22	Kameeldrift – N1 North – Bela Bela - R101- Modimolle – N1 North – Mookgopong – Mokopane. - Polokwane (Total Distance from transmitter station: 210 km)	Measure signal on N1 north route, Bela Bela, Modimolle, Mookgopong, N1 north route between Kameeldrift and Polokwane.
2	2015/03/17 2015/09/23	Kameeldrift – N4 East – Bronkhorstspruit – N4 East – Emalahleni – Middelburg. (Total Distance from transmitter station: 112 km)	Measure signal on N4 east route, Bronkhorstspruit, Emalahleni, N4 east route between Kameeldrift and Middelburg.
3	2015/03/18 2015/09/25	Kameeldrift – N1 South – R21 – OR Tambo International Airport – Boksburg – Benoni – R23 – Heidelberg – N3 South – Villiers. (Total Distance from transmitter station: 154 km)	Measure signal on N3 south route, OR Tambo International, Benoni, Heidelberg, N3 south route between Kameeldrift and Villiers.
4	2015/03/19 2015/09/28	Kameeldrift – N4 West – Brits – Rustenburg. (Total Distance from transmitter station: 124 km)	Measure signal on N4 west route, Brits, Rustenburg, N4 west route between Kameeldrift and Rustenburg.
5	2015/03/23 2015/09/29	Kameeldrift – R573 – Moloto – Kwamhlanga – Kwaggafontein – Marblehall – N11 – Groblersdal – R33 – Tafelkop – Luckau. (Total Distance from transmitter station: 151 km)	Measure signal on R573 north-east route, Moloto, Kwamhlanga, Kwaggafontein, Marblehall, N11, Groblersdal, R33, Tafelkop, R573 north-east route between Kameeldrift and Luckau.
6	2015/03/24 2015/09/30	Kameeldrift – N1 South – R50 – Delmas – R50 – Leandra – N17 - Trichardt – Secunda Mall – N17 – Bethal – R35 – Morganzon. (Total Distance from transmitter station: 176 km)	Measure signal on R50 south-east route, Delmas, R50, Leandra, N17, Trichardt, Secunda, N17, Bethal, R35, south-east route between Kameeldrift and Morganzon.
7	2015/03/25 2015/10/01	Kameeldrift – N1 South – N14 – Krugersdorp – R28 – N12 – Potchefstroom – N12 – Klerksdorp. (Total Distance from transmitter station: 212 km)	Measure signal on N14 south-west route, Krugersdorp, R28, N12, Potchefstroom, N12, Klerksdorp, south-west route between Kameeldrift and Klerksdorp.
8	2015/03/26 2015/10/02	Kameeldrift – N4 West – R80 – Soshanguve – Jericho – R511 – R510 – Thabazimbi. (Total Distance from transmitter station: 152 km)	Measure signal on R511 north-west route, R80, Soshanguve, Jericho, R511, R510, Thabazimbi, north-west route between Kameeldrift and Thabazimbi.

Table 8: Drive-By Measurement Routes

7. MEASUREMENT ANALYSIS

Measurement analyses were conducted with the objective to determine and verify the potential benefits of the DRM30 technology as a potential radio broadcast platform. The measurement analysis and findings described in this section include both the analysis and findings on both the antenna systems (Broadcom and KinStar) as well as coverage measurement results measured on both antenna systems.

7.1. CORRECTION FACTOR

This section provides a brief explanation of the Correction Factor (CF) requirement as well as the calculation thereof.

The field strength parameter (in dBµV/m) is used in radio propagation coverage predictions and analysis. Measurement tools measure signal strength levels (in dBm or dBµV). Determining the field strength value from the measured signal strength value require the antenna correction factor to be calculated and included with the gains and losses of all the elements of the measurement system including the antenna dipole factor (DF). The unit used for field strength measurement is Volt per meter (V/m) or micro-volt per meter (µV/m).

The total correction factor are determined by reading the antenna dipole factor from the antenna factor graph and also by including all the measurement system gains and losses. This correction factor could either be included in the measurement system setup configuration, or added afterwards during the analysis of the measurement values. The formula used are indicated below and the measurement system correction factor tabled in **table 9**.

Formula:

CF = Antenna Factor - G + Feeder insertion Loss + Connector's Insertion loss + Height Loss Correction factor (L_h)

R&S®HE010E antenna system correction factor for Band 6 (MF) at 1.44 MHz			
No.	**Description**	**Factor (dB)**	**Comments**
1	Antenna Factor for R&S®HE010E @ 1.44 MHz	10.3	Dipole Factor is added to the measured signal strength measurement unit (dBµV) value to enable it to be converted to a field strength measurement (dBµV/m) unit value
2	R&S®HE010E antenna gain	0	Gain to be subtracted from measurement
3	Coaxial cable & connector loss	0	Loss to be added to measurement
4	Antenna height loss correction factor	0	Loss to be added to measurement
Total Correction Factor		**10.3**	Total value of correction factor be added to the measured signal strength measurement value

Table 9: Correction factor of the R&S®HE010E antenna system for Band 6 (MF) at 1.44 MHz

The information provided by Rhode & Schwarz state that the antenna factor for the R&S®HE010E active antenna system already included the gains and the losses in the measurement result.

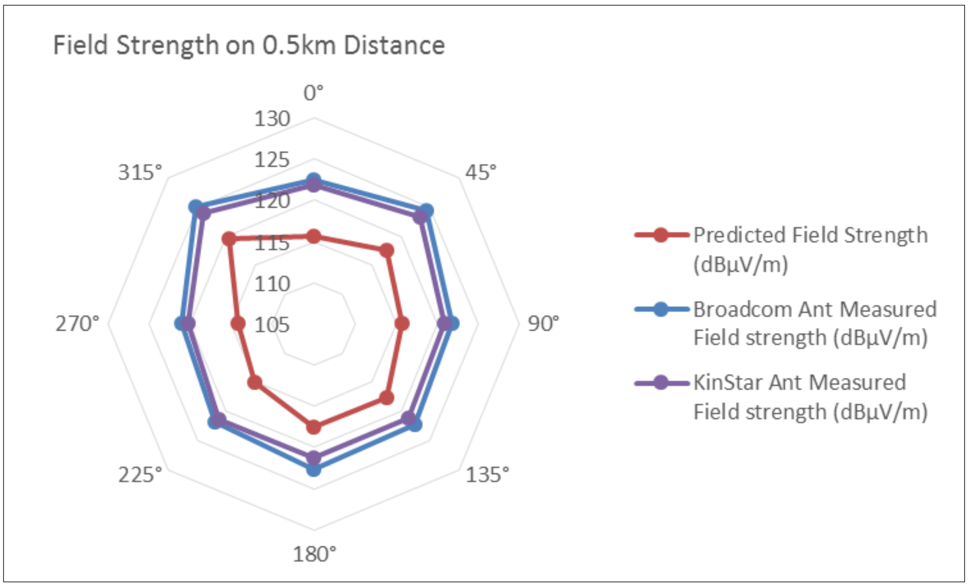
7.2. BASIC ANTENNA RADIATION ANALYSIS

Antenna directivity analysis was conducted by using both the predicted as well as the measured field strength values for correlation purposes. Analysis were conducted on both the Broadcom and KinStar antenna systems. Special notice should be taken that an analogue narrow band pilot signal was used during the measurement exercise.

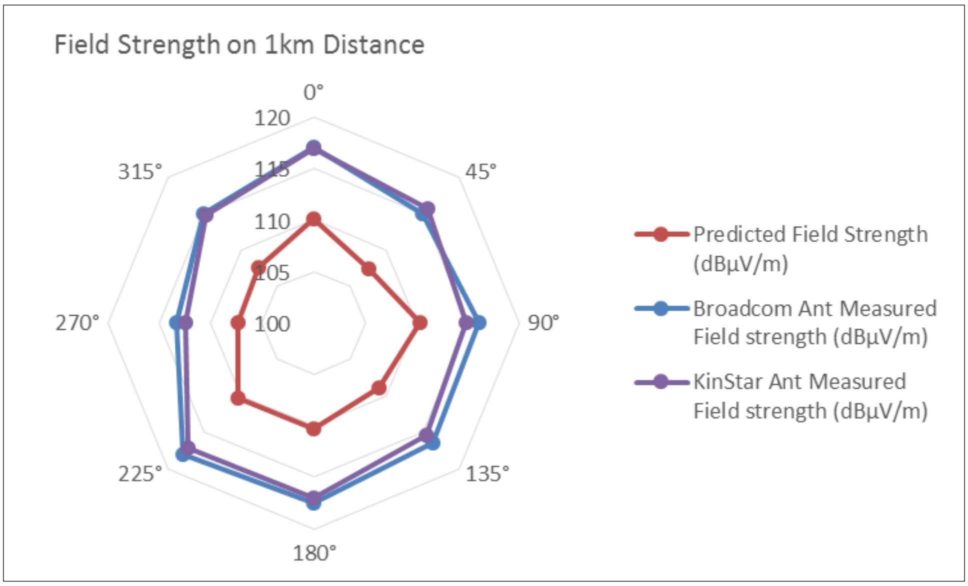
Correlation results are presented graphically in **graphs 3** to **7**. Details of the 32 measurement test points are tabled in **table 13** in **annexure A**.

Findings on the analysis of the correlated results can be summarized as follow:

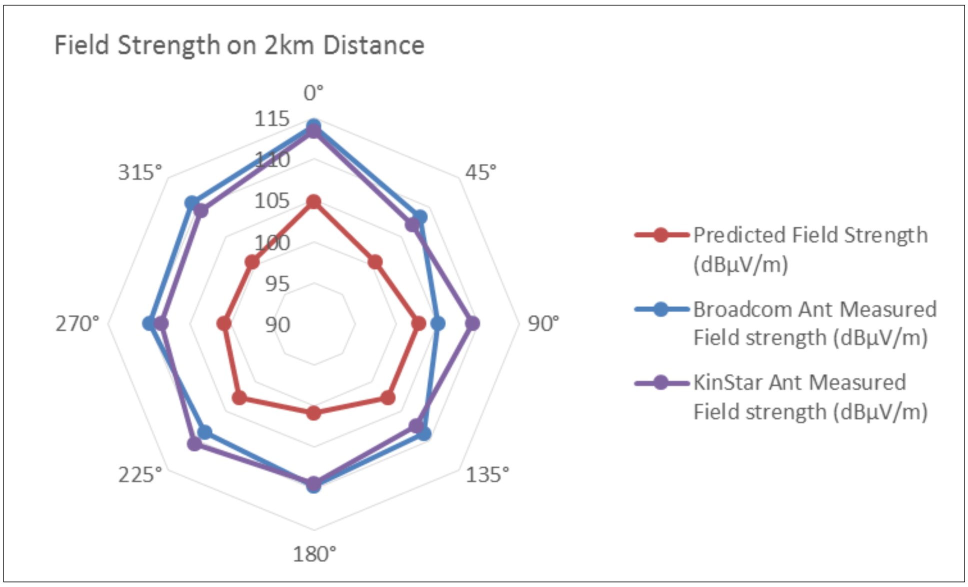
1. Predicted field strength values of the Broadcom antenna and the KinStar antenna were found to be the same on all 32 test points;
2. Measured field strength values were found in most cases to be higher than predicted. (Overall average of 32 measurement values indicated results higher than predicted by 7.7 dB for the Broadcom antenna and 6.6 dB for the KinStar antenna);
3. The maximum difference between measured and predicted values for both antennas (Broadcom and KinStar) was located on the 90º radial at a distance of 5 km from the transmitter station as indicated in **graph 6**;
4. Averaging the predicted and measured values per radial and analysing the results provided some indication of the antenna directivity for both antennas (Broadcom and KinStar) as indicated in **graph 7**;
5. The measured horizontal radiation pattern and predicted radiation pattern were found to be comparable except for the measurement values which measure slightly higher than predicted;
6. The Broadcom antenna measurements were found in most cases to be higher than the KinStar antenna measurements;
7. The KinStar antenna measured higher than the Broadcom antenna on the 45º radial at a distance of 1km from the transmitter's station as indicated in **graph 4.** The KinStar antenna also measured higher than the Broadcom antenna on both the 90º and 225º radials, at a distance of 2 km from the transmitter station which is indicated in **graph 5**;
8. The KinStar antenna measured lower than predicted on the 135º radial at a distance of 5km from the transmitter station as indicated in **graph 6**;
9. The average difference in values between the Broadcom antenna and the KinStar antenna indicate that the Broadcom antenna measured higher than the KinStar antenna as indicated in **graph 7**;
10. Measurements in the future should include both an analogue pilot signal as well as a DRM30 wide band signal;
11. Future measurements should include spectrum graphs as well.



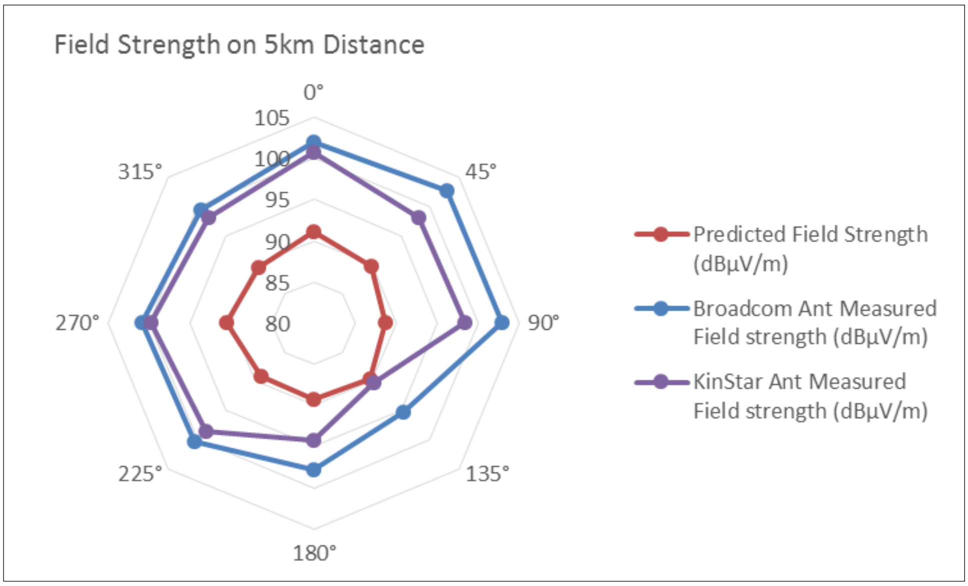
Graph 3: Measured field strength at test points located 0.5km from the transmitter station in 8 radial directions.



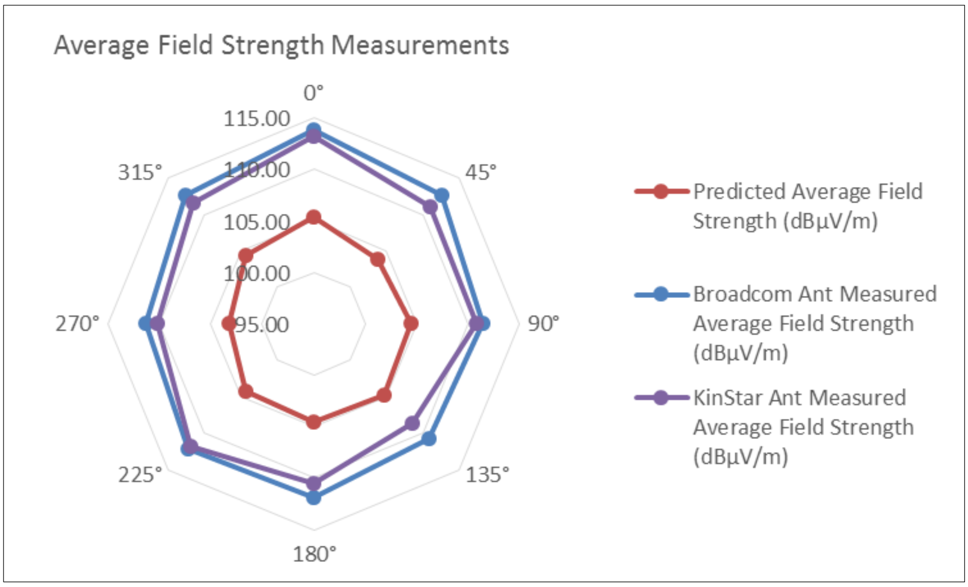
Graph 4: Measured field strength at test points located 1km from the transmitter station in 8 radial directions.



Graph 5: Measured field strength at test points located 2km from the transmitter station in 8 radial directions.



Graph 6: Measured field strength at test points located 5km from the transmitter station in 8 radial directions.



Graph 7: Calculated average field strength for all test point measurements which include all 4 distances (0.5km, 1km, 2km and 5km) from the transmitter station on each of the 8 radials.

7.3. COVERAGE ANALYSIS

Coverage analyses require the measurement values to be correlated with the predicted values as well as with the ITU specified performance indicators.

7.3.1. BACKGROUND ON GROUND-WAVE AND SKY-WAVE PROPAGATION

When services are broadcasted on medium frequency (MF) radio signals, the radio signals are being propagated in all directions. The MF radio signals can however be grouped and defined in two main grouping waves, namely ground-wave and sky-wave. Refer to **figure 1** for a graphical representation of ground-wave coverage, skip zone and sky-wave coverage.

Ground-wave radio propagation occur as the signal propagate from the transmitter in close proximity to the ground. Propagated ground-wave radio signals also tends to follow the curvature of the earth. The propagated ground-wave also cause currents to be induced in the earth's surface, resulting in the "slowing down" of the propagated wave which impacts the propagation path, causing it to follow the curvature of the earth and enable it to travel beyond the horizon. Ground-wave propagation is more dominant during the day-time.

Since the transmitted radio wave is propagated in all directions, some of the waves travel either directly via ground-waves, or are reflected from the earth's surface skywards. The ionosphere is a region of the upper atmosphere, from about 80 km to 1000 km in altitude, where neutral air is ionized by solar photons and cosmic rays. When high frequency signals enter the ionosphere obliquely, they are back-scattered from the ionized layer as scatter waves as indicated in **figure 1**. If the mid-layer ionization is strong enough, compared to the signal frequency, a scatter wave can exit the bottom of the layer earthwards as if reflected from a mirror. Earth's surface (ground or water) then diffusely reflects the incoming wave back towards the ionosphere. The signal may effectively "bounce" or "skip" between the earth and ionosphere two or more times (multi-hop propagation). Under specific atmospheric conditions (mainly at night) more radio signals are back-scattered from the ionosphere resulting in more of these signals to be returned to earth. These signals are termed sky-waves. The impact of sky-wave propagation is therefore more noticeable at night-time.

The sky-wave propagation becomes significant between the periods after sunset up to sunrise the next morning. Although sky-wave propagation has the potential to enable large distances to be covered under certain atmospheric conditions, it unfortunately also has the ability to have a destructive impact on the ground-wave. This is mainly due to the reflected sky-wave causing interference with the original propagated ground-wave. This is called Sky-wave interference. The Sky-wave interference area is called the Sky-wave interference zone.

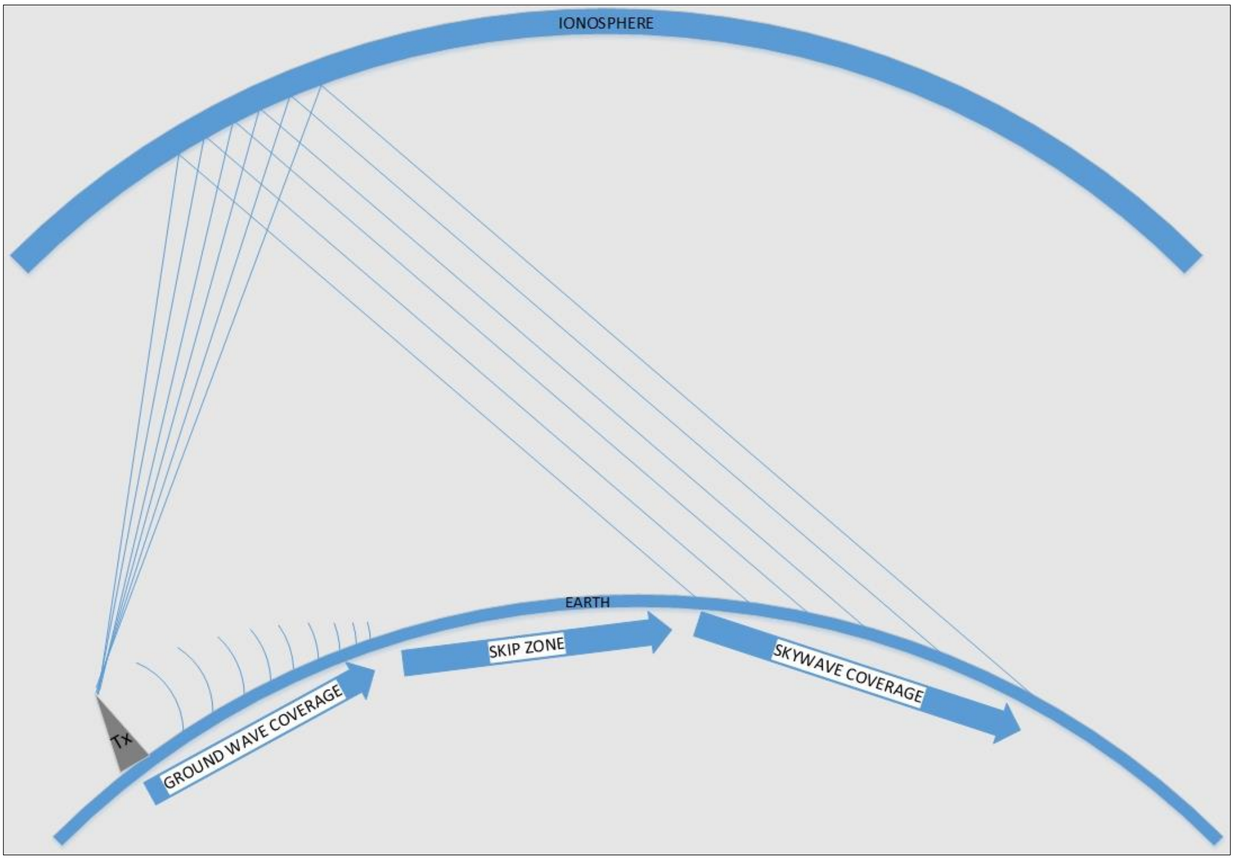


Figure 1: Ground-wave coverage, skip zone and sky-wave coverage.

7.3.2. GROUND-WAVE AND SKY-WAVE PREDICTIONS

The prediction of field strength for digital sound broadcasting systems is covered in Recommendation ITU-R P.1321. This recommendation also refer to two other recommendations, recommendation ITU-R P.368-7 for ground-wave predictions and recommendation ITU-R P. 1147 for Sky-Wave predictions.

Recommendation ITU-R P.368-7 is a calculation model that is specifically used to calculate ground-wave propagation which are used for ground-wave coverage predictions.

Recommendation ITU-R P. 1147 is a calculation model that is specifically used to calculate sky-wave propagation which are used to predict sky-wave coverage.

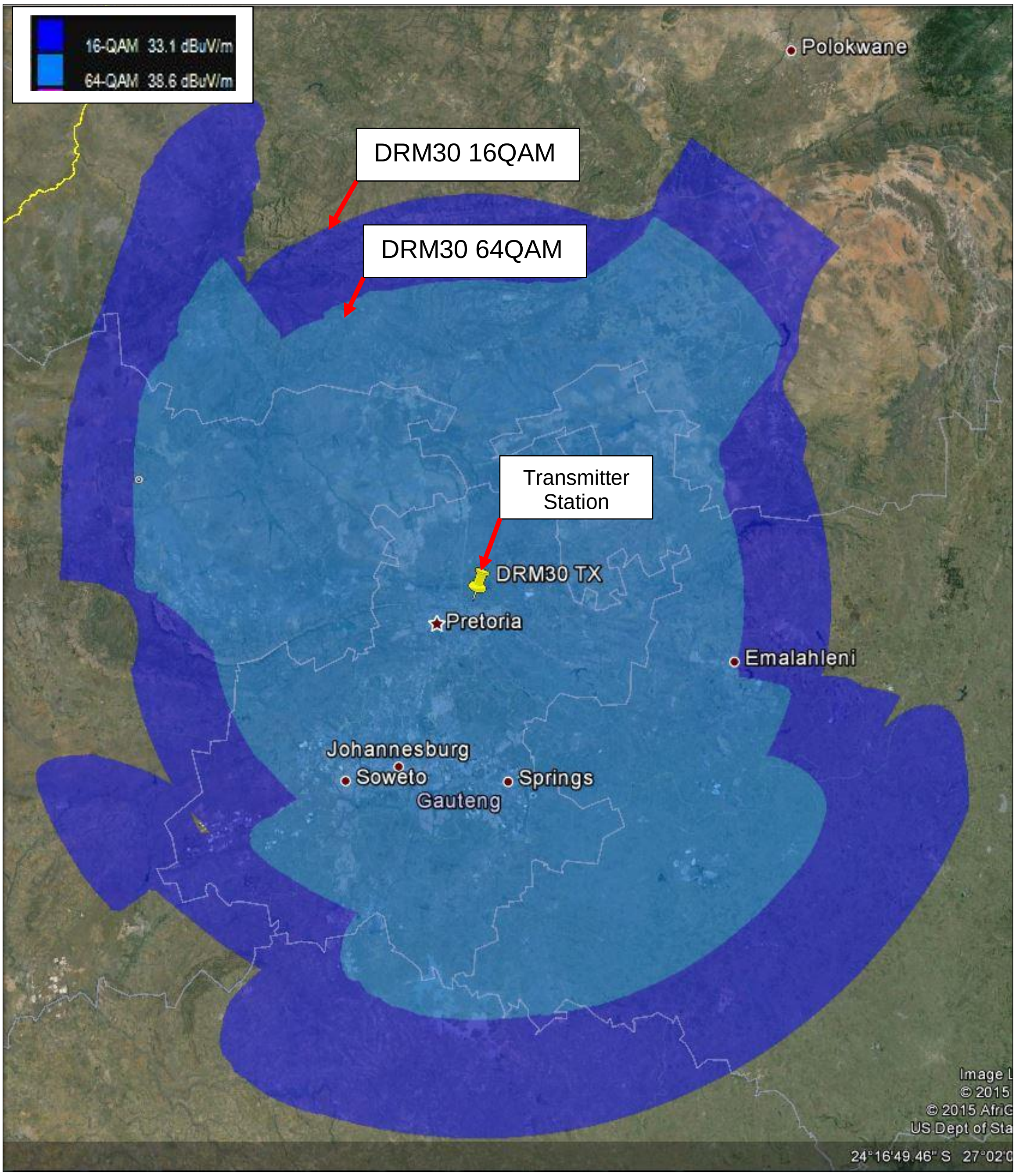
7.3.3. GROUND CONDUCTIVITY DATA

Ground conductivity data (.sol file) was obtained by using the ITU Digitized World Map (IDWM2Raster) software. The conductivity and permittivity values were imported into an ICS Telecom planning tool in a clutter file (.sol) format and used as a clutter layer. This enabled the planning tool to simulate ground-conductivity to ensure it is also included as a variable in coverage predictions.

7.3.4. PREDICTED GROUND-WAVE COVERAGE AREA

Notice should be taken that the ground-wave predictions on both antennas were conducted by using the antenna patterns of an isotropic antenna.

The ground-wave coverage area was predicted by using the ITU-R P.368-7 propagation prediction model. This prediction model excluded man-made noise such as bridges, high voltage overhead cables, tall buildings etc. The predicted DRM30 signal coverage areas with the Main Service Channel (MSC) modulated on 16QAM and 64QAM digital modulation schemes are indicated in **map 10**.



Map 10: Predicted DRM30 ground-wave coverage areas (16QAM & 64QAM).

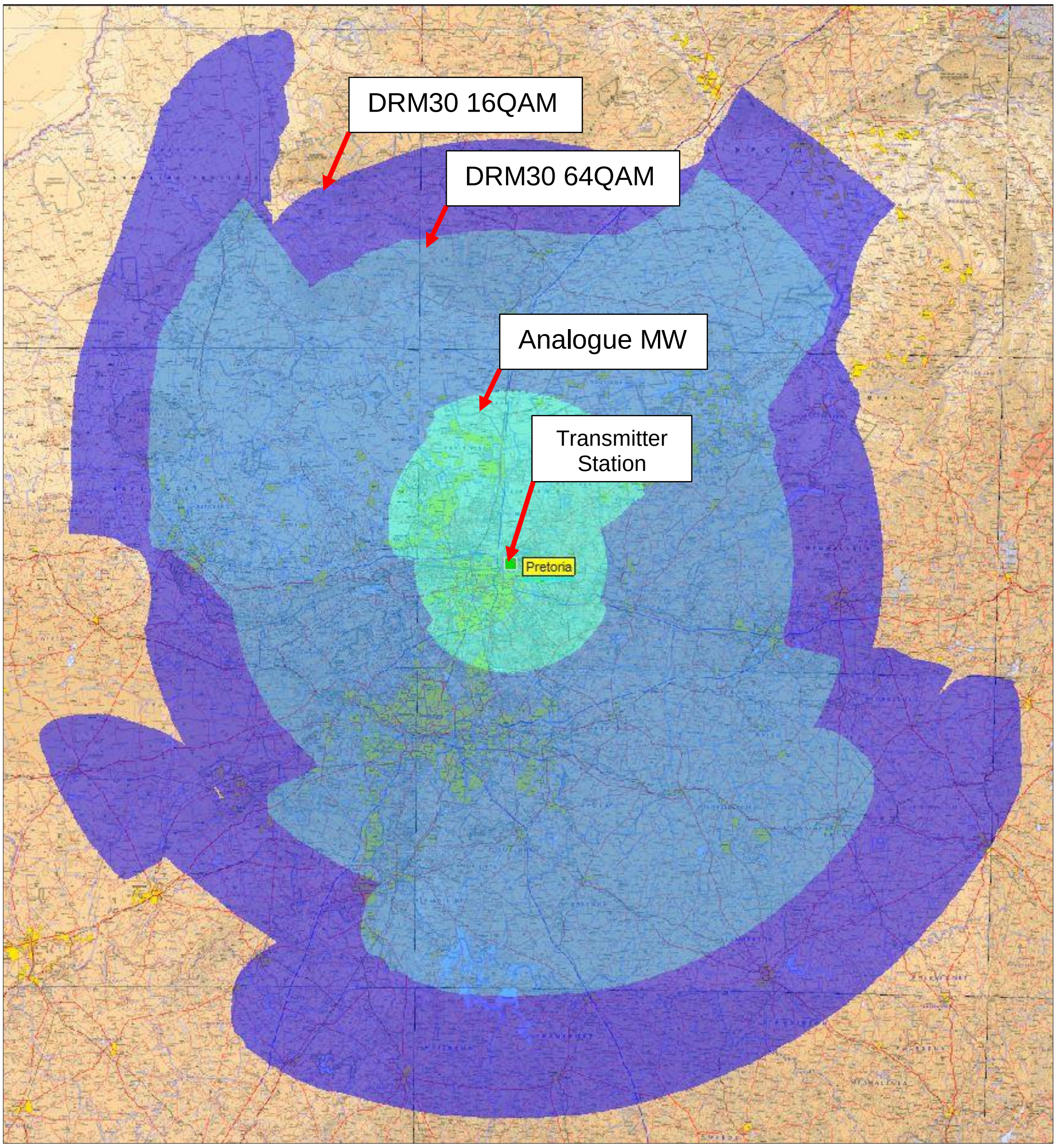
The relation between the predicted analogue and digital coverage areas (16QAM & 64QAM) based on the same transmit power (10kW) is indicated in **table 10** and **map 11**.

Differences in predicted coverages areas can be noted as follows:

- DRM30 configured on 16QAM modulation (protection 0, average code rate 0.5) provides a more robust signal with a larger area coverage but with less capacity for content;
- DRM30 configured on 64QAM modulation (protection 0, average code rate 0.5) provides a less robust signal with a slightly smaller coverage area but more capacity for content;
- Analogue MW covers the smallest area.

Predicted Area Coverage			
Tx output power	**Total area covered**	**Modulation**	**Field strength**
10kW	87710 km²	16QAM	33.1 dBµV/m
10kW	51195 km²	64QAM	38.6 dBµV/m
10kW	6197 km²	AM	60 dBµV/m

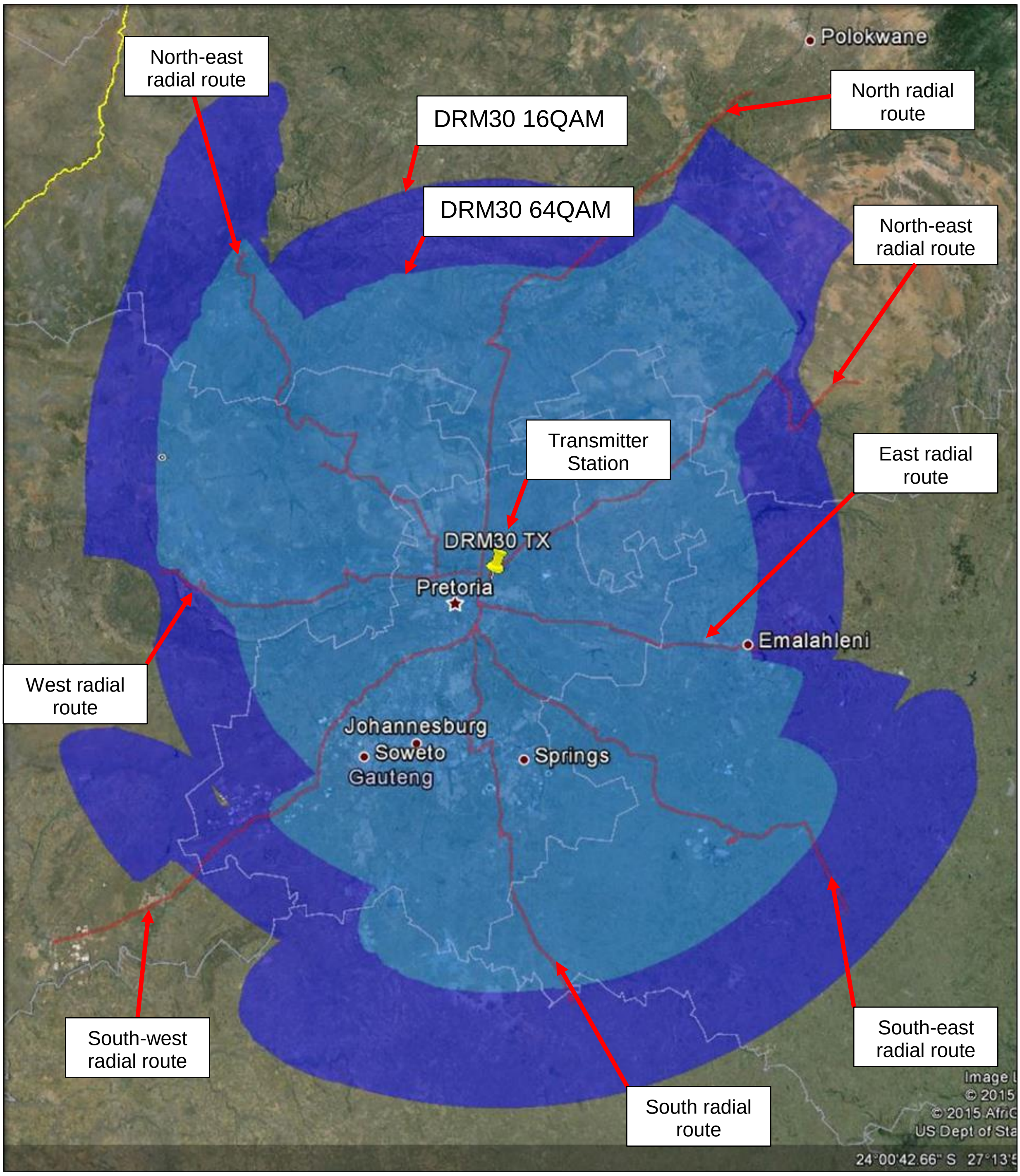
Table 10: Predicted Area Coverage



Map 11: Predicted comparison between 10kW analogue MW and 10kW DRM30 (16 & 64QAM modulation)

7.3.5. GROUND-WAVE ANALYSIS

Ground-wave measurements were conducted in eight radial directions in the predicted ground-wave coverage area. Eight radial routes were measured using both drive-by and static point measurement methods. Measurements routes in the eight radial directions are indicated in **Map 12**.



Map 12: Measurement routes in eight radial directions located in the DRM30 coverage area.

Map 13: Map indicating area around transmitter station

7.3.5.1. MEASUREMENT CORRELATIONS – GROUND-WAVE

One of the objectives of the measurement trial was the evaluation of actual measured coverage versus the predicted coverage. This was achieved by importing Drive-By measurement values into an ICS planning tool and correlating the field strength measurement values with the predicted field strength values. The number of Drive-By measurement values which was imported for the Broadcom antenna was 580477 and 619718 for the KinStar antenna.

Correlation results were analysed and the analysis results provided in the distribution spread graphs (**graph 8** and **graph 9**) which provide an indication of the number of values deviating in a predetermined margin (dB's) between the measured and predicted values. Analysis result values are also provided in a table (**table 11** and **table 12**).

Analysis of the field strength correlation results between the measured **Broadcom antenna** and the predicted values are summarized as follow:

- 177647 (30.6%) field strength measurement values correlated exactly with the predicted values;
- 295587 (50.9%) field strength measurement values correlated within a ±3 dB margin from the predicted field strength measurement values;
- 335477 (57.8%) field strength measurement values correlated within a ±6 dB margin from the predicted field strength measurement values;
- 346680 (59.7%) field strength measurement values was above 0dB which is an indication of an under-prediction.

Analysis of the field strength correlation results between the measured **KinStar antenna** and the predicted values are summarized as follow:

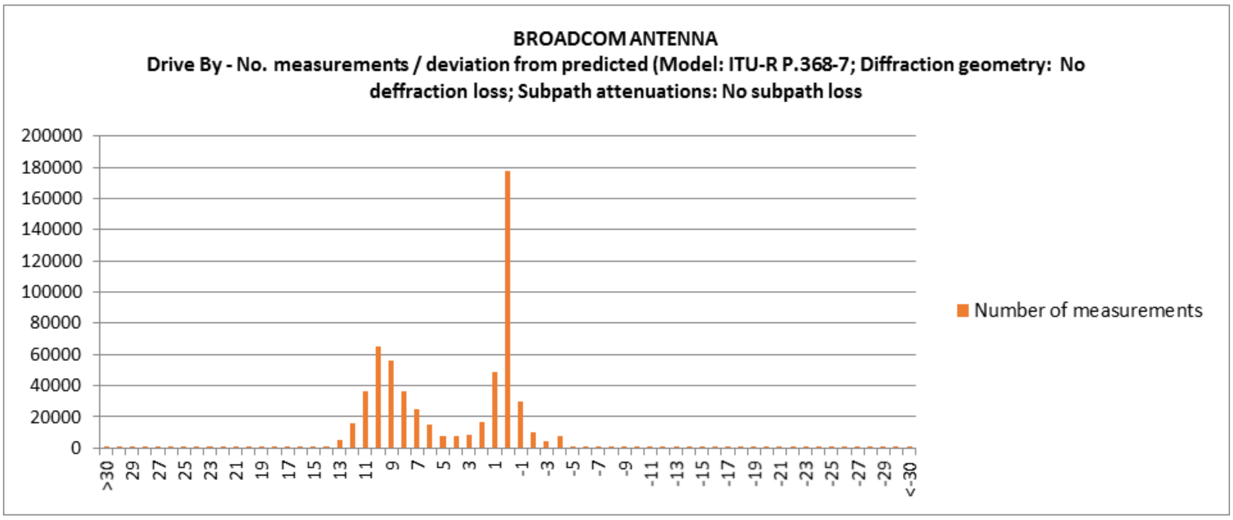
- 366883 (59.2%) field strength measurement values correlated exactly with the predicted values;
- 594392 (95.9.%) field strength measurement values correlated within a ±3 dB margin from the predicted field strength measurement values;
- 613372 (99.0%) field strength measurement values correlated within a ±6 dB margin from the predicted field strength measurement values.

Comparison of the field strength correlation results between the Broadcom antenna and the KinStar antenna can be summarized as follow:

- The total Drive-By measurements conducted on the Broadcom antenna was 580477 which are 39098 measurements less (6.34%) than the 619718 measurement values measured on the KinStar antenna;
- The number of the measurement values which correlated exactly with the predicted values on the Broadcom antenna was 177647 (30.6%) measurement values and for the KinStar antenna • 366883 (59.2%) measurement values;
- Comparison of the distribution graphs (**graph 8** and **graph 9**) provide a clear indication that the measurement values of the KinStar antenna correlated better with the predicted values compared to correlations conducted on the Broadcom antenna.

Studying the correlated field strength distribution graphs (**graph 8** and **graph 9**) and the tabled results (**table 11** and **table 12**) findings can be summarized as follow:

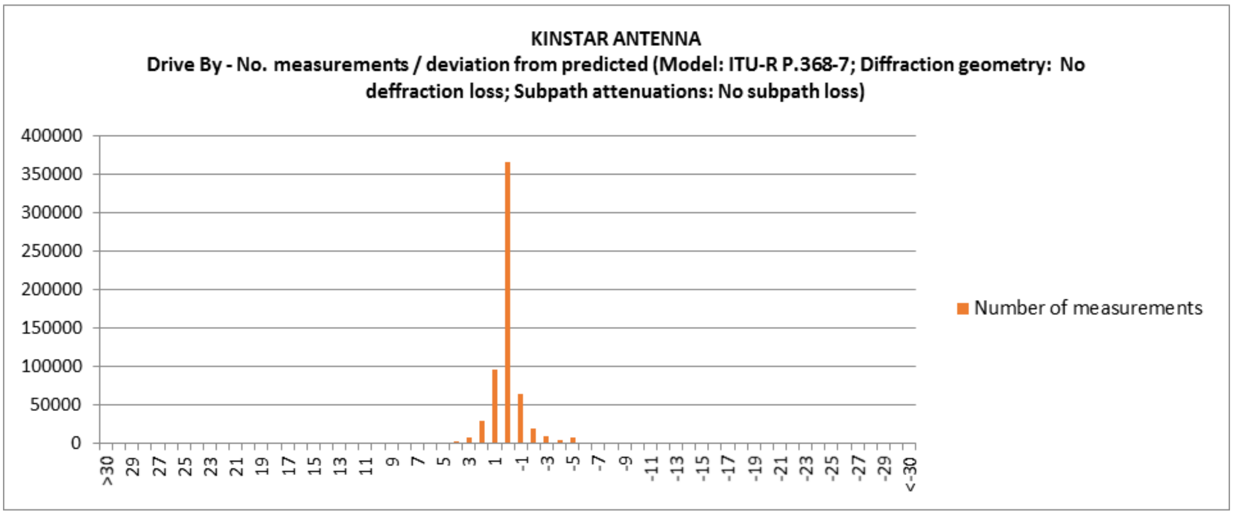
- The planning tool was capable to conduct field strength coverage predictions more accurately on the KinStar antenna compared to predictions conducted on the Broadcom antenna;
- The planning tool indicated an under-prediction on the Broadcom antenna;
- Planning of the DRM30 transmitter technology can be conducted successfully with the aid of the ATDI ICS TELECOM planning tool.



Graph 8: Correlation distribution graph indicating deviation between predicted and measured field strength values for Broadcom antenna.

Deviation from Predicted summary			
No. Measurements = 0dB	177647	30.6	%
No. Measurements < 0dB	56150	9.7	%
No. Measurements > 0dB	346680	59.7	%
No. Measurements within 1dB	256425	44.2	%
No. Measurements within 2dB	283240	48.8	%
No. Measurements within 3dB	295587	50.9	%
No. Measurements within 4dB	311292	53.6	%
No. Measurements within 5dB	320231	55.2	%
No. Measurements within 6dB	335477	57.8	%
No. Measurements <>6dB	245000	42.2	%
No. Measurements within 30dB	580435	100.0	%
No. Measurements <>20dB	42	0.0	%
No. Total Measurements	580477	100.0	%

Table 11: Deviation from prediction for the Broadcom antenna.



Graph 9: Correlation distribution graph indicating deviation between predicted and measured field strength values for KinStar antenna.

Deviation from Predicted summary			
No. Measurements = 0dB	366883	59.2	%
No. Measurements < 0dB	112201	18.1	%
No. Measurements > 0dB	140634	22.7	%
No. Measurements within 1dB	527451	85.1	%
No. Measurements within 2dB	577434	93.2	%
No. Measurements within 3dB	594392	95.9	%
No. Measurements within 4dB	601969	97.1	%
No. Measurements within 5dB	611674	98.7	%
No. Measurements within 6dB	613372	99.0	%
No. Measurements <>6dB	6346	1.0	%
No. Measurements within 30dB	619674	100.0	%
No. Measurements <>20dB	44	0.0	%
No. Total Measurements	619718	100.0	%

Table 12: Deviation from prediction for the KinStar antenna.

7.3.5.2. GROUND-WAVE PERFORMANCE ANALYSIS (DRM30)

Ground-wave measurements for Broadcom antenna and KinStar antenna were conducted in eight radial directions and the measured parameters statistically analysed per distance from the transmitter, which ranged between 114 km to 207 km, depending on the service quality reception experienced on the relevant route.

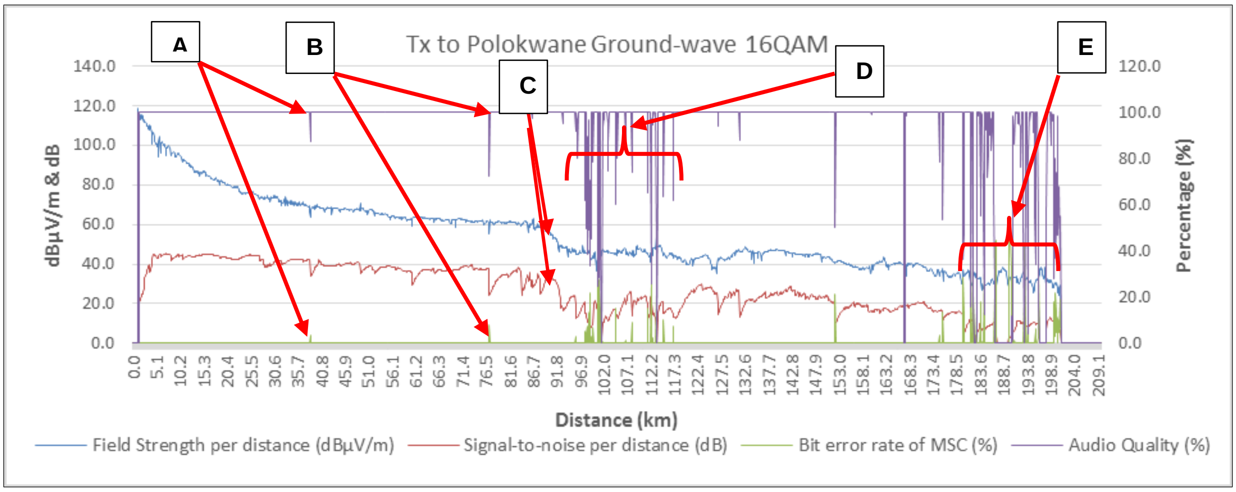
Statistical measurement results are graphically presented in **graphs 25** to **40** (Broadcom antenna) for the which are included in **Annexure B** and **graphs 41** to **56** (KinStar antenna) which are included in **Annexure C**. Graphical presentation of the results include measurements conducted on all radial directional routes and on two different modulation settings (16QAM & 64QAM). This was achieved by conducting measurements on a lower modulation setting (16QAM) driving in a direction away from the transmitter and when returning to the transmitter, conducting measurements on a higher modulation setting (64QAM). Measurement results on the eight radial routes on the Broadcom antenna are indicated in **graphs 25** to **graphs 40** in **Annexure B** and the results on the KinStar antenna in **graphs 41** to **56** in **Annexure C**.

Analogue AM measurements were also conducted on two radial routes (**north radial** and **south radial**) on the KinStar antenna, this was done by only driving in a direction away from the transmitter station. The graphical representation of the measurement results on the two radial routes are indicated in **graphs 61** to **graph 62** in **Annexure E**.

Describing each one of the radial routes in detail would become quite diffusive which therefore resulted in the detailed explanation on the analysis of one of the routes measured (**north radial route**). The other graphs could then be studied as required to obtain an indication of the ground-wave performance on the specific selected route.

The route (**north radial route**) which was chosen to discuss the ground-wave analysis is the route from the transmitter station (located in Pretoria) to Polokwane (16 QAM modulation) and back to the transmitter station (64QAM modulation). Graphical presentation of the measured parameter values on the **Broadcom** antenna measurement route are indicated in **graph 10** (16QAM) and **graph 11** (64QAM). Graphical representation of the measured parameter values on the **KinStar** antenna measurement route are indicated in **graph 12** and **graph 13**.

The analogue AM measurements are presented in **graph 14** and were only conducted on the KinStar antenna.

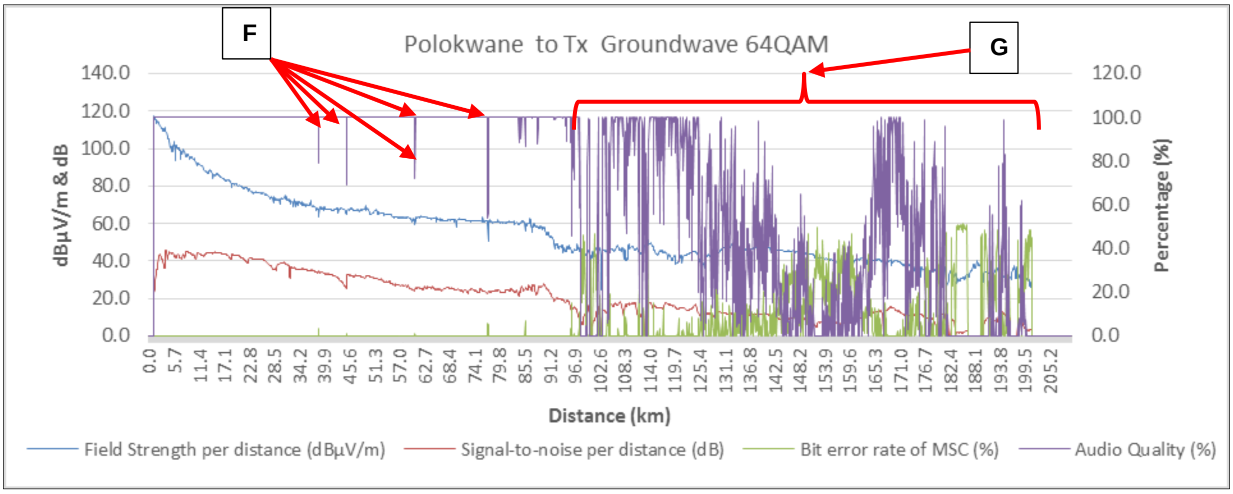


Graph 10: DRM30 measurements on route from transmitter to Polokwane (16QAM) _Broadcom Antenna

Studying **graph 10** (16QAM) the measurement parameters indicate the following:

- Measurement results indicate a slight decrease in audio quality (purple graphical line) and signal to noise (S/N) ratio (red graphical line) for a short distance, at the tollgate ± 37 km from the transmitter station (Indicated with label **A** in **graph 10**).
- Measurement results indicate a larger decrease in audio quality (purple graphical line) and S/N (red graphical line) for a short distance when passing under a bridge ± 76 km from the transmitter station (Indicated with label **B** in **graph 10**).
- Measurement results indicate a significant decrease in field strength (blue graphical line) as well as the S/N (red graphical line), starting at a distance of ± 90km from the transmitter station (Indicated with label **C** in **graph 10**).
- The route to the north approached a mountainous terrain (Indicated with label **D** in **graph 10**) which resulted in a decrease in the field strength, decrease in S/N, increase in BER and degradation of audio quality. Degradation of the signal in the mountainous terrain was due to various factors which included signal propagation path obstructions due to the terrain and also changes in the ground-conductivity which could clearly be noticed when correlated with the planning tool.
- Both the field strength and the S/N values continued to degrease as the distance from the transmitter increased.
- Exiting the mountainous terrain resulted in an improvement of the field strength and S/N, resulting in the reduction of BER and improvement of audio quality. The overall quality of the signal was good and stable till another mountainous terrain was approached and entered.
- Entering of the mountainous terrain at a distance of ± 180 km from the transmitter station resulted in a decrease of the field strength,

decrease in S/N, increase in BER and decrease of the audio quality (Indicated with label **E** in **graph 10**). This was as a result of a combination of factors which included the distance from the transmitter, change in ground-conductivity and propagation path obstruction by mountains. The quality of the signal kept on changing till complete signal failure a few kilometers before the Polokwane town which is located at a distance ±200 km from the transmitter station.



Graph 11: Route from Polokwane to transmitter (64QAM) _Broadcom Antenna

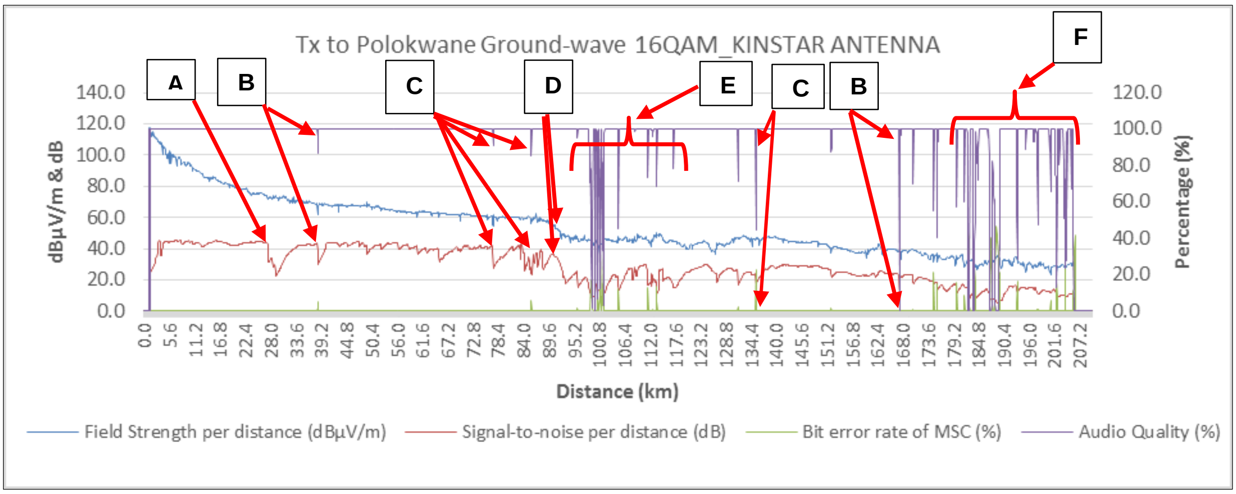
Studying **graph 11** (64QAM) the measurement parameters indicate the following:

- When the route measurement from Pretoria to Polokwane was completed the modulation setting was changed from the rugged 16QAM modulation setting, to the less-rugged 64QAM modulation setting. Measurements were then conducted on the same route in an opposite direction from Polokwane to the transmitter station located in Pretoria;
- Although the field strength did not change significantly on the 64QAM setting (compared to the 16QAM setting) the reduction on the S/N levels was significant, resulting in an increase of the BER and decrease in the audio quality (Indicated with label **G** in **graph 11**);
- The route from the north approached a mountainous terrain (Indicated with label **G** in **graph 11**) which resulted in a decrease in the field strength, decrease in S/N, increase in BER and degradation of audio quality. Degradation of the signal in the mountainous terrain was due to various factors which included signal propagation path obstructions due to the terrain and also changes in the ground-conductivity which could clearly be noticed in the planning tool;
- Measurement results indicate a slight decrease in audio quality (purple graphical line) and S/N (red graphical line) for a short distance, at tollgates and when passing under a bridges (Indicated with label **F** in **graph 11**);

- All measurement parameters improved when the mountainous terrain changed to non-mountainous terrain on the route towards the transmitter station.

Comparison between the 16QAM and 64QAM Broadcom antenna measurement results indicated the following:

- Comparisons between the measurement results on 16QAM modulation (**graph 10)** and 64QAM (**graph 11**) indicate the field strength to be more-or-less similar on both graphs, but with a significant decrease in S/N values, increase in BER and the degradation of the audio quality, especially in the area marked "**G**" on **graph 11**;
- The less rugged modulation setting resulted in a severe degradation of the signal on the route located between ± 97 km to 200 km from the transmitter station. Recovery of a stable signal was only measured ±97 km from the transmitter station.
- The combination of a less-rugged modulation setting (64QAM), mountainous terrain and poor ground-conductivity resulted in signal failure between Polokwane and Bela-Bela;
- Although the quality of the measurement parameters improved south of Bela-Bela, the measurement parameters indicate the signal to be more susceptible to interference from external elements (marker **F** in **graph 11**), compared to the 16QAM modulated signal (marked **A**,**B** and **C in graph 11**);
- The effective coverage area will therefore reduce significantly when configured on a higher modulation scheme (64QAM) compared to a lower modulation scheme (16QAM).

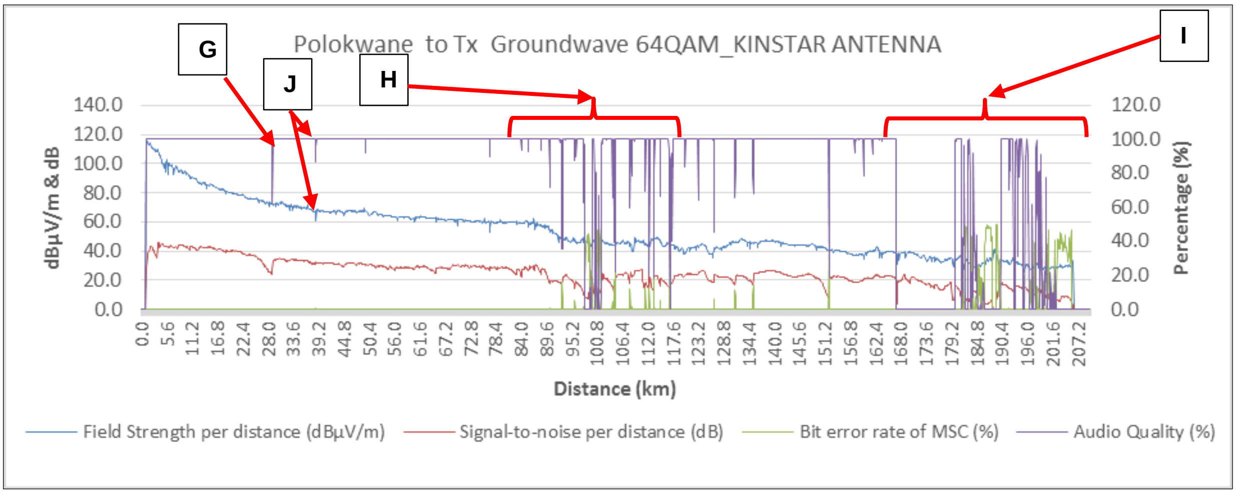


Graph 12: Route from transmitter to Polokwane (16QAM) _KinStar Antenna

Studying **graph 12** (16QAM) the measurement parameters indicate the following:

- Passing under a bridge resulted in a short decrease in the S/N marked **A** in **graph 12** at a location of ±28 km from the transmitter station;
- The signal level S/N (red graphical line) and audio quality (purple graphical line) indicate a decrease for a short distance at the tollgate located at ±37 km and ±168 km from the transmitter station (marked **B** in **graph 12**);
- The signal level S/N (red graphical line) and audio quality (purple graphical line) indicate a decrease for a short distance, passing under bridges located at a distance of ± 76 km, ± 83 km and ± 133 km from the transmitter station (marked **C** in **graph 12**);
- The field strength (blue graphical line) as well as the S/N (red graphical line) indicate a significant decrease at a distance of ± 90 km from the transmitter station (marked **D** in **graph 12**);
- As the northern part of the route approached a mountainous terrain it resulted in a decrease field strength, decrease in S/N, increase in BER and degradation of audio quality (marked **E** in **graph 12**). Degradation of the signal in the mountainous terrain was due to various factors which included signal propagation path obstructions (due to the terrain) and also changes in the ground-conductivity which could clearly be noticed when correlating with the planning tool;
- The S/N, bit error ratio and the audio quality in the area just north of Bela-Bela (marked **E** in **graph 12**) were found to be better than the Broadcom antenna (marked **D** in **graph 10**);
- The field strength and the S/N values continued to degrease as the distance from the transmitter increased;
- The field strength and S/N improve when exiting the mountainous terrain which resulted in the reduction of BER and improvement of audio quality. The overall quality of the signal was good and stable till another mountainous terrain was approached and entered.

- The field strength, S/N and audio quality decrease while the BER increase (marked **F** in **graph 12**) due to the mountainous terrain at a distance of ± 180 km from the transmitter station. This was as a result of a combination of factors which included the distance from the transmitter, change in ground-conductivity and propagation path obstruction by the mountainous terrain. The quality of the signal kept on changing till complete signal failure occurred a few kilometers before the Polokwane town, located at a distance ±200 km from the transmitter. On this radial route (**graph 12**) the degradation on the audio was found to be less severe when compared to the Broadcom antenna measurement exercise on the same radial route (**graph 10**).



Graph 13: Route from Polokwane to transmitter (64QAM) _ KinStar Antenna

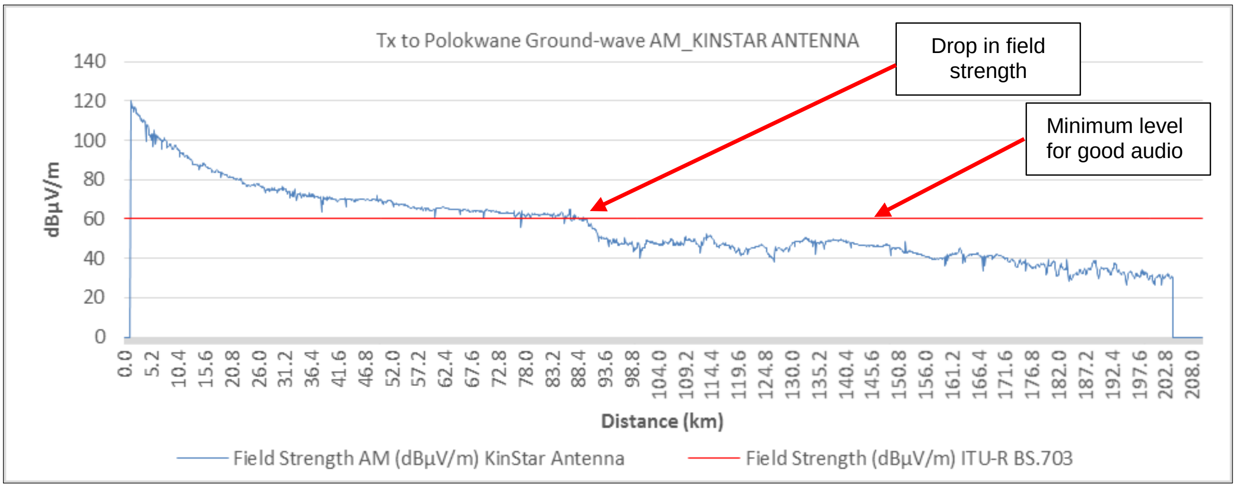
Studying **graph 13** (64QAM) the measurement parameters indicate the following:

- Once the route measurement from Pretoria to Polokwane was completed, the modulation was changed from the rugged 16QAM modulation setting, to the less-rugged 64QAM modulation setting. Measurements were then conducted in an opposite direction on the route from Polokwane to the transmitter station located in Pretoria;
- Increase in distance from the transmitter station resulted in decrease in field strength level, decrease in S/N, increase in BER and degradation of audio quality (marked **I** in **graph 13**);
- The route from the north approached a mountainous terrain (Indicated with label **H** in **graph 13**) which resulted in a decrease in the field strength, decrease in S/N, increase in BER and degradation of audio quality. Degradation of the signal in the mountainous terrain was due to various factors which included signal propagation path obstructions due to the terrain and also changes in the ground-conductivity, which could clearly be noticed, when comparing the measurement result locations with the planning tool;

- Although the signal level and the BER remained unchanged, the S/N and audio quality (red and purple graphical lines) decreased (marked **G** in **graph 13**). The decrease in the S/N was caused by passing under a bridge at a distance of ±28 km from the transmitter station;
- Measurement results indicate a slight decrease in signal level and audio quality (Blue and purple graphical lines) for a short period of time at the tollgate located ± 37 km from the transmitter station (marked **J** in **graph 13**);
- All measurement parameters improved as the distance from transmitter station decreased (driving back from Polokwane towards Pretoria).

Comparison between the 16QAM and 64QAM KinStar antenna measurement results indicated the following:

- Comparisons between the measurement results in **graph 12** and **13** indicate the field strength to be more-or less similar on both graphs but with a significant decrease in S/N, increase in BER and the degradation of the audio quality, especially in the area marked by “**H**” on **graph 13**. The less rugged modulation setting resulted in a severe degradation of the signal on the route located between ±166 km to 207 km from the transmitter station. Recovery of a stable signal was only detected ±97 km from the transmitter station. The combination of a less-rugged modulation setting, mountainous terrain and less ground-conductivity resulted in signal failure between Polokwane and Bela-Bela;
- Although the quality of the measurement parameters improved south of Bela-Bela, the measurement parameters indicate the signal to be more susceptible to interference from external elements (marked **G** and **J** in **Graph 13**), compared to the 16QAM modulated signal (**graph 12**).



Graph 14: Route from transmitter to Polokwane (AM Analogue) _ KinStar Antenna

Studying **graph 14** the analogue field strength measurement parameters indicate the following:

- Only the field strength parameter was measured on the AM analogue signal as indicated in **graph 14** above;
- The analogue field strength were found to follow the same trend as the measured DRM30 field strength levels;
- The field strength in **graph 14** indicate a reduction below the required level of 60 dBµV/m after a distance of ±90 km from the transmitter station. This is the minimum required field strength to ensure a good quality analogue medium wave signal according to the ITU Recommendation ITU-R BS.703;
- Degradation of the signal was mainly experienced due to the mountainous terrain and less ground-conductivity (between Bela-Bela and Polokwane) in the area;

Comparison between the 16QAM, 64QAM and analogue AM on the **KinStar antenna** measurement results indicated the following:

- The measured field strength (blue graphical line) level followed the same trend as the DRM30 measurement levels irrespective of the type of modulation scheme used;
- All three modulation schemes (16QAM, 64QAM and analogue AM) were affected by tollgates, bridges, high voltage overhead cables and whenever driving in mountainous terrain areas;
- All three modulation schemes (16QAM, 64QAM and analogue AM) indicated a decrease in field strength level at a distance of ±90 km from the transmitter station (behind a mountain);
- The field strength measurement pattern is more-or-less the same for **graph 12**, **13** and **14** because the measurements were conducted on the same radial route (north radial route);
- AM signal measurements indicated degradation of AM audio quality in mountainous terrain areas where some of the DRM30

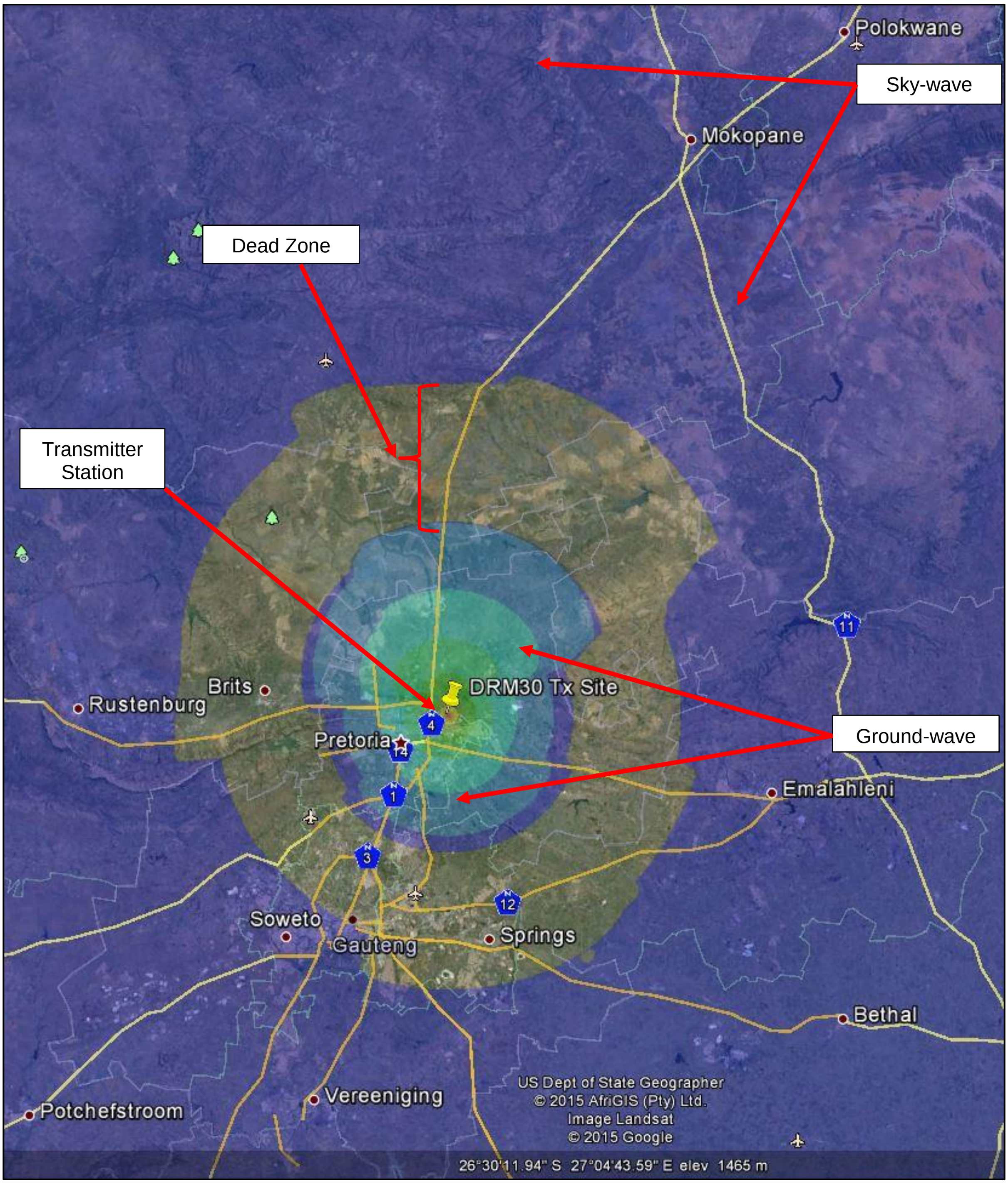
measurements (16QAM and 64QAM) indicated a slight improvement in decode-ability and audio quality;

- According to ITU recommendation (ITU-R BS.703) the minimum field strength of 60 dBµV/m is required for analogue commercial receivers to provide good audio quality;
- According to ITU recommendation (ITU-R BS.1615-1) the minimum field strength required for good audio quality on 16QAM and 64QAM DRM30 modulated signals are 33.1 dBµV/m and 38.6 dBµV/m respectively. Field measurements however indicated that a good DRM30 audio quality (100%) was only achieved at a field strength level of 56.2 dBµV/m for a 16QAM signal and 57.5 dBµV/m for a 64QAM signal. Based on these measurement findings it would therefore be preferable to consider to include an additional margin of 23.1dB and 18.9dB respectively to the recommended ITU field strength values for 16QAM and 64QAM DRM30 modulated signals to compensate for potential decode-ability constrains of the DRM30 modulated signal. Including these additional margins would have a direct impact on the decode-able DRM30 coverage area. Coverage predictions based on these additional margins are presented in **map 22** under **annexure G** which provide an indication on how decode-ability constrains of the DRM30 signal could impact the predicted coverage area which are based on the ITU recommended field strengths;
- DRM30 measurements on the more-rugged 16QAM modulation signal indicated that a decodable signal was measured at an average omnidirectional distance of 78 km from the transmitter station. The less-rugged 64QAM modulation signal indicated that a decodable signal was measured at an average omnidirectional distance of 68 km from the transmitter station. Changing the modulation from a less-rugged modulation scheme (64QAM) to a more-rugged modulation scheme (16QAM) indicate that the average coverage distance from the transmitter could be improved which would result in larger area coverage;
- The ground-wave signal is affected by various ground conditions which include ground conductivity, terrain roughness and dielectric constant. The planning tool include a ground conductivity layer to assist in ground-wave predictions. According to the planning tool predictions there are different ground conductivity layers located in the areas where measurements where conducted. These different conductivity layers are presented in **map 21** under **annexure F**. Changes in signal strength measurements correlated with the predicted conductivity information which indicate that ground conductivity has a direct impact on the signal strength measurement values.

7.3.6. PREDICTED SKY-WAVE COVERAGE AREA

Notice should be taken that the sky-wave predictions on both antennas were conducted by using the antenna patterns of an isotropic antenna.

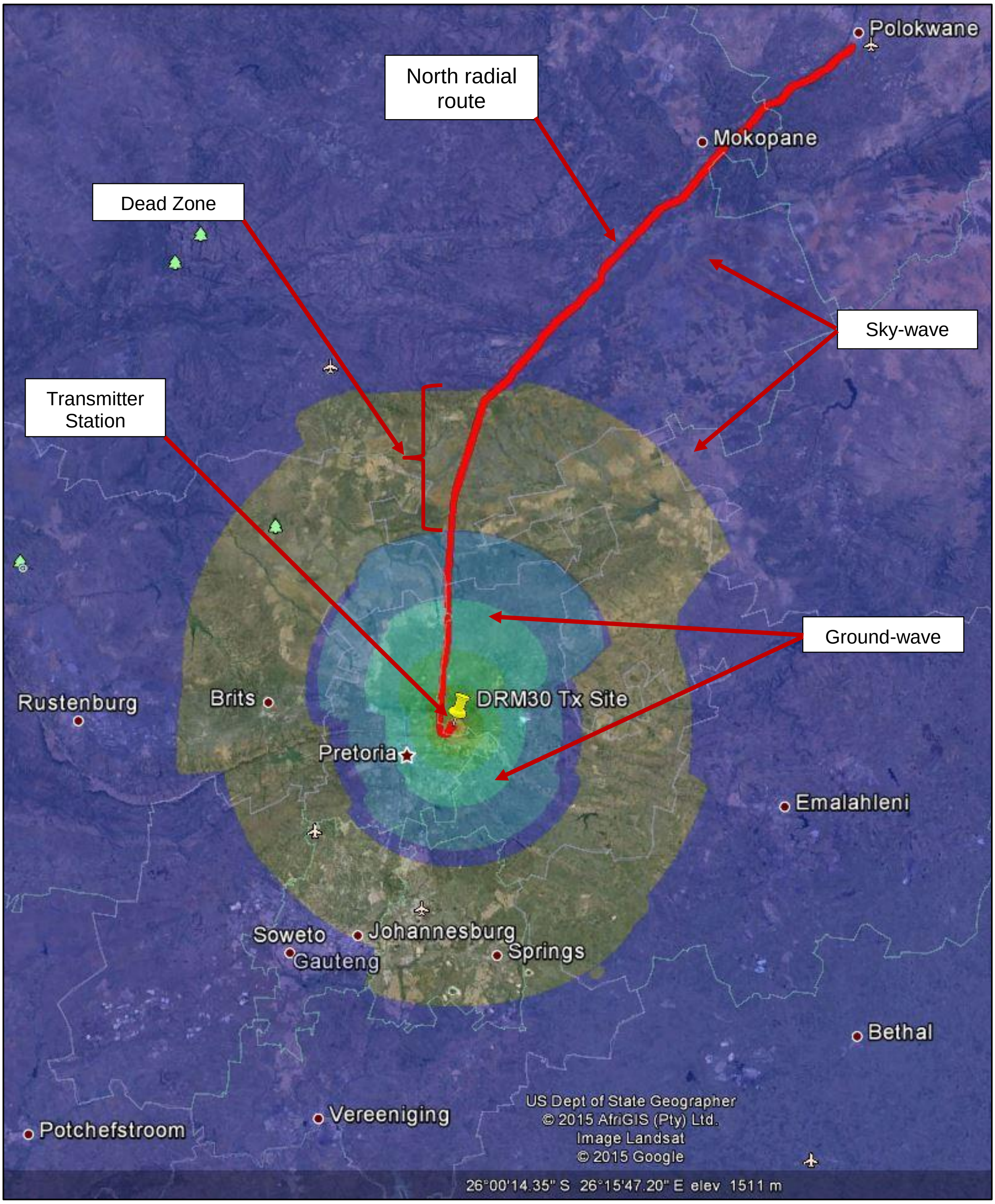
The sky-wave prediction is indicated in **map 14** below. The ground-wave coverage area was predicted by using the ITU-R P.1147 propagation prediction model. This prediction model excluded man-made noise such as bridges, high voltage overhead cables, tall buildings etc.



Map 14: Sky-wave predicted DRM30 coverage area.

7.3.7. SKY-WAVE ANALYSIS

Sky-wave measurements were conducted by driving on the route indicated in **map 15** below.



Map 15 Sky-wave measurement Drive-By measurement route.

7.3.7.1. MEASUREMENT CORRELATIONS – SKY-WAVE

Correlations between 74550 measured and predicted field strength values for the Broadcom antenna are presented in **figure 2** which indicate the predicted field strength (green) and the measured field strength (yellow). On the route from the transmitter station to Polokwane the predicted dead-zone is also indicated in **figure 2**. Studying the correlated measured field strength values indicated that the negative impact of the sky-wave is only experienced at a later stage (more distant) on the route than predicted. The negative impact of the sky-wave is indicated by the ripple on the correlated measured field strength values in **figure 2**. Sky-wave dead-zone predictions conducted with the planning tool therefore differ considerably from the actual measured values as indicated in **figure 2**.

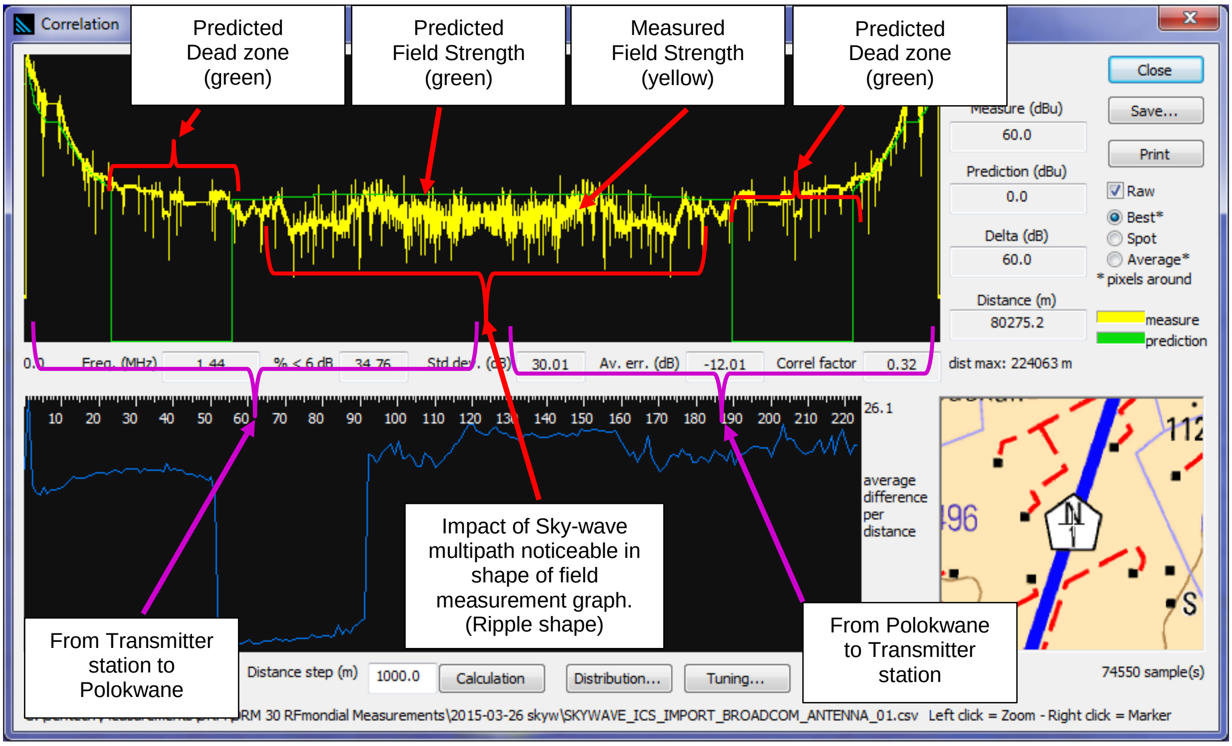


Figure 2: Sky-wave correlation for the Broadcom antenna (route from transmitter station to Polokwane and back).

Correlations between 74207 measured and predicted field strength values for the KinStar antenna are presented in **figure 3** which indicate the predicted field strength (green) and the measured field strength (yellow) on the route from the transmitter station to Polokwane. The predicted dead-zone is also indicated in **figure 3**. Studying the correlated measured field strength values indicate that the negative impact of the sky-wave is only experienced at a later stage (more distant location) on the route than predicted. The negative impact of the sky-wave is indicated by the ripple on the correlated measured field strength values in **figure 3**. Sky-wave dead-zone predictions by the planning tool therefore differ considerably from the actual measured values as indicated in **figure 3**.

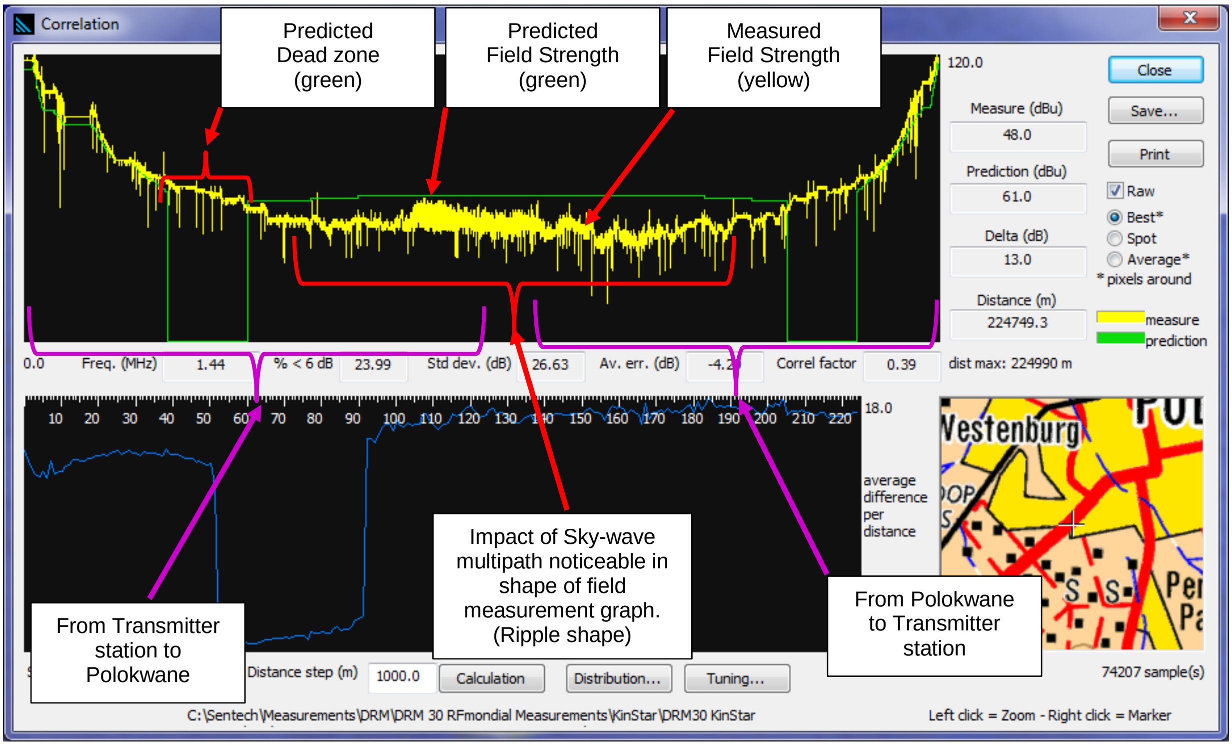


Figure 3: Sky-wave correlation for the KinStar antenna (route from transmitter station to Polokwane and back).

Comparison between the Broadcom antenna and the KinStar antenna sky-wave correlations indicate the following:

- Studying the “ripple effect” on the sky-wave multipath impact area between the two antenna’s clearly indicate more severe sky-wave multipath interference on the Broadcom antenna compared to the KinStar antenna.

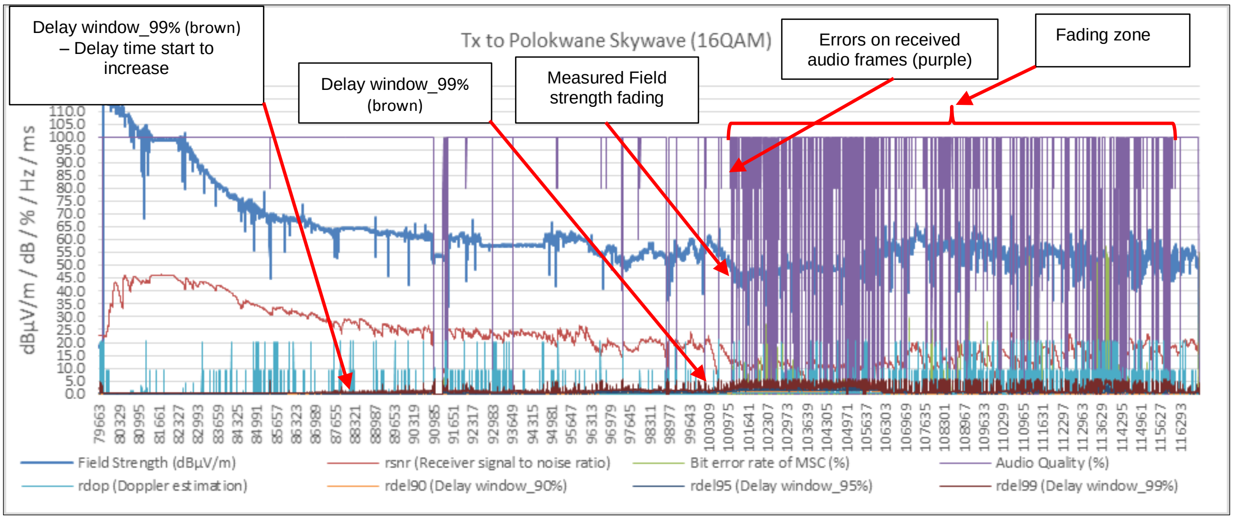
7.3.7.2. SKY-WAVE PERFORMANCE ANALYSIS

Determining the impact of the sky-wave on the propagated ground-wave signal coverage area required measurements to be conducted during night-time (between sun-set and sun-rise). Measurements were conducted only on one radial route (north of the transmitter station), from the transmitter station to Polokwane with the Main Service Channel (MSC) on a 64QAM modulation setting, as well as from Polokwane to the transmitter station with the MSC on the lower and more rugged 16QAM modulation setting. The night-time measurements were conducted on both the Broadcom and KinStar antenna systems.

7.3.7.2.1. SKY-WAVE IMPACT ON BROADCOM ANTENNA

The graph below (**graph 15**) provide details of the sky-wave measurements results on the Broadcom antenna with the MSC configured to a 16QAM modulation setting. The following measured parameters were analysed:

- Field Strength (dBµV/m) – indicated in blue;
- S/N (dB) - indicated in red;
- Bit Error Rate (%) - indicated in green;
- Audio Quality (%) - indicated in purple;
- Doppler Estimation (Hz) - indicated in aqua;
- Delay Window (ms) - indicated in brown.



Graph 15: Sky-wave measurements (16QAM modulation) Broadcom Antenna.

Studying the measured parameter values provide a clear indication of how the sky-wave impacted negatively on the ground-wave .The *Delay window* parameter trend line on the graph (**graph 15**) provide a clear indication of the impulse response of the delayed sky-wave signal which started to interfere with the ground-wave. The *Delay window* measurement clearly indicate that a delayed signal was received (sky-wave) resulting in a delayed multipath effect starting at a location ±53 km north of the transmitter station. This correlated well with the predicted sky-wave fading zone, which predicted the severity of the sky-wave to start at a distance of ±55 km (**maps 14** and **15**). Although the *Delay window* parameter and predicted starting point of the sky-wave was calculated and measured at a distance of ±53 km from the transmitter station, the degradation impact thereof on the ground-wave signal was only noted 47 km further north on this route, at a distance of ±100 km from the transmitter station. The impact of the sky-wave on the ground-wave increased slowly (increase in *Delay window* at 53 km from transmitter station) as the distance from the transmitter station increased. This resulted in a slow decrease of the S/N between the ground-wave and sky-wave till the point was reached where the sky-wave multipath caused the S/N to be too low to ensure good decode-ability (at a distance of ±100 km). At this point the *Delay window*, *Doppler estimation*, and BER increased rapidly resulting in a decrease in audio quality and which resulted in total audio failure.

Both the ground-wave and sky-wave signals were not decode-able till ±116 km from the transmitter station. The sky-wave started to become the more dominant signal after ±116 km from the transmitter station. The sky-wave S/N, BER and audio quality improved, resulting in pure sky-wave reception from this point until the end of the measurement route with clear audio reception.

Studying **graph 15** as well as well as the impulse response measurement screen-shots (**Figure 4**, **5** and **6**) the following could be noticed:

- Between Hammanskraal and Bela-Bela (±90 km from the transmitter station) the impulse response measurement (**figure 4**) indicated that although multipath presence can be noted, the impact thereof on the ground-wave was not noticeable at all;
- Between Modimolle and Mokopane (±170 km from the transmitter station) the impulse response measurement (**figure 5**) indicated that the impact of the increased sky-wave signal level, due to more constructive multipath (more sky-wave signals received in-phase) on the ground-wave, resulted in both the ground-wave and the sky-wave to be more or less at the same level, resulting in audio decode-ability failure as indicated in **figure 5**;
- At a distance of 3km before Polokwane (±220 km from the transmitter station) the sky-wave was the more dominant signal resulting in an improvement of the sky-wave clear signal level, sky-wave S/N, decrease of BER and increase of audio quality which enabled sky-wave reception as indicated in **figure 6**. The impulse response measurement (**figure 6**) indicate that the sky-wave was the most dominant signal at this point, which explain why sky-wave reception was possible at this point.

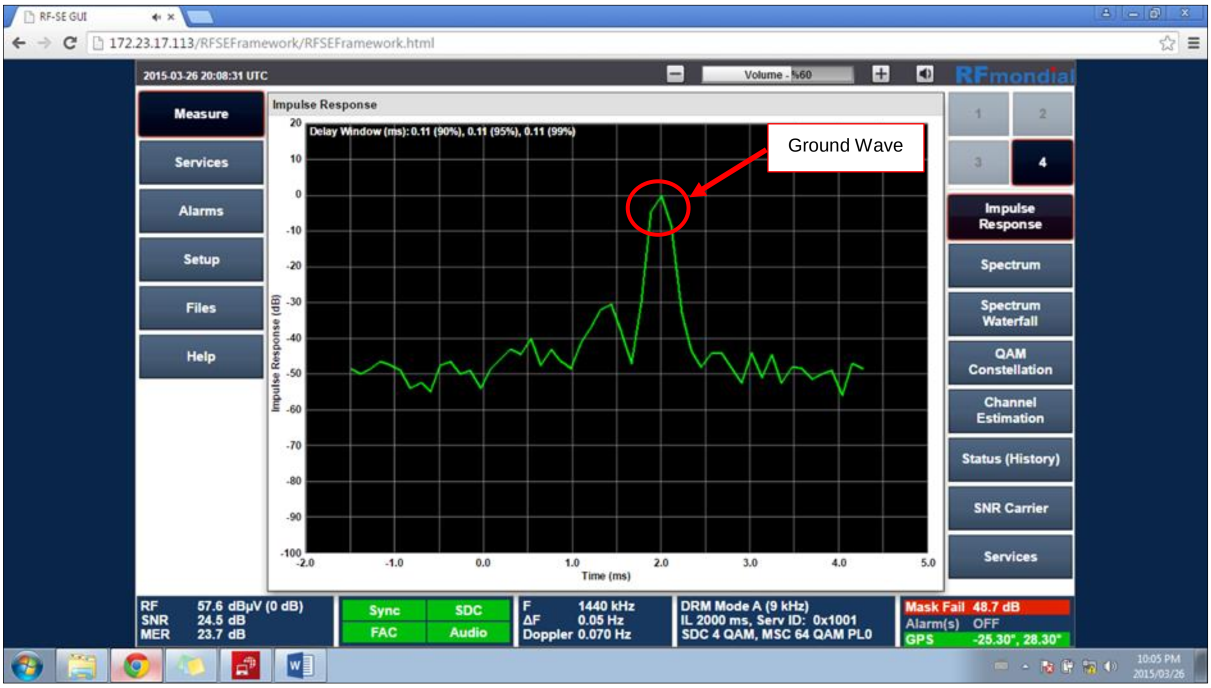


Figure 4: Broadcom antenna. Impulse response indicating that the ground wave is dominant.

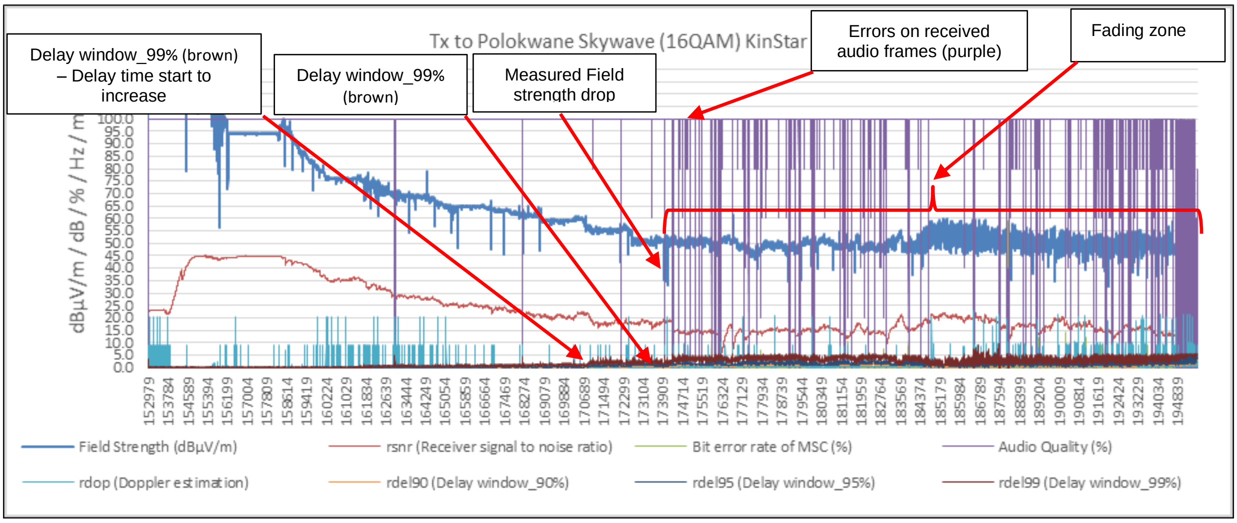
Figure 5: Broadcom antenna. Impulse response indicating the fading zone.

Figure 6: Broadcom antenna. Impulse response indicating that the sky wave is dominant.

7.3.7.2.2. SKY-WAVE IMPACT ON KINSTAR ANTENNA

The graph below (**graph 16**) provide details of the sky-wave measurements results on the KinStar antenna with the MSC configured to 16QAM modulation. The following measured parameters were analysed:

- Field Strength (dBµV/m) – indicated in blue;
- S/N (dB) - indicated in red;
- Bit Error Rate (%) - indicated in green;
- Audio Quality (%) - indicated in purple;
- Doppler Estimation (Hz) - indicated in aqua;
- Delay Window (ms) - indicated in brown.



Graph 16: Sky-wave measurements (16QAM modulation) KinStar Antenna.

The measured parameter values in **graph 16** provide a clear indication of how the sky-wave impacted negatively on the ground-wave .The *delay window* parameter trend line on the graph (**graph 16**) provide a clear indication of the impulse response of the delayed sky-wave signal which increased slowly till it started to interfere with the ground-wave signal. The *delay window* measurement clearly indicate that a delayed signal was received (sky-wave) which resulted in a delayed multipath effect at a location ±90 km north of the transmitter station. This does not correlate well with the predicted sky-wave fading zone, which predicted the severity of the sky-wave to start at a distance of ± 55 km (**maps 14** and **15**). Although the delay window parameter of the sky-wave was measured at a distance of ±90 km from the transmitter, the negative impact thereof on the ground-wave signal was only noted 10 km further north on this route, at a distance of ±100 km from the transmitter station. The impact of the sky-wave on the ground-wave increased slowly (increase in delay window at ±90 km from transmitter) as the distance from the transmitter station increased. This resulted in a slow decrease of the *S/N* between the ground-wave and sky-wave, from a distance of ±100 km from the transmitter station. At this point the *Delay Window*, *Doppler Estimation*, and BER increased rapidly resulting in a decrease in audio quality which eventually resulted in intermittent audio failure. There were no dominant sky-wave signal from Polokwane onward as in the case of the Broadcom antenna measurements.

Studying **graph 16** as well as well as the impulse response measurement screen-shots (**Figure 7**, **8** and **9**) on the KinStar antenna the following could be noticed:

- Between the transmitter station and Hammanskraal (±30 km from the transmitter station) the impulse response measurement (**figure 7**) indicated that although multipath presence can be noted, the impact thereof on the ground-wave was not noticeable at all;
- Between Modimolle and Mookgopong (±104 km from the transmitter station) the impulse response measurement (**figure 8**) indicated that the sky-wave signal level increased due to more constructive multipath (more sky-wave signals received in-phase);
- **Figure 9** indicate the impulse response between Mookgopong and Polokwane where the sky-wave signal and the ground-wave signal maintain the same level, which resulted in audio drop-outs. The audio quality (purple) in **graph 16** indicate that there is no improvement on the audio quality between Mookgopong and Polokwane, on the contrary the audio quality decrease a few kilometers from Polokwane (±220 km from the transmitter station).

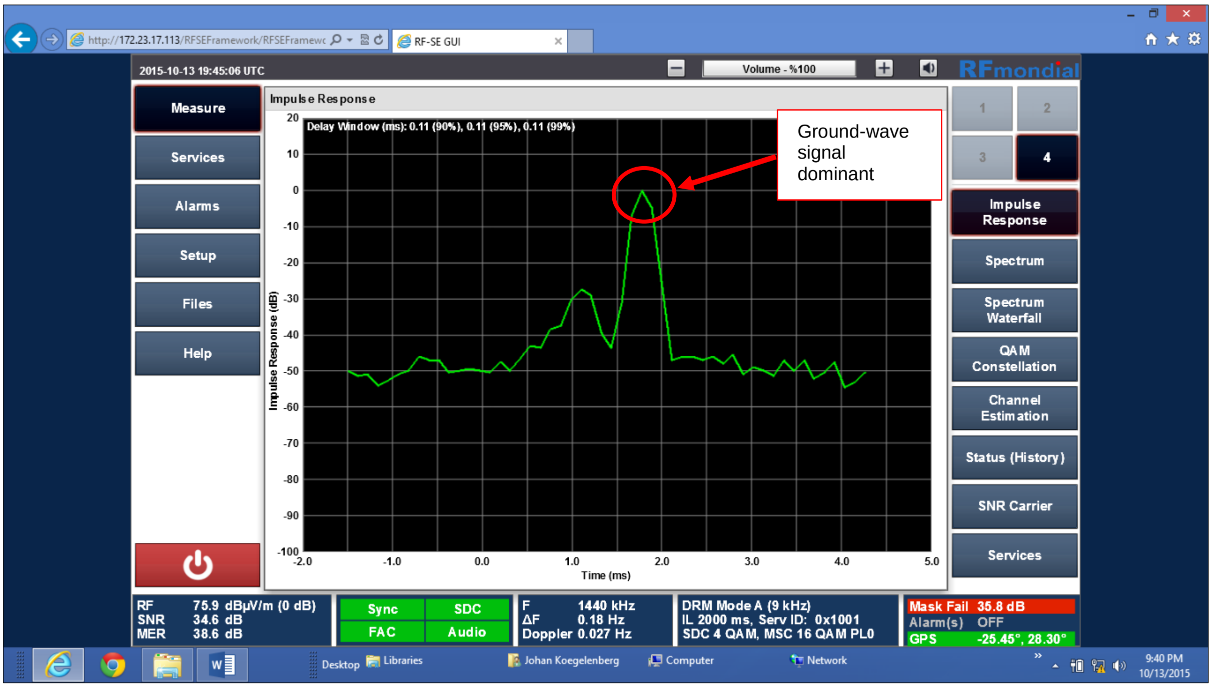


Figure 7: KinStar Antenna. Impulse response indicating that the ground-wave is dominant.

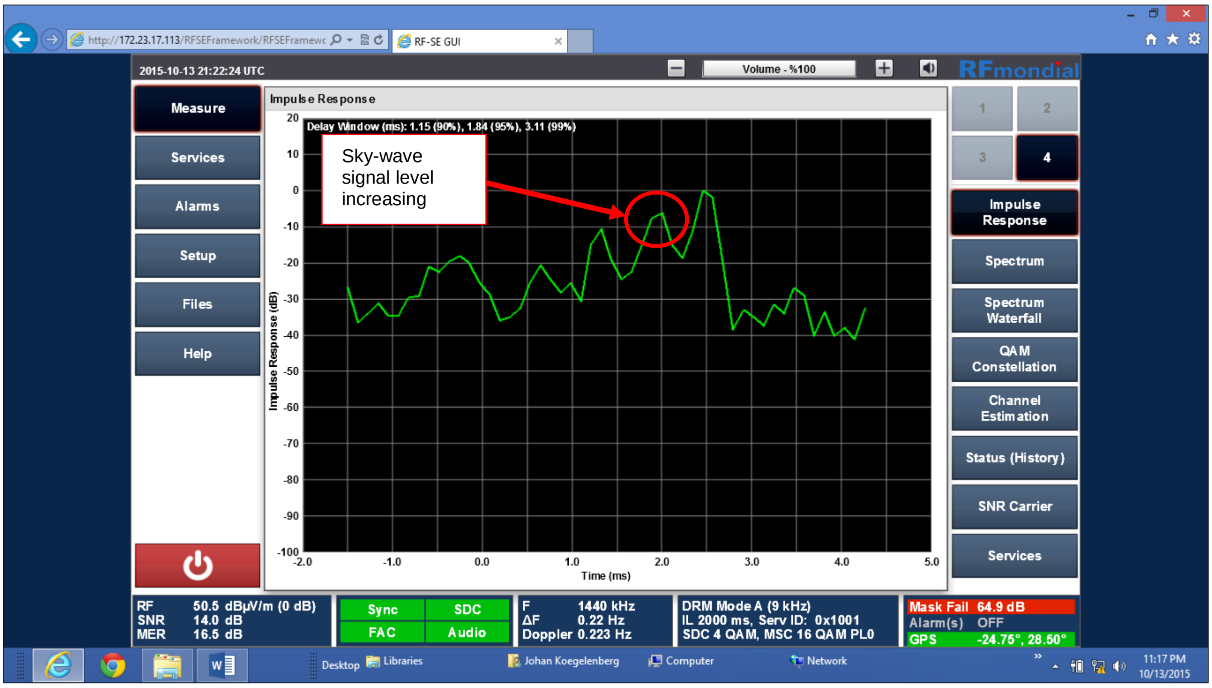


Figure 8: KinStar Antenna. Impulse response indicating increase in sky-wave level.

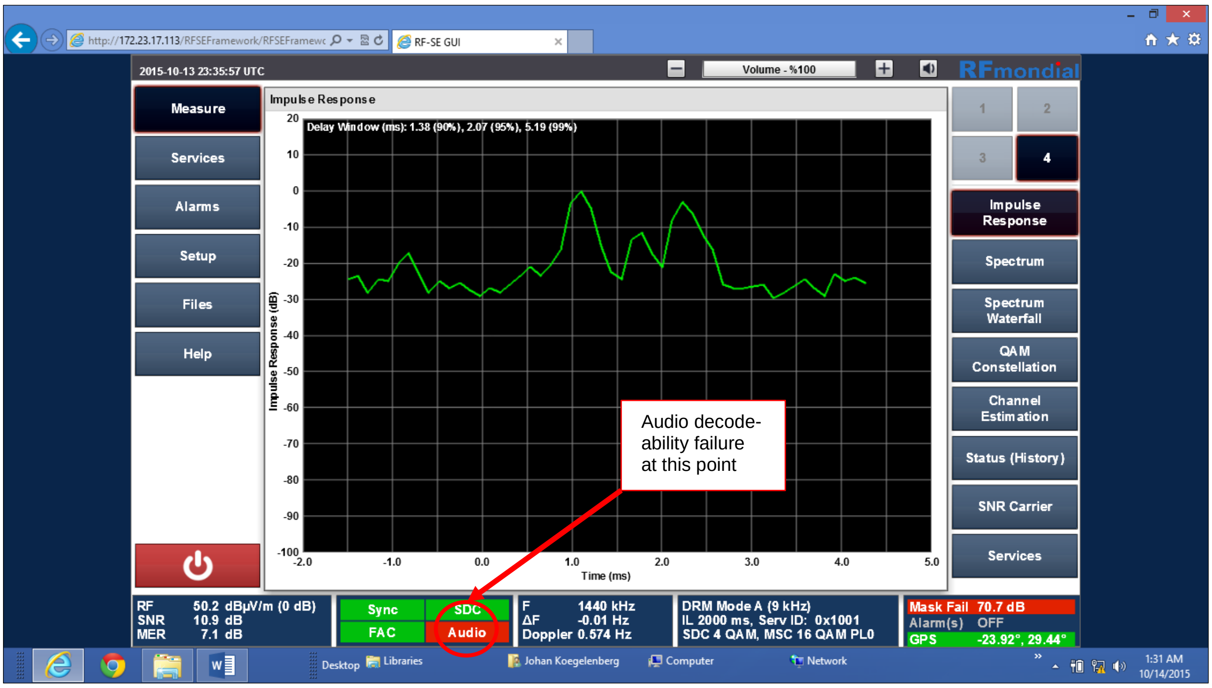
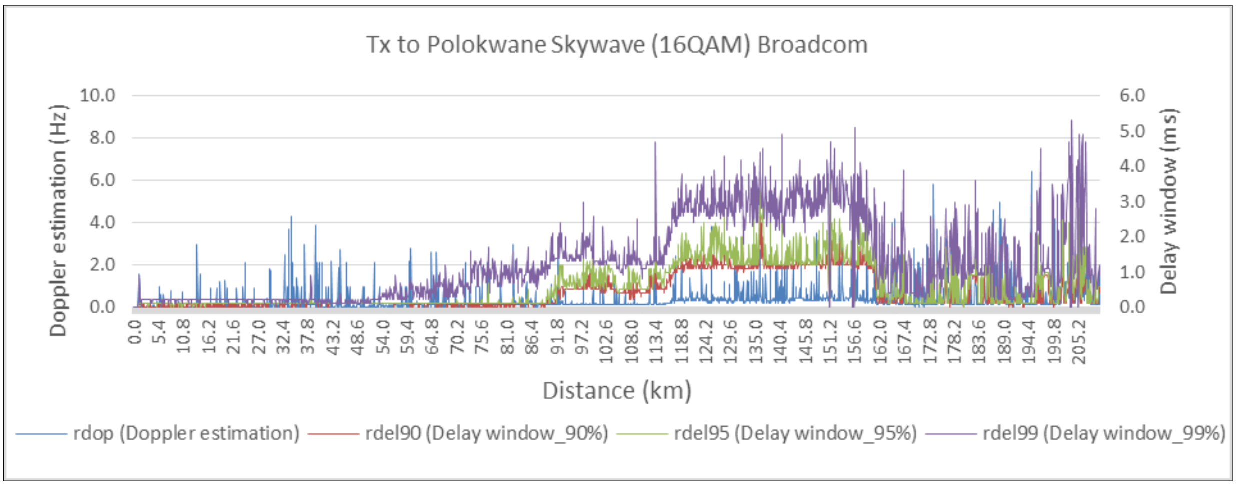


Figure 9: KinStar Antenna. Impulse response indicating ground-and-sky-wave at the same level.

7.3.7.2.3. SKY-WAVE IMPACT DIFFERENCES

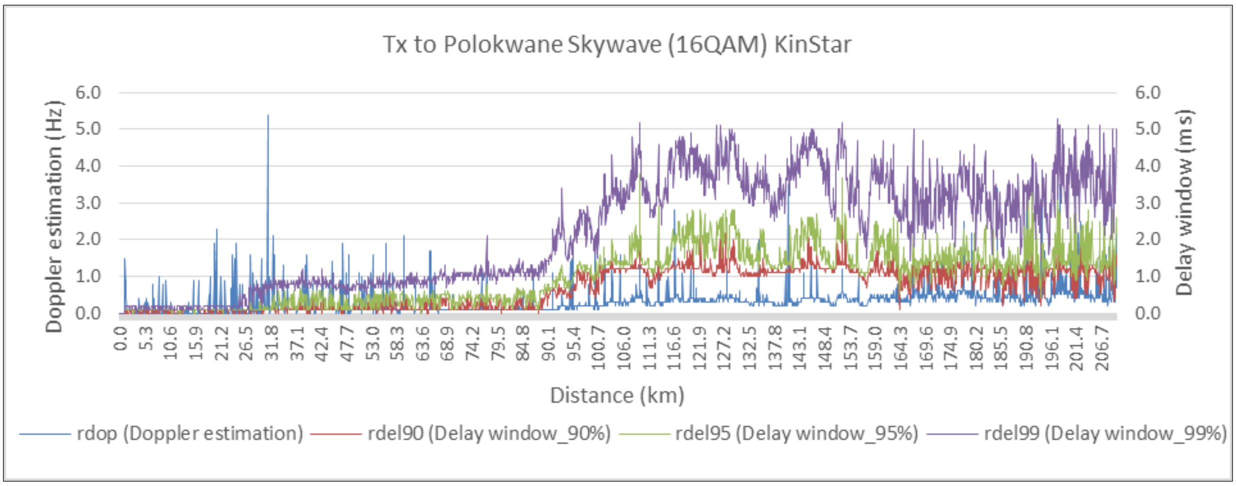
The following differences was noted when comparing the sky-wave impact on the ground-wave of both the Broadcom and KinStar antennas:



Graph 17: Broadcom antenna 16QAM Doppler estimation and Delay windows.

- Broadcom antenna (16QAM) *Doppler* and *Delay window* measurements (**Graph 17**) indicate an increase of sky-wave presence at a distance of ±90 km from the transmitter station. The negative impact of the sky-wave was clearly noticed at a distance between 114 km and 160 km from the transmitter station as indicated by the increase of the *Doppler* and *Delay window* parameter levels in **graph 17**. The main cause of the multi-path interference was due to an increase in sky-wave propagation, as well as the degradation of the ground-wave signal level, due to the distance from the transmitter station. Less interference were however experienced at a distance from 160 km onwards due to the sky-wave becoming the more dominant signal and the ground-wave insignificant. Both the *Doppler* and *Delay window* levels decreased rapidly due to the insignificance of the ground-wave which weren't able to provide a reference for the *Doppler* and *Delay window* estimations. Sky-wave signal was decode-able in the northern direction;
- The impulse response measurement (**figure 5**) indicate that the sky-wave signal interfered with the ground-wave signal resulting in audio drop-outs at a distance of ±160 km from the transmitter station on the Broadcom antenna;
- The Broadcom antenna measurement indicated that the sky-wave became the more dominant signal a few kilometres before Mokopane resulting in pure sky-wave

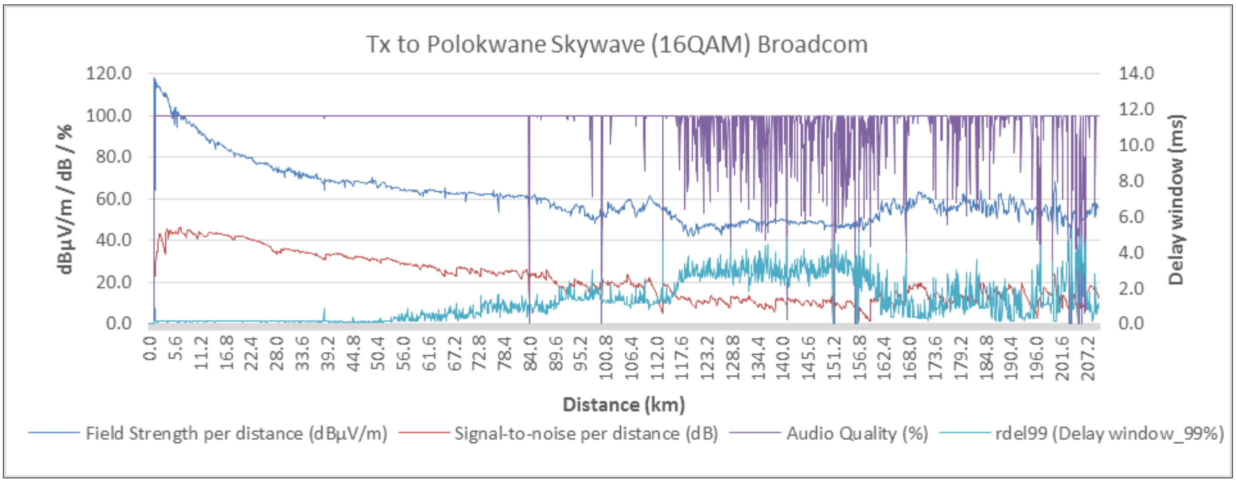
reception until the end of the measurement route (±220 km from the transmitter station) as indicated in **figure 6**.



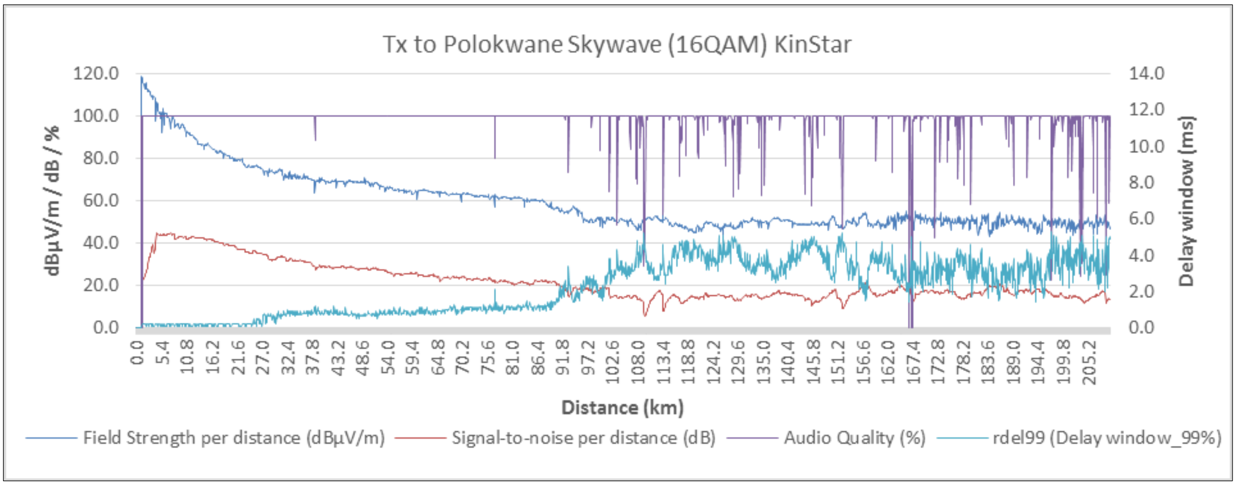
Graph 18: KinStar antenna 16QAM Doppler estimation and Delay windows.

- KinStar antenna (16QAM) *Doppler estimation* and *Delay window* measurements (**Graph 18**) indicate an increase of sky-wave presence at a distance of ±30 km from the transmitter station. The negative impact of the sky-wave was clearly noticed at a distance between 90 km and 210 km from the transmitter station, as indicated by the increase of the *Doppler* and *Delay window* parameter levels in **graph 18**. The main cause of the multi-path interference was due to an increase in sky-wave propagation levels, as well as the degradation of the ground-wave signal levels, due to the distance from the transmitter station. There was no pure sky-wave propagation from 160 km onwards;
- The KinStar antenna impulse response measurement (**figure 8**) indicated that the sky-wave interfered with the ground-wave at a distance of ±104 km from the transmitter station;
- The KinStar antenna measurements indicate the impulse response (**Figure 9**) between Mookgopong and Polokwane that the sky-wave signal and the ground-wave signal maintained more or less the same level which resulted in intermittent audio reception. The audio quality (purple) in **graph 18** indicate severe audio drop-outs between Mookgopong and Polokwane. Audio drop-outs increased in an area located a few kilometers from Polokwane (±220 km from the transmitter station) and no sky-wave reception was possible at all.

The graphs below indicates differences that was noted when comparing the sky-wave impact on the ground-wave of both the Broadcom and KinStar antennas:



Graph 19: Broadcom antenna 16QAM sky-wave measurements.



Graph 20: KinStar antenna 16QAM sky-wave measurements

- The *Delay window* parameter (aqua graphical line) in **graph 19** and **graph 20** indicated an increase of sky-wave presence at a distance of ±60 km from the transmitter station on the Broadcom antenna and at a distance of ±30 km on the KinStar antenna. There was no audio drop-outs on both antennas at this point because the ground-wave is still the dominant signal;
- The sky-wave was clearly noticed on the Broadcom antenna at a distance between 114 km and 160 km from the transmitter station as indicated by the increase of the *Delay window* parameter level in **graph 19**, the interference caused a decrease in field strength and S/N levels and severe audio drop-outs. Less interference were however experienced at a distance from 160 km onwards due to the sky-wave becoming the more dominant signal and the ground-wave insignificant as indicated by the decrease of the *Delay window* level, increase in field strength and S/N;

- The sky-wave was clearly noticed on the KinStar antenna at a distance between 90 km and 210 km from the transmitter station, as indicated by the increase of the *Delay window* parameter level in **graph 20**, the interference caused a decrease in field strength and S/N levels and audio drop-outs. Audio drop-outs remained constant until the measurements was stopped at a distance of 210 km, this indicated that no dominant sky-wave was present on the measurement route.

7.4. SIGNAL PERFORMANCE FINDINGS

This section provide details on the overall performance of the transmitted signal for both the Broadcom and KinStar antennas.

7.4.1. GROUND-WAVE SIGNAL PERFORMANCE FINDINGS

7.4.1.1. 16QAM MODULATED SIGNAL

The table below (**table 13**) indicate the average predicted and decodable coverage distances on the Broadcom and KinStar antennas.

AVERAGE COVERAGE DISTANCE (16QAM)										
Radial Direction	Broadcom Antenna				KinStar Antenna				Delta btw Broadcom Antenna and KinStar Antenna	
	Predicted Distance (km)	Actual Decoded Distance (km)	Difference between Predicted and Actual in kilometers (km)	Difference between Predicted and Actua in percentage (%)	Predicted Distance (km)	Actual Decoded Distance (km)	Difference between Predicted and Actual in kilometers (km)	Difference between Predicted and Actua in percentage (%)	Delta between Broadcom (+) and KinStar (-) (km)	Delta between Broadcom (+) and KinStar (-) (%)
	16QAM	16QAM	16QAM	16QAM	16QAM	16QAM	16QAM	16QAM	16QAM	16QAM
North	134	94	40	30.1	134	100	33.8	25.2	-6.5	-6.5
North-east	126	87	39	31.3	126	80	46.3	36.7	6.9	8.0
East	118	55	63	53.6	118	48	69.9	59.2	6.6	12.1
South-east	177	98	79	44.4	177	91	85.6	48.4	7	7.1
South	177	64	113	63.7	177	71	105.8	59.8	-7	-9.8
South-west	143	110	33	23.4	143	99	43.7	30.6	10.3	9.4
West	123	52	71	57.6	123	62	61.1	49.7	-9.8	-15.8
North-west	183	82	101	55.1	183	68	114.8	62.7	14	17.0
Average	148	80	67	45	148	78	70	47	3	3

Table 13: 16QAM Ground-wave predicted and measured decodable distances

The following ground-wave signal performance findings could be concluded based on the results in **table 13**:

- Measurements on both antennas indicate that the ground-wave signal does not propagate equally in all eight horizontal radial directions, therefore the distance of the decode-able signal will differ in each radial direction (refer to **table 13**). The reason for the difference in service reception distance in the various radial directions depended on a variety of factors ranging from antenna propagation characteristics, ground conductivity, type of topographical terrain and man-made noise;
- Measurements on the **Broadcom antenna** with the more-rugged 16QAM modulated signal indicated that a decodable signal was measured at an average omnidirectional distance of 80 km from the transmitter station (refer to **table 13**), ranging from 52 km till 110 km on the various radial measurement routes (refer to **graphs 25** to **32** in **Annexure B**);
- Measurements on the **KinStar antenna** with the more-rugged 16QAM modulation signal indicate that a decodable signal was measured at an average omnidirectional distance of 78 km from the

transmitter station (refer to **table 13**), ranging from 48 km till 100 km on the various radial measurement routes (refer to **graphs 41** to **48** in **Annexure C**);

- The average omnidirectional distance covered by the Broadcom antenna was 3 km further than the average omnidirectional distance of the KinStar antenna. This indicated that the Broadcom antenna was able to provide ±3% further coverage on the measurement route than the KinStar antenna when comparing the average omnidirectional distance of the 8 radial routes;
- The audio quality of the received signal on 16QAM from both antennas was not good (due to low modulation). The signal was however less susceptible to the negative impact of the type of topographical terrain, ground-conductivity, atmospheric conditions, man-made noise etc.

7.4.1.2. 64QAM MODULATED SIGNAL

The table below (**table 14**) indicate the average predicted and decodable coverage distances on the Broadcom and KinStar antennas.

AVERAGE COVERAGE DISTANCE (64QAM)										
Radial Direction	Broadcom Antenna				KinStar Antenna				Delta btw Broadcom Antenna and KinStar	
	Predicted Distance (km)	Actual Decoded Distance (km)	Difference between Predicted and Actual in kilometers (km)	Difference between Predicted and Actua in percentage (%)	Predicted Distance (km)	Actual Decoded Distance (km)	Difference between Predicted and Actual in kilometers (km)	Difference between Predicted and Actua in percentage (%)	Delta between Broadcom (+) and KinStar (-) (km)	Delta between Broadcom (+) and KinStar (-) (%)
	64QAM	64QAM	64QAM	64QAM	64QAM	64QAM	64QAM	64QAM	64QAM	64QAM
North	112	75	37	32.9	112	94	18	16.4	-18.4	-19.7
North-east	126	78	48	38.3	126	77	49	39.0	0.9	1.2
East	93	37	56	60.2	93	63	30	32.6	-25.7	-41.0
South-east	137	79	58	42.4	137	*	*	*	*	*
South	134	26	108	80.7	134	70	64	48.0	-43.9	-63.0
South-west	104	81	23	22.0	104	60	44	42.1	20.9	25.8
West	107	35	72	67.6	107	46	61	56.6	-11.7	-25.2
North-west	134	68	67	49.6	134	69	65	48.2	-1.9	-2.7
Average	116	57	59	50	116	68	47	40	-11	-18

Table 14: 64QAM Ground-wave predicted and measured decodable distances

* Due to a temporary error in the RFmondial RF-SE12, the devise was unable to measure the *rafs (audio status) TAG* which is used to calculate decoded distance (see graph 51).

The following ground-wave signal performance findings could be concluded based on the results in **table 14**:

- Measurements on both antennas indicate that the ground-wave signal does not propagate equally in all eight horizontal radial directions, therefore the distance of the decode-able signal will differ in each radial direction (refer to **table 14**). The reason for the difference in service reception in the various directions depend on a variety of factors ranging from antenna propagation characteristics, ground conductivity, type of topographical terrain and man-made noise;

- Measurements on the **Broadcom antenna** with the less-rugged 64QAM modulated signal indicated that a decodable signal was measured at an average omnidirectional distance of 60 km from the transmitter station (refer to **table 14**), ranging from 26 km till 81 km on the various radial measurement routes (refer **graphs 33** to **40** in **Annexure B**);
- Measurements on the **KinStar antenna** with the less-rugged 64QAM modulation signal indicated that a decodable signal was measured at an average omnidirectional distance of 68 km from the transmitter station (refer to **table 14**), ranging from 46 km till 94 km on the various radial measurement routes (refer to **graphs 49** to **56** in **Annexure C**);
- The average omnidirectional distance of the KinStar antenna was 11 km further than the average omnidirectional distance of the Broadcom antenna. This indicated that the KinStar provide ±18% improvement in average coverage distance compared to the Broadcom antenna;
- Although the audio quality of the received signal on 64QAM for both antennas was good, it was more susceptible to the negative impact of the type of topographical terrain, ground-conductivity, atmospheric conditions, man-made noise due to the higher modulation setting.

The type of modulation setting (16QAM vs 64QAM) had a major impact on the decode-ability of the signal, which had a direct impact on the coverage area in which the receivers were able to decode the signal. Changing the modulation from a higher modulation (64QAM) to a lower modulation (16QAM) the average coverage distance (from the transmitter) could be improved. The negative aspect of configuring to the low, more robust 16QAM configuration is that the audio quality is not as good as the 64QAM modulated signal. Another negative aspect was that only one audio service could be carried by the 16QAM modulation setting in comparison to the two services on the 64QAM modulation setting.

The type of antenna (Broadcom vs KinStar) had an impact on the average omnidirectional distance in which the DRM30 signal was decodable. The Broadcom antenna had a 3 km further average omnidirectional distance than the KinStar antenna on the 16QAM modulation scheme. The KinStar antenna had an 11 km further average omnidirectional distance than the Broadcom antenna on the 64QAM modulation scheme.

7.4.2. SKY-WAVE SIGNAL PERFORMANCE FINDINGS

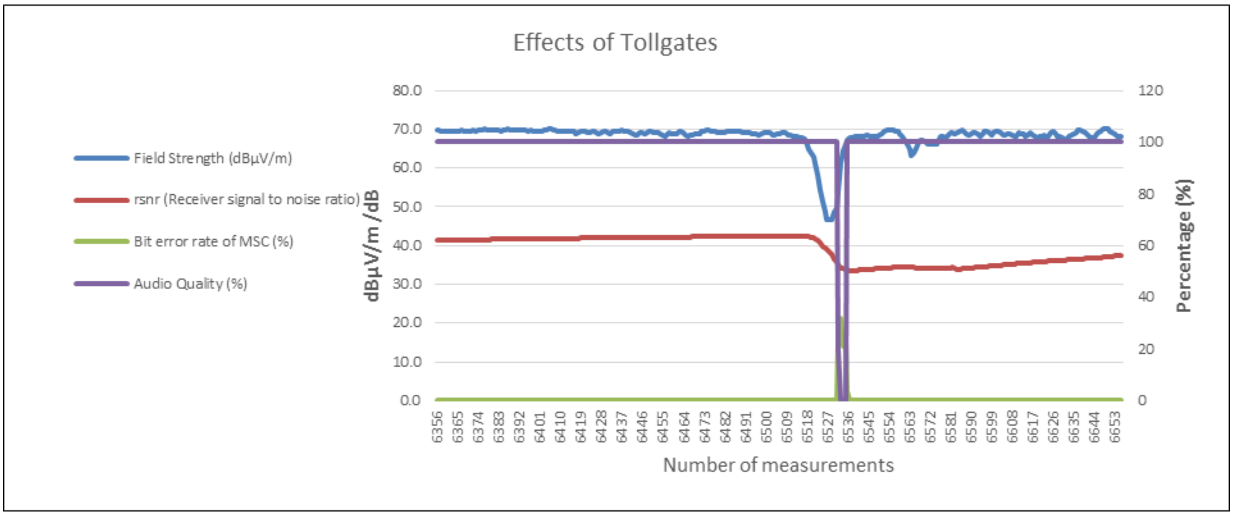
The following sky-wave signal performance findings could be made based on the measurement analysis:

- Measurement results on both antennas indicated that the interference from the sky-wave did not negatively impact the DRM30 ground-wave coverage area during the night;
- Measurements on the Broadcom antenna indicated that the sky-wave became the more dominant carrier at a distance of ±116 km from the transmitter station;
- Measurements results indicated that the KinStar antenna had less sky-wave interference on the ground-wave compared to Broadcom antenna and that the sky-wave propagation was almost non-existent beyond the ground-wave coverage area on the KinStar antenna.

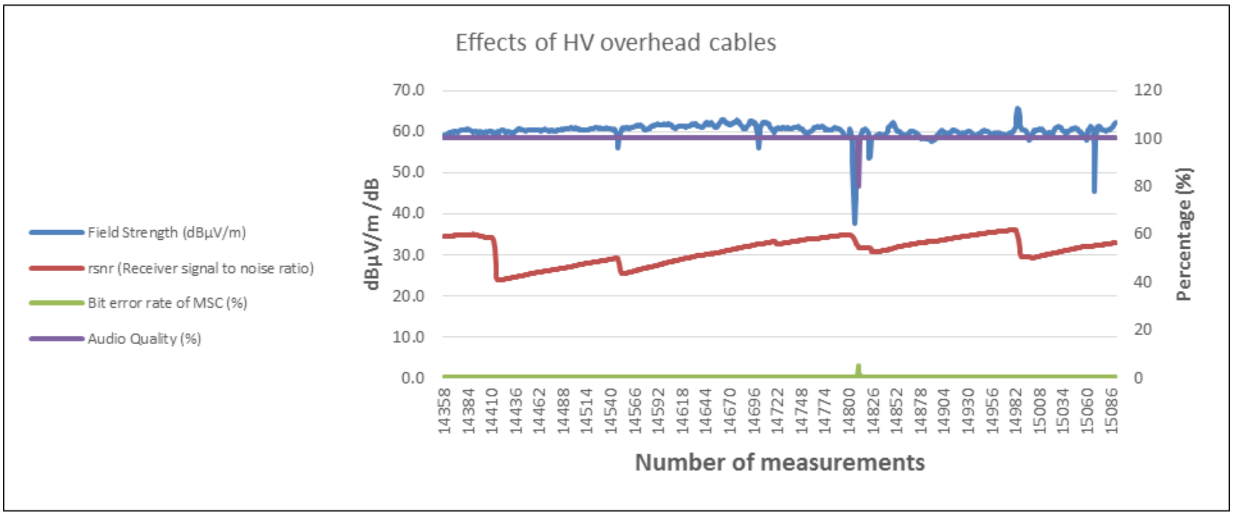
7.4.3. FACTORS IMPACTING NEGATIVELY ON SIGNAL PERFORMANCE

Several factors have been identified to have negative impact on the performance of the signal with regard to signal reception which include the following:

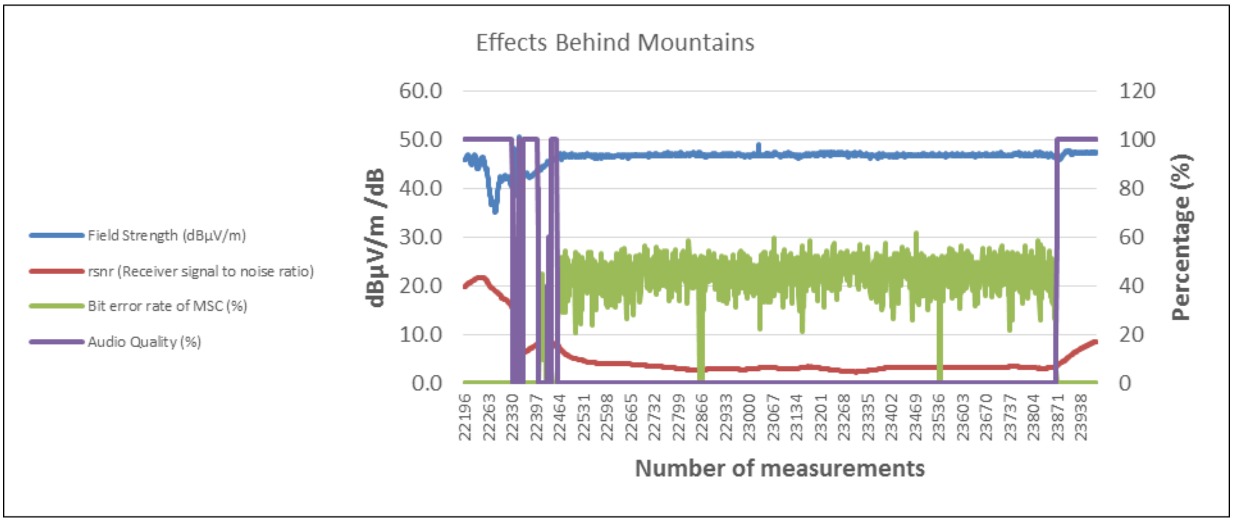
- Passing through toll-gates impacted negatively on both the received field strength and the S/N levels which reduced and recovered rapidly whenever the measurement vehicle passed through tollgates. This resulted in an increase of BER and the reduction of audio quality for a short time period (indicated in **graph 21**);
- Driving underneath high voltage overhead cables also caused the received field strength and the S/N levels to reduce and recover rapidly which also resulted in an increase of BER and reduction of audio quality for a short time period (indicated in **graph 22**);
- Mountainous terrains impacted negatively on S/N, BER and Audio Quality. Poor ground conductivity in mountainous terrains seem to have a negative impact on signal propagation (refer to measurement analysis **graph 23**);
- Driving underneath bridges caused the received field strength and the S/N levels reduce rapidly which resulted in an increase of BER and reduction of audio quality (refer to measurement analysis **graph 24**);
- Night-Time sky-wave interference (refer to measurement analysis **graph 15** and **graph 16**);
- Antenna design has an enormous impact on signal performance. This was clearly noticeable when the Broadcom antenna measurement results was compared with the measurement results on the KinStar antenna. One of the most important aspects noticed was the importance of the antenna to produce a good broadband signal (good overall in band). Providing good transmit signal levels to most of the digital signal carriers were found to be essential. One of the other antenna requirement findings was that by providing an antenna with the capability to propagate more energy in the ground-wave resulted in an improved signal in the coverage area resulting in larger area coverage. The other positive aspect with regard to more concentrated energy in the direction of the ground-wave was that less energy is propagated skywards which means that there is less sky-wave interference impact on the ground-wave coverage during the night time.



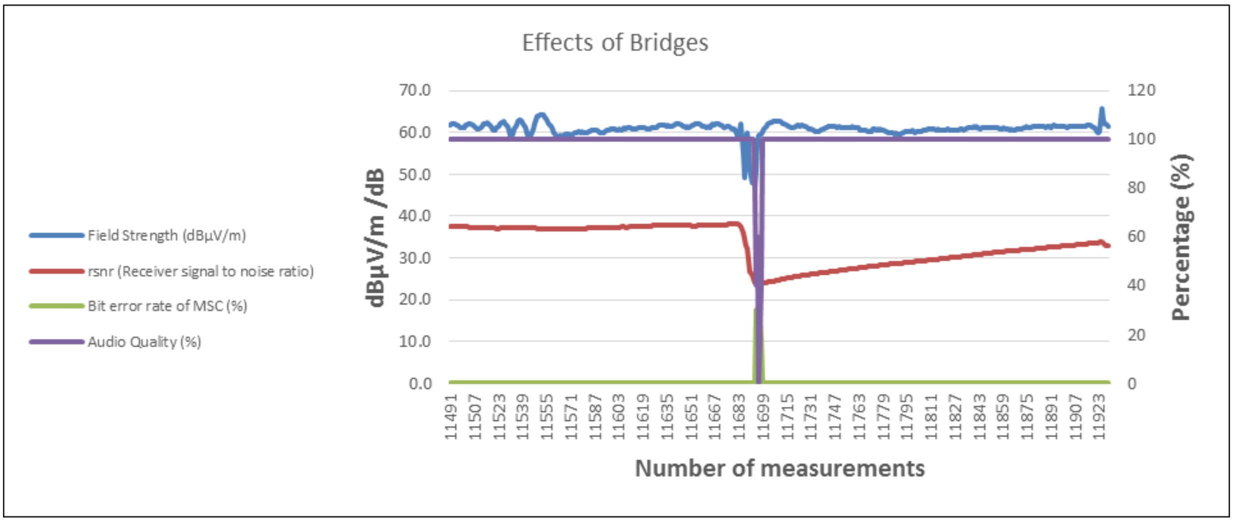
Graph 21: Tollgate impacting negatively on service and audio quality.



Graph 22: High voltage overhead cables impacting negatively on service and audio quality.



Graph 23: Mountainous terrain impacting negatively on service and audio quality.



Graph 24: Driving underneath bridges impacting negatively on service and audio quality.

6.5. PERFORMANCE OF COMMERCIAL RECEIVERS

The commercial receivers used to evaluate the DRM30 signal decode-ability and quality are tabled in **table 15**. Performance of the commercial receivers were monitored at various static locations on the various radial routes. At each static measurement location each one of the receivers were tested to determine if the signal was decode-able and also to monitor the audio quality. Evaluation of the performance of the commercial receivers indicated that the overall performance of the various commercial receivers varied considerably with regard to their sensitivity and their ability to decode the received signal. The most sensitive commercial receiver was the Morphy Richards 27024, followed by the UniWave Di-Wave 100. The other two commercial receivers performed quite poor with regard to sensitivity and decode-ability.

Test-point (TP) locations where the commercial receivers were tested during the drive-by measurement exercises in the 16QAM and 64QAM coverage areas of the two types of antennas (Broadcom and KinStar) are indicated in **maps 16, 17, 18** and **19**. Commercial receiver performance was also tested in the analogue (AM) coverage area at the locations indicated in **map 20**.

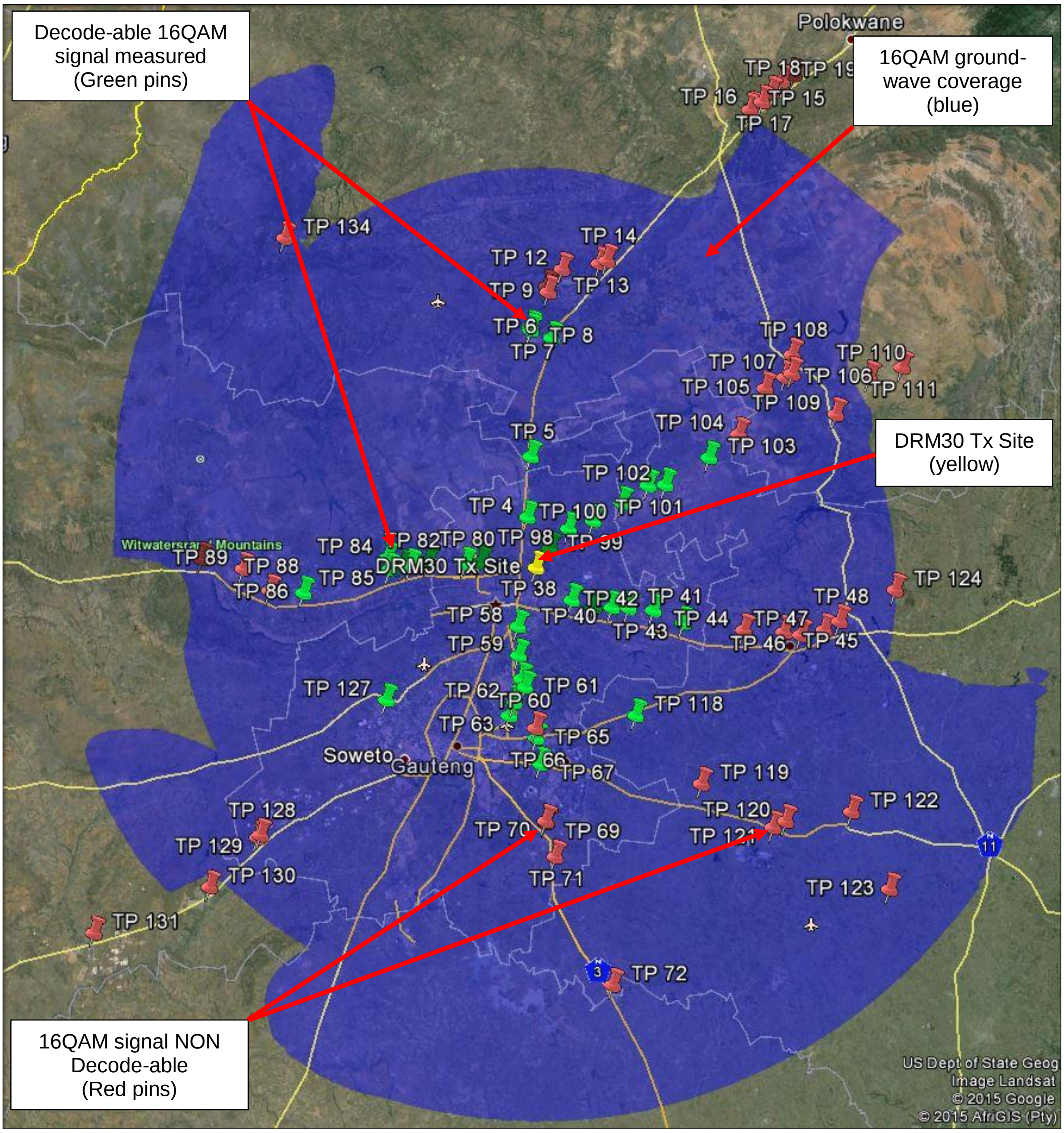
Results on the commercial receiver performance in the different signal coverage areas can be summarized as follow:

- In the Broadcom antenna 16QAM ground-wave coverage area a total number of 83 test points were recorded, out of which 36 test points (green pins on **map 16**) indicated the signal to be receivable and decode-able with good audio quality and 47 test points (red pins on **map 16**) were found to be non-decode-able. Statistically 43% of the measured test points was decode-able in the Broadcom antenna 16QAM predicted ground-wave coverage area;
- A total number of 87 test points were recorded in the KinStar antenna 16QAM ground-wave coverage area, out of which 31 test points (green pins on **map 17**) indicated the signal to be receivable and decode-able with good audio quality and 56 test points (red pins on **map 17**) were found to be non-decode-able. Statistically 36% of the measured test points was decode-able in the KinStar antenna 16QAM predicted ground-wave coverage;
- Out of a total number of 50 test points in the Broadcom antenna 64QAM ground-wave coverage area, 14 test points (green pins on **map 18**) indicated the signal to be receivable and decode-able with good audio quality and 36 test points (red pins on **map 18**) were found to be non-decode-able. Statistically 28% of the measured test points was decode-able in the Broadcom antenna 64QAM predicted ground-wave coverage area and 72% non-decode-able;
- In the KinStar antenna 64QAM ground-wave coverage area a total number of 57 test points were recorded, out of which 18 test points (green pins on **map 19**) indicated the signal to be receivable and decode-able with good audio quality and 39 test points (red pins on **map 19**) were found to be non-decode-able. Statistically 32% of the measured test points was decode-able in the KinStar antenna 64QAM predicted ground-wave coverage area;
- A total of 14 test points in the KinStar antenna analogue AM ground-wave coverage area were recorded, out of which 4 test points (green pins on **map 20**) indicated the signal to be good and 10 test points (red pins on **map 20**) were

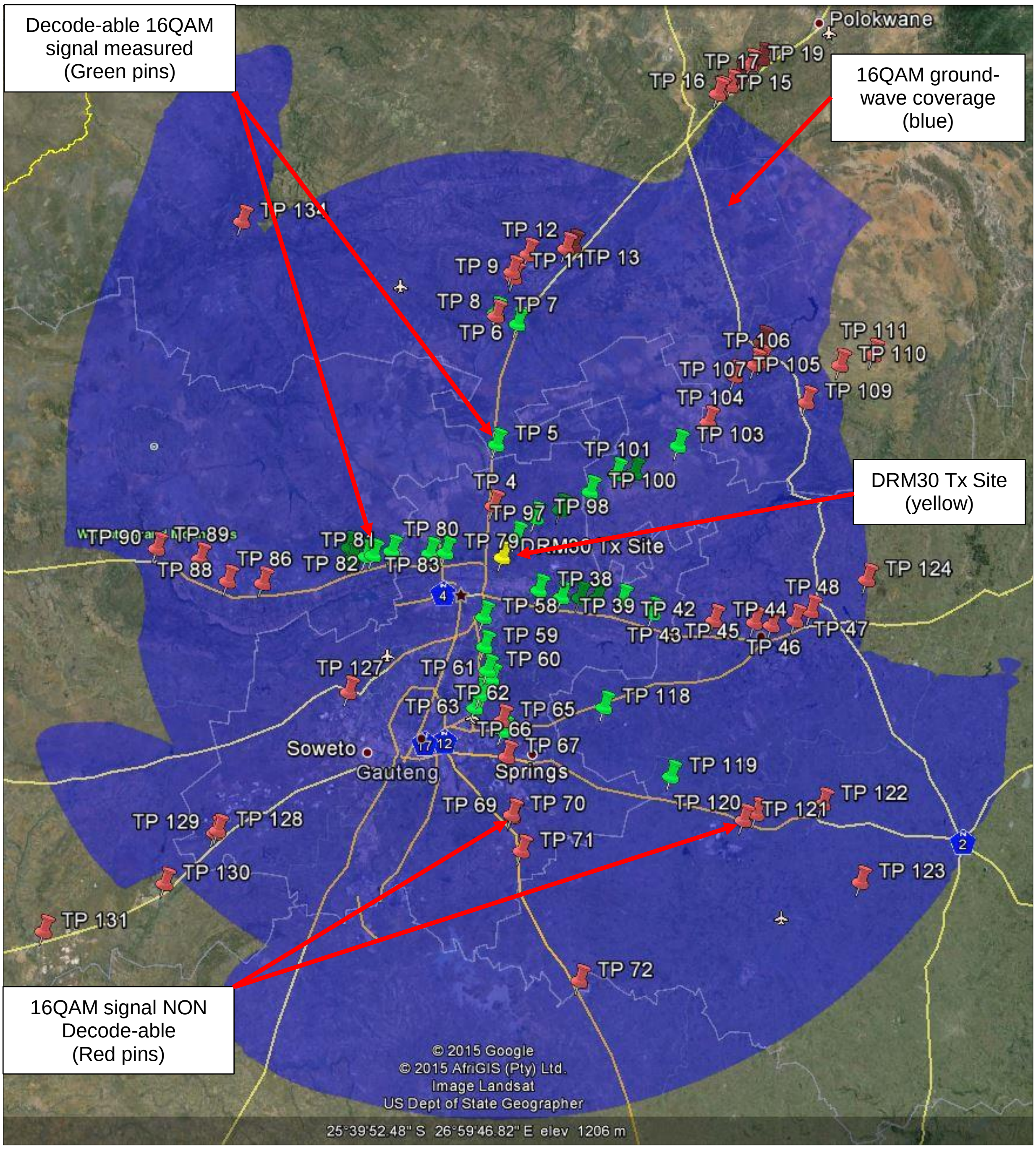
found to be noisy and bad. Statistically 29% of the measured test points indicated a good audio quality in the analogue AM ground-wave coverage area.

Commercial Monitoring Receivers		
Manufacture	**Model**	**Picture**
Morphy Richards	27024	
UniWave	Di-Wave 100	
Himalaya	DRM2009	
NewStar	DR-111	

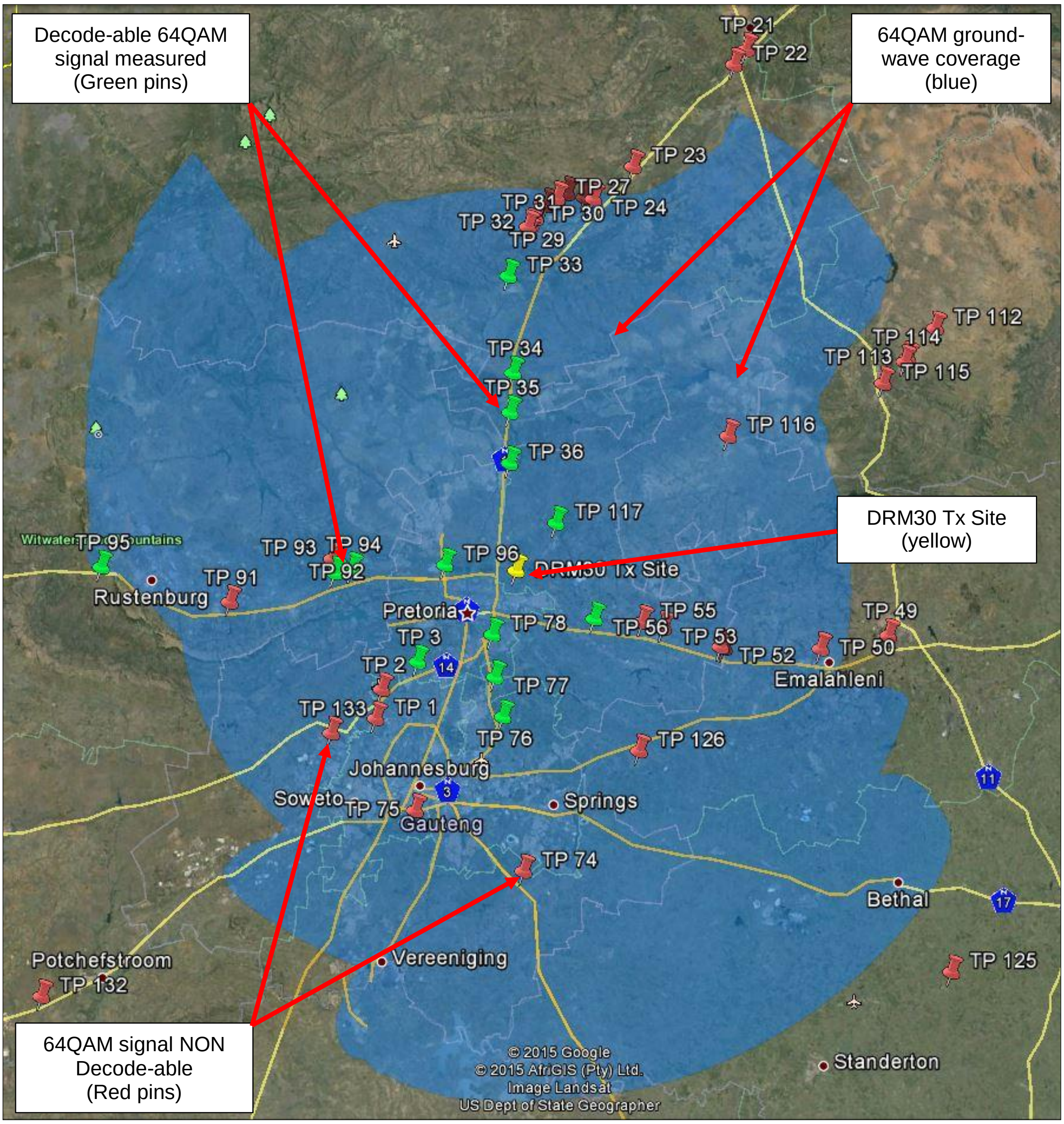
Table 15: DRM30 commercial receivers used in DRM30 trial.



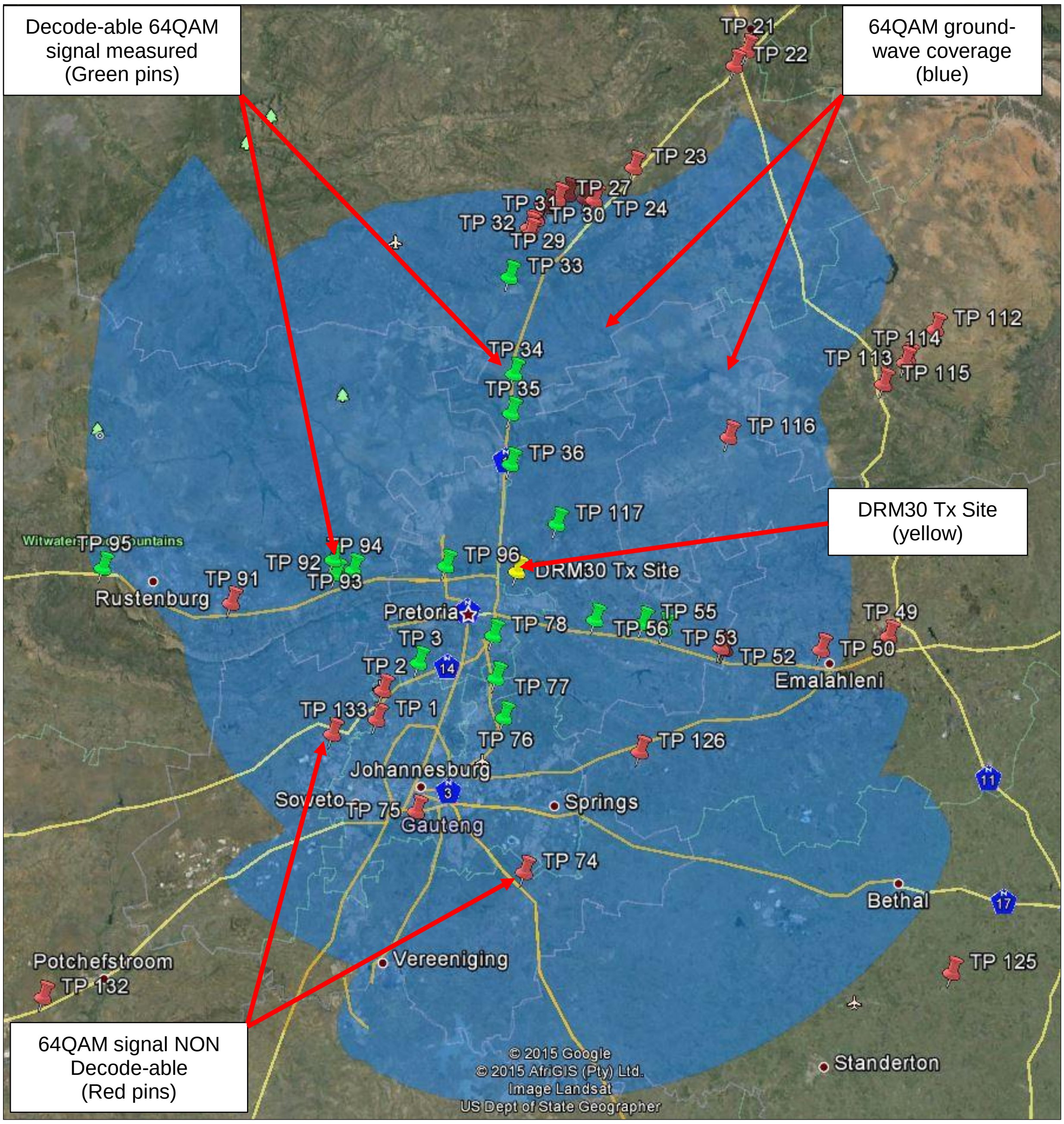
Map 16: Commercial receiver test points in the predicted Broadcom antenna 16QAM ground-wave coverage.



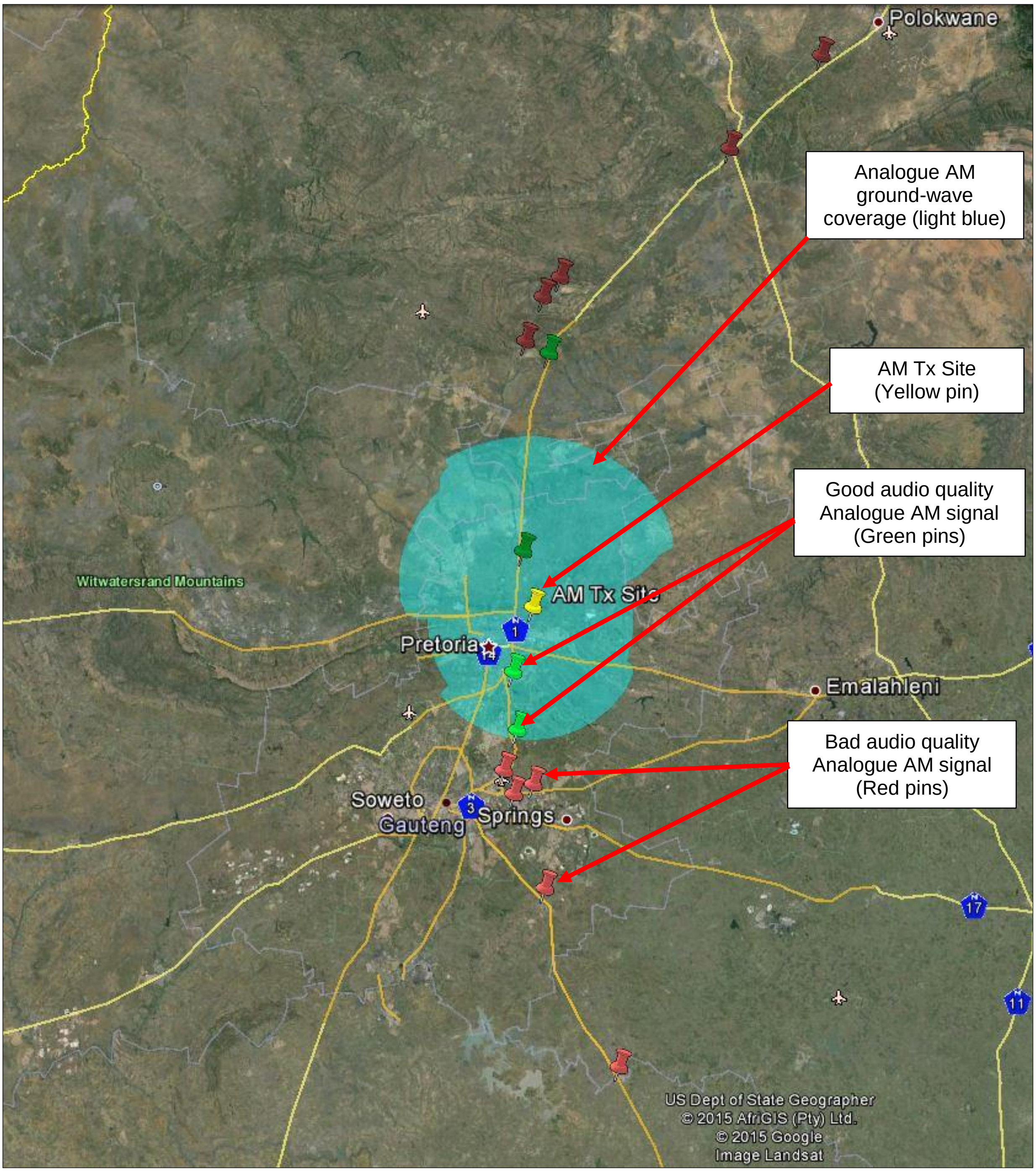
Map 17: Commercial receiver test points in the predicted KinStar antenna 16QAM ground-wave coverage.



Map 18: Commercial receiver test points in the predicted Broadcom antenna 64QAM ground-wave coverage.



Map 19: Commercial receiver test points in the predicted KinStar antenna 64QAM ground-wave coverage.



Map 20: Commercial receiver test points in the predicted KinStar antenna analogue AM ground-wave coverage.

7. CONCLUSIONS

Sufficient measurement data was obtained for analysis purposes which assisted in reaching a conclusion on the overall performance of the DRM30 technology. The following conclusions could be made based on the DRM30 trial:

- Both Low profile MW antennas (Broadcom and KinStar) were capable to provide good signal coverage;
- The KinStar antenna have a better VSWR over the 9 kHz bandwidth;
- Measurement tools were easily obtainable and the overall performance of the tools were found to be satisfactory;
- The measurement method selected by allocating routes per radial proved to be successful since it provided a good indication of the area coverage;
- Configuration of the DRM30 modulation (16QAM and 64QAM) during the measurement exercise provided sufficient information to determine the differences in performance between the two modulation schemes (16QAM and 64QAM);
- Both antenna system’s (Broadcom and KinStar) measured horizontal radiation patterns indicated performance results which were better than predicted;
- Measurements with the analogue test signal (no modulation, narrow band signal) indicated that the Broadcom antenna have slightly higher gain than the KinStar antenna;
- Field strength correlation results between predicted and measured values indicate the predictions to be fairly accurate (50.9% of measured values within ±3dB on the Broadcom antenna and 95.9% of measured values within ±3dB on the KinStar antenna). Coverage predictions on the KinStar antenna were therefore found to be much more accurate;
- Field strength measurement results indicated that the propagated ground-wave does not radiate equally in all horizontal directions due to ground conductivity, nature of the topographical terrain, man-made noise etc.;
- Modulation configuration selection had a direct impact on signal coverage area and data throughput (data rate). The 16QAM modulation configuration setting provided a more robust signal resulting in a larger signal coverage area compared to the 64QAM modulated signal which provided a higher data rate and a smaller signal coverage area;
- DRM30 indicated improved spectrum usage in that DRM30 was capable of transmitting two audio services on the same AM frequency and bandwidth;
- Added to the audio service text messages and Journaline were also transmitted which was seen on the receiver end;
- The Broadcom antenna provided slightly better DRM30 ground-wave coverage than the KinStar antenna when the decode-ability of the 16QAM signal were compared. The Broadcom antenna have slightly higher gain than the KinStar antenna;
- The KinStar antenna provided slightly better DRM30 ground-wave coverage than the Broadcom antenna when the decode-ability of the 64QAM signal were compared. This was due to the better VSWR over the 9 kHz bandwidth on the KinStar antenna compared to the Broadcom antenna;
- The measured DRM30 signal performed better than the measured analogue AM signal with regard to area coverage;

- Both the DRM30 signal and analogue AM signal were susceptible to signal degradation caused by man-made noise (tollgates, bridges, high voltage overhead cables etc.);
- Sky-wave field strength measurements indicated that the Broadcom antenna had more interference caused by the sky-wave compared to the KinStar antenna. This was noticeable when measurement results indicated more sky-wave reflections caused by the Broadcom antenna compared to the KinStar antenna. The sky-wave interference occurred outside the daytime ground-wave coverage area which confirm that it should not have a negative impact on the daytime ground-wave coverage area;
- Services cannot be guaranteed in the sky-wave coverage areas;
- DRM30 measurement results indicated that all commercial receivers performed poorly with regard to signal reception when compared to the DRM30 measurement test results and the ITU recommendations;
- Performance between the different DRM30 commercial receiver manufacturer models differed quite significantly, indicating quite a vast difference with regard to sensitivity;
- The evaluated DRM30 commercial receivers were also found to be quite power intensive resulting in regular battery changes. This was also an indication of poor power efficiency which might be a problem in areas where no electricity is available;
- Availability of affordable and good quality DRM30 receivers as well as the limited number of manufacturers should be taken into consideration before selecting DRM30 as a broadcast medium;
- DRM30 broadcast can be considered as a greener technology due to 40% reduction in electricity consumption compared to the AM broadcast when covering the same area;
- DRM30 provides better audio quality and larger area coverage compared to analogue AM.

Due to time limitations not all tests were conducted, it is therefore recommended that the following could be conducted in future measurement trials:

- Antenna pattern measurements (Airborne measurements);
- Single frequency network (SFN) operation using the DRM30 system;
- Receiver evaluation;
- Emergency warning feature (EWF);
- Alternative frequency signaling (analogue AM, FM and DAB);
- Additional features (DRM Text messages and Journaline text information service).

8. REFERENCES

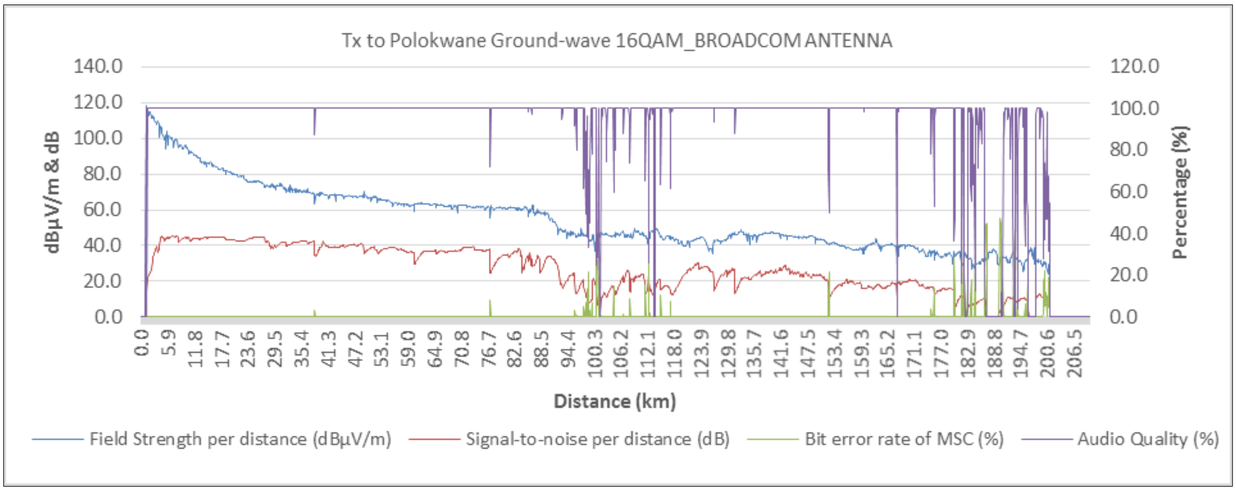
1. ETSI ES 201 980, Digital Radio Mondiale (DRM); System Specification;
2. ETSI TS 102 349, Digital Radio Mondiale (DRM); Receiver Status and Control Interface (RSCI);
3. ITU-R BS.1615-1, “Planning parameters” for digital sound broadcasting at frequencies below 30 MHz;
4. EBU-Tech 3330, Technical Base For DRM Services Coverage Planning;
5. DRM Introduction and Implementation Guide, Revision 2, September 2013;
6. ITU-R P.1321, Propagation factors affecting systems using digital modulation techniques at LF and MF;
7. ITU-R P.386-7, Ground-wave propagation curves for frequencies between 10 kHz and 30 MHz;
8. ITU-R P.1147-2, Prediction of sky-wave field strength at frequencies between 150 kHz and 1700 kHz;
9. ITU-R P.832-2, World Atlas of Ground Conductivities;
10. ITU-R BS.703, Characteristics of AM sound broadcasting reference receivers for planning purposes;
11. ITU Radio communication Study Groups, Document 6E/175-E, 18 March 2005.

ANNEXURE A

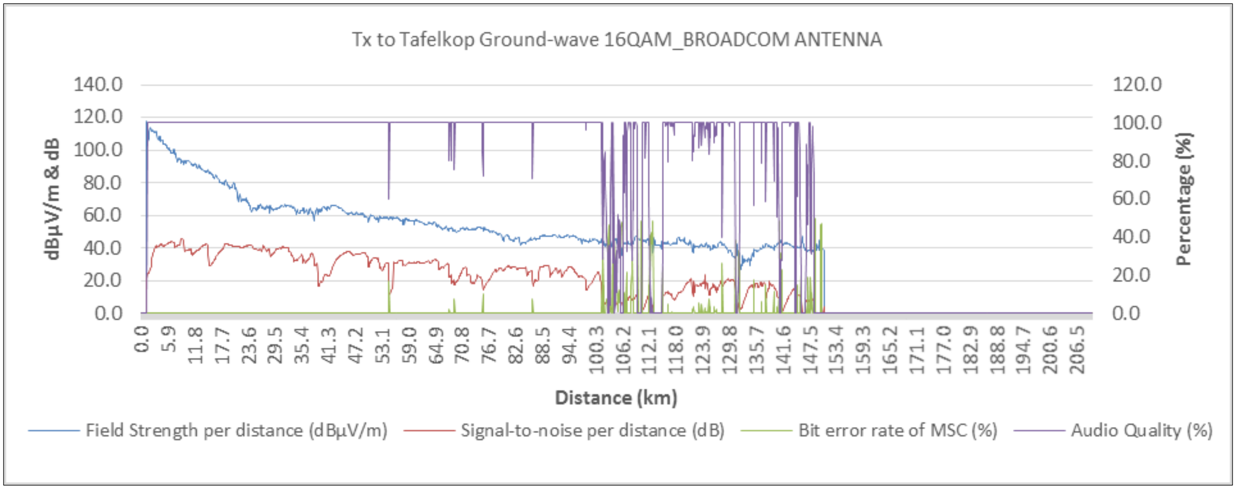
Measurement signal and test point description											Broadcom Antenna Measurements						KinStar Antenna Measurements						Delta between Broadcom and KinStar Antenna
Path Details		Measurement Test and Test Point details									POTOMAC INSTRUMENTS FIM-4100			RFmondial RF-SE12			POTOMAC INSTRUMENTS FIM-4100			RFmondial RF-SE12			
											Field Strength			Field Strength			Field Strength			Field Strength			Delta
Distance (m)	Azimuth (°) Test Point to Transmitter	Test No.	Test Point No.	Measurement test point description	Test Point Antenna Height (m)	Test Antenna (Type)	Long (Xadm) (East)	Lat (Yadm) (South)	Rx freq (MHz)	Rx polarization	Field strength measurement (dBµV/m)	Predicted FSR (dBµV/m)	Delta btw Actual & Predicted (Only dBµV measurement value)	Field strength measurement (dBµV/m)	Predicted FSR (dBµV/m)	Delta btw Actual & Predicted (Only dBµV measurement value)	Field strength measurement (dBµV/m)	Predicted FSR (dBµV/m)	Delta btw Actual & Predicted (Only dBµV measurement value)	Field strength measurement (dBµV/m)	Predicted FSR (dBµV/m)	Delta btw Actual & Predicted (Only dBµV measurement value)	Delta between Broadcom and KinStar Antenna
1020	0°	TEST01	TP01	Kameeldrift area	1.5	Loop Antenna	28.19017	25.39424	1.44	V	117.10	110.1	7.0	115.60	110.1	5.5	116.90	110.1	6.8	114.00	110.1	3.9	0.2
1281	45°	TEST02	TP02	Kameeldrift area	1.5	Loop Antenna	28.19379	25.39418	1.44	V	115.00	107.5	7.5	115.80	107.5	8.3	115.70	107.5	8.2	115.60	107.5	8.1	-0.7
1000	90°	TEST03	TP03	Kameeldrift area	1.5	Loop Antenna	28.19445	25.40118	1.44	V	116.00	110.3	5.7	117.60	110.3	7.3	114.80	110.3	4.5	117.10	110.3	6.8	1.2
1131	135°	TEST04	TP04	Kameeldrift area	1.5	Loop Antenna	28.19359	25.40383	1.44	V	116.40	108.9	7.5	116.50	108.9	7.6	115.50	108.9	6.6	115.60	108.9	6.7	0.9
1000	180°	TEST05	TP05	Kameeldrift area	1.5	Loop Antenna	28.19086	25.40454	1.44	V	117.50	110.3	7.2	120.00	110.3	9.7	117.00	110.3	6.7	119.00	110.3	8.7	0.5
1000	225°	TEST06	TP06	Kameeldrift area	1.5	Loop Antenna	28.18399	25.40335	1.44	V	118.00	110.3	7.7	118.70	110.3	8.4	117.20	110.3	6.9	118.50	110.3	8.2	0.8
1300	270°	TEST07	TP07	Kameeldrift area	1.5	Loop Antenna	28.18201	25.40130	1.44	V	113.30	107.3	6.0	114.50	107.3	7.2	112.40	107.3	5.1	114.60	107.3	7.3	0.9
1273	315°	TEST08	TP08	Kameeldrift area	1.5	Loop Antenna	28.18365	25.39459	1.44	V	115.10	107.6	7.5	114.20	107.6	6.6	114.80	107.6	7.2	114.10	107.6	6.5	0.3
4800	0°	TEST09	TP09	Rynoue AH	1.5	Loop Antenna	28.19069	25.37388	1.44	V	102.00	91.1	10.9				100.80	91.1	9.7	102.30	91.1	11.2	1.2
4952	45°	TEST10	TP10	Roodeplaat Dam Nature Reserve	1.5	Loop Antenna	28.21077	25.38171	1.44	V	102.80	89.8	13.0				98.10	89.8	8.3	99.40	89.8	9.6	4.7
5304	90°	TEST11	TP11	Baviaanspoort	1.5	Loop Antenna	28.22162	25.40176	1.44	V	102.80	88.7	14.1				98.30	88.7	9.6	99.50	88.7	10.8	4.5
5021	135°	TEST12	TP12	Mamelodi	1.5	Loop Antenna	28.21200	25.42076	1.44	V	95.40	89.6	5.8				90.30	89.6	0.7	91.20	89.6	1.6	5.1
5100	180°	TEST13	TP13	Eersterus	1.5	Loop Antenna	28.19092	25.42590	1.44	V	97.79	89.3	8.5				94.30	89.3	5.0	92.90	89.3	3.6	3.5
5166	225°	TEST14	TP14	Ekklesia	1.5	Loop Antenna	28.16540	25.42073	1.44	V	100.36	89.1	11.3				98.50	89.1	9.4	97.40	89.1	8.3	1.9
4701	270°	TEST15	TP15	Montana Gardens	1.5	Loop Antenna	28.16185	25.40133	1.44	V	100.79	90.5	10.3				99.80	90.5	9.3	100.00	90.5	9.5	1.0
5048	315°	TEST16	TP16	N1 Highway	1.5	Loop Antenna	28.16374	25.38449	1.44	V	99.45	89.5	10.0				98.10	89.5	8.6	97.70	89.5	8.2	1.4
1603	0°	TEST17	TP17	Kameeldrift area	1.5	Loop Antenna	28.19025	25.39209	1.44	V	113.96	104.8	9.2				113.40	104.9	8.5	115.30	104.9	10.4	0.6
2263	45°	TEST18	TP18	Kameeldrift area	1.5	Loop Antenna	28.20046	25.39210	1.44	V	108.30	100.6	7.7				106.90	100.6	6.3	109.00	100.6	8.4	1.4
1903	90°	TEST19	TP19	Kameeldrift area	1.5	Loop Antenna	28.20168	25.40167	1.44	V	105.00	102.8	2.2				109.20	102.8	6.4	102.80	102.8	0.0	-4.2
1910	135°	TEST20	TP20	Kameeldrift area	1.5	Loop Antenna	28.19567	25.40597	1.44	V	108.90	102.7	6.2				107.50	102.7	4.8	106.40	102.7	3.7	1.4
2200	180°	TEST21	TP21	Kameeldrift area	1.5	Loop Antenna	28.19089	25.41243	1.44	V	109.66	100.9	8.8				109.40	100.9	8.5	108.50	100.9	7.6	0.3
1910	225°	TEST22	TP22	Kameeldrift area	1.5	Loop Antenna	28.18175	25.40573	1.44	V	108.66	102.7	6.0				110.50	102.7	7.8	112.90	102.7	10.2	-1.8
2202	270°	TEST23	TP23	Kameeldrift area	1.5	Loop Antenna	28.17507	25.40167	1.44	V	109.89	100.9	9.0				108.50	100.9	7.6	108.70	100.9	7.8	1.4
2263	315°	TEST24	TP24	Kameeldrift area	1.5	Loop Antenna	28.18091	25.39222	1.44	V	110.80	100.6	10.2				109.40	100.6	8.8	109.10	100.6	8.5	1.4
608	0°	TEST25	TP25	Kameeldrift area	1.5	Loop Antenna	28.19102	25.39534	1.44	V	122.44	115.6	6.8				121.80	115.6	6.2	122.50	115.6	6.9	0.6
500	45°	TEST26	TP26	Kameeldrift area	1.5	Loop Antenna	28.19177	25.39591	1.44	V	124.35	117.6	6.8				123.30	117.7	5.6	122.90	117.7	5.2	1.1
600	90°	TEST27	TP27	Kameeldrift area	1.5	Loop Antenna	28.19297	25.40138	1.44	V	121.80	115.8	6.0				120.90	115.8	5.1	122.20	115.8	6.4	0.9
500	135°	TEST28	TP28	Kameeldrift area	1.5	Loop Antenna	28.19202	25.40280	1.44	V	122.32	117.6	4.7				121.20	117.7	3.5	121.40	117.7	3.7	1.1
500	180°	TEST29	TP29	Kameeldrift area	1.5	Loop Antenna	28.19068	25.40313	1.44	V	122.74	117.6	5.1				121.30	117.7	3.6	119.70	117.7	2.0	1.4
640	225°	TEST30	TP30	Kameeldrift area	1.5	Loop Antenna	28.18515	25.40255	1.44	V	121.85	115.1	6.8				121.30	115.1	6.2	112.40	115.1	-2.7	0.5
700	270°	TEST31	TP31	Kameeldrift area	1.5	Loop Antenna	28.18432	25.40128	1.44	V	121.01	114.2	6.8				120.20	114.2	6.0	121.50	114.2	7.3	0.8
412	315°	TEST32	TP32	Kameeldrift area	1.5	Loop Antenna	28.18535	25.40103	1.44	V	125.13	119.6	5.5				123.90	119.6	4.3	122.40	119.6	2.8	1.2
											AVERAGE		7.7						6.6				1.1

Table 16: Static Antenna Measurement Test Point Details

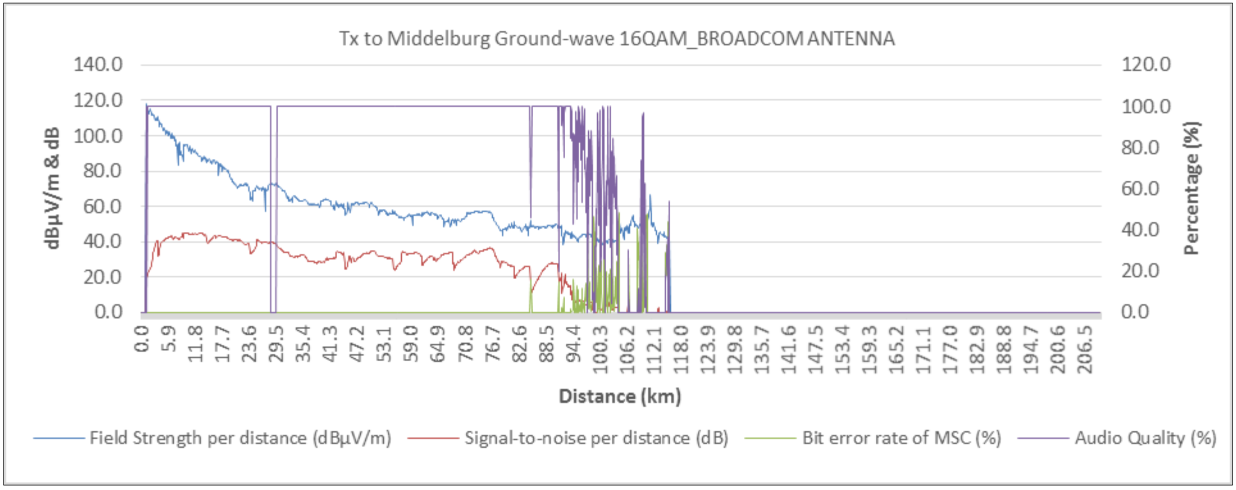
ANNEXURE B



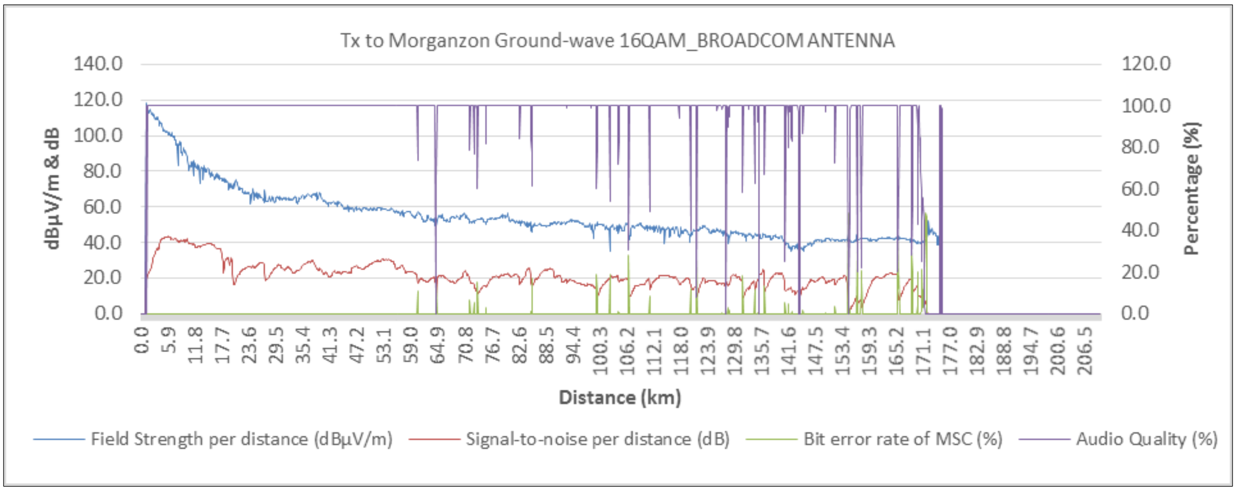
Graph 25: Broadcom Antenna north radial route – 16QAM



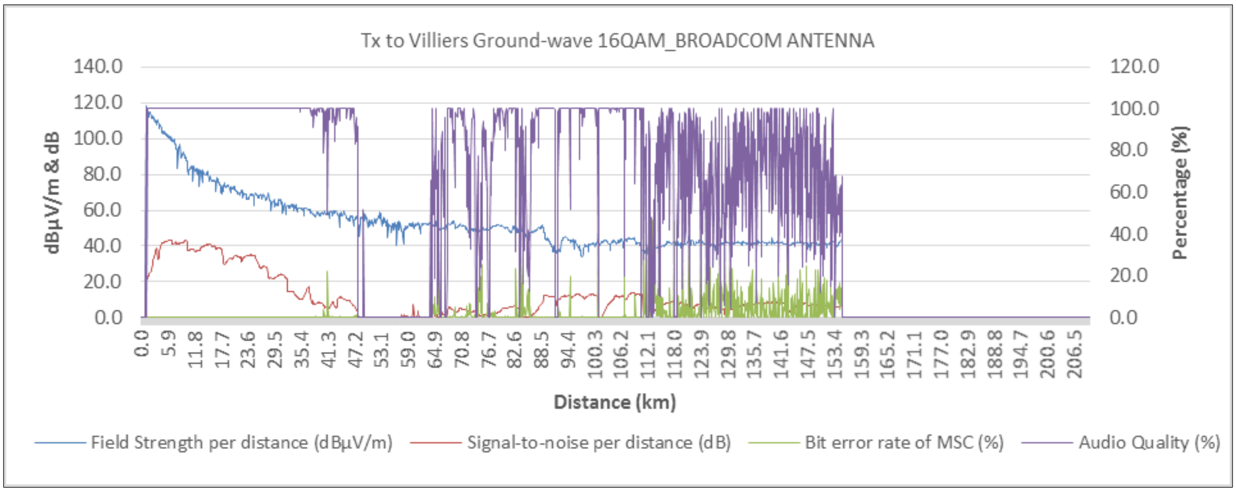
Graph 26: Broadcom Antenna north-east radial route – 16QAM



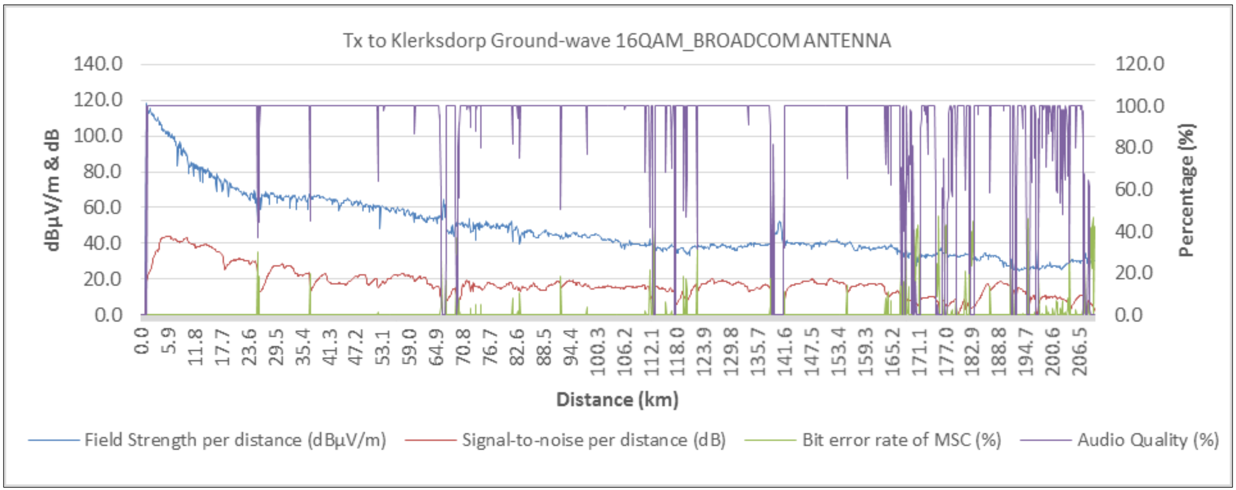
Graph 27: Broadcom Antenna east radial route – 16QAM



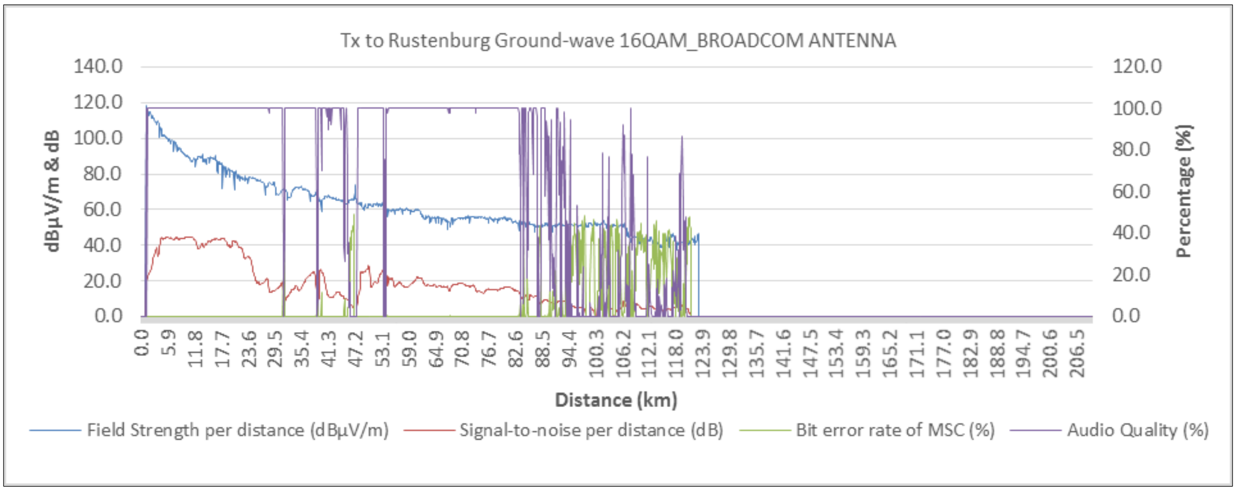
Graph 28: Broadcom Antenna south-east radial route – 16QAM



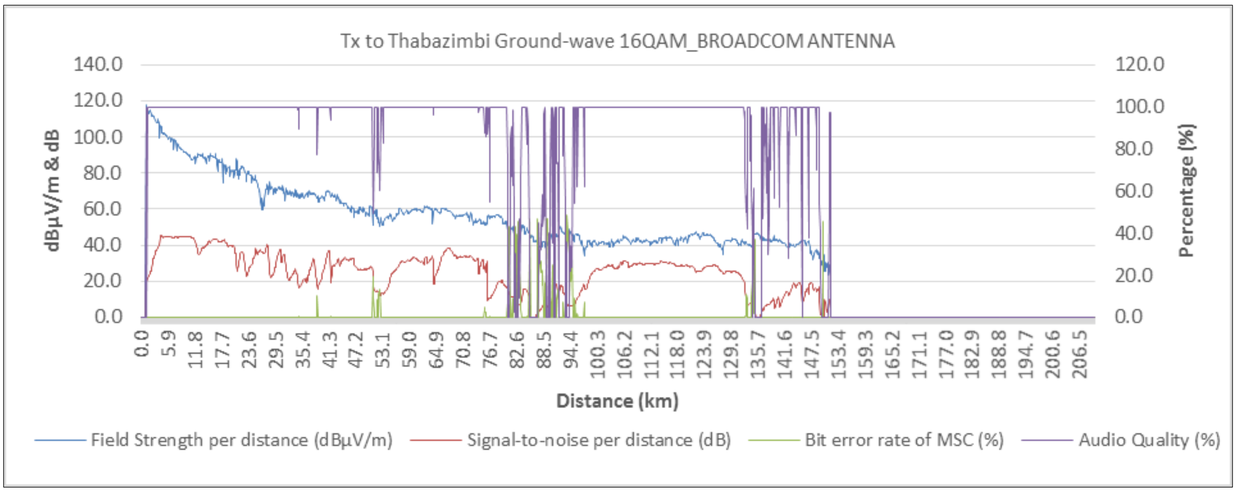
Graph 29: Broadcom Antenna south radial route – 16QAM



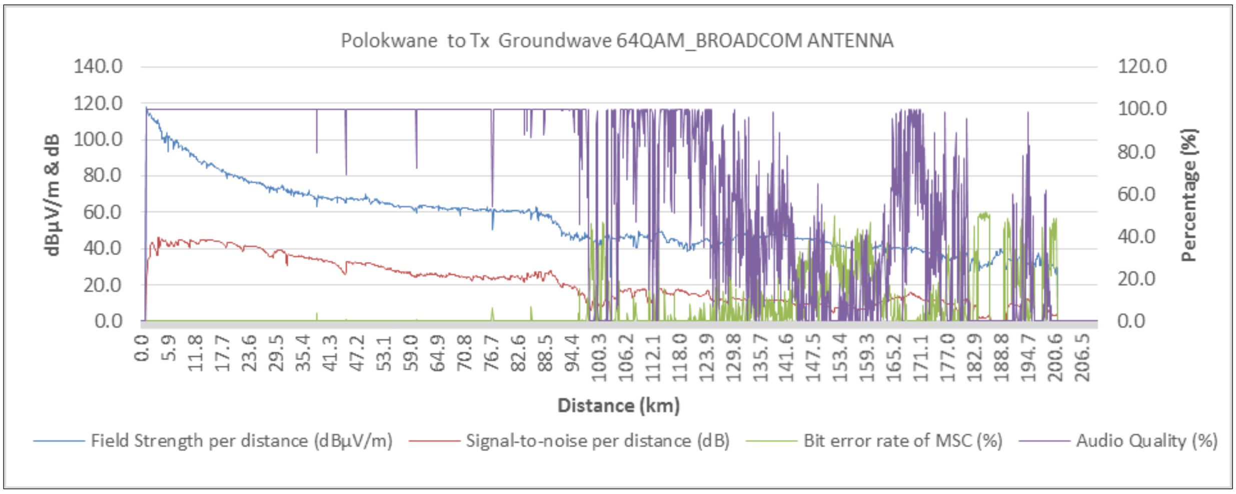
Graph 30: Broadcom Antenna south-west radial route – 16QAM



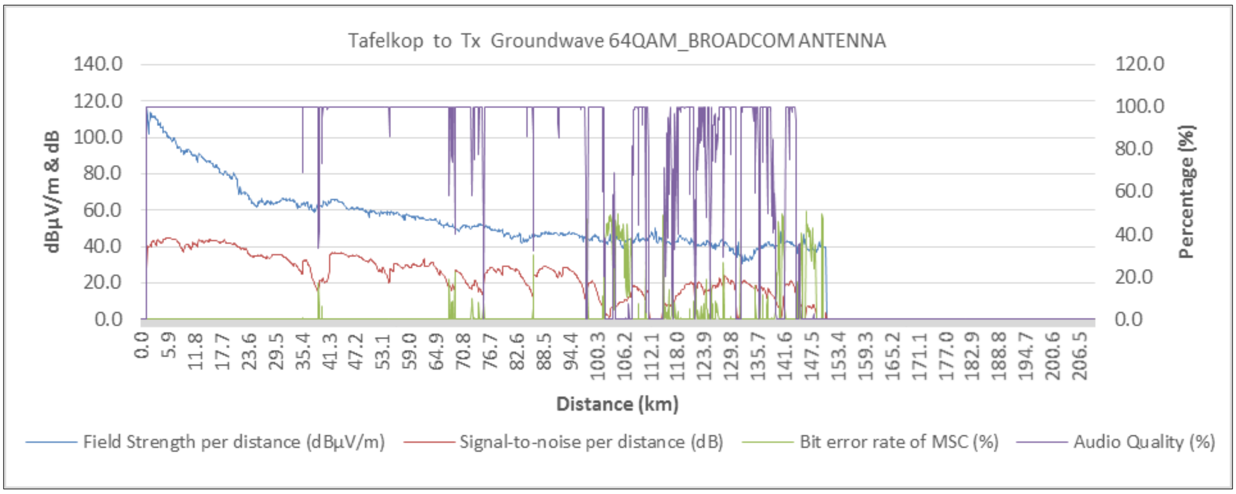
Graph 31: Broadcom Antenna west radial route – 16QAM



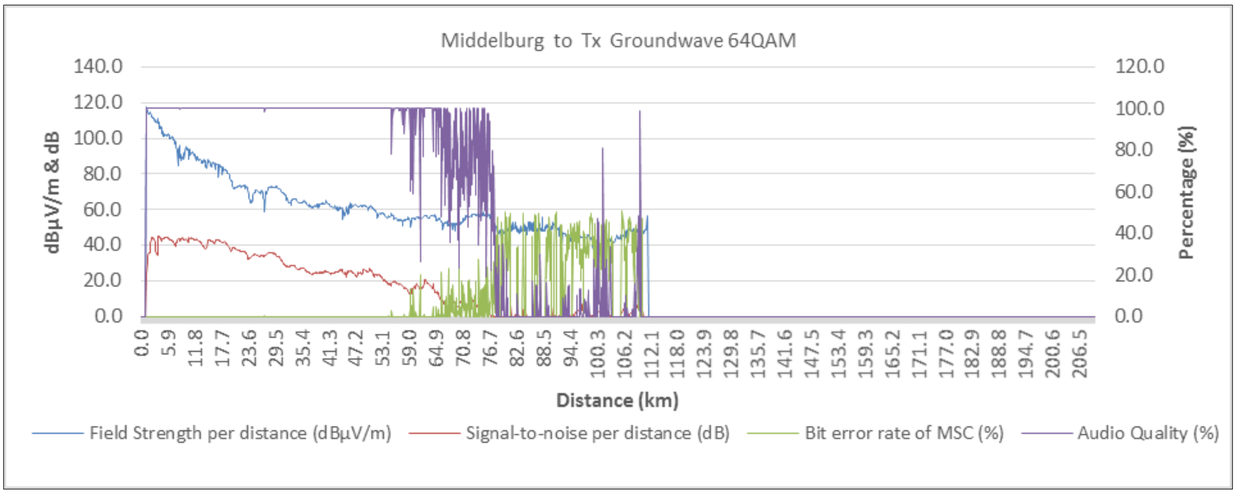
Graph 32: Broadcom Antenna north-west radial route – 16QAM



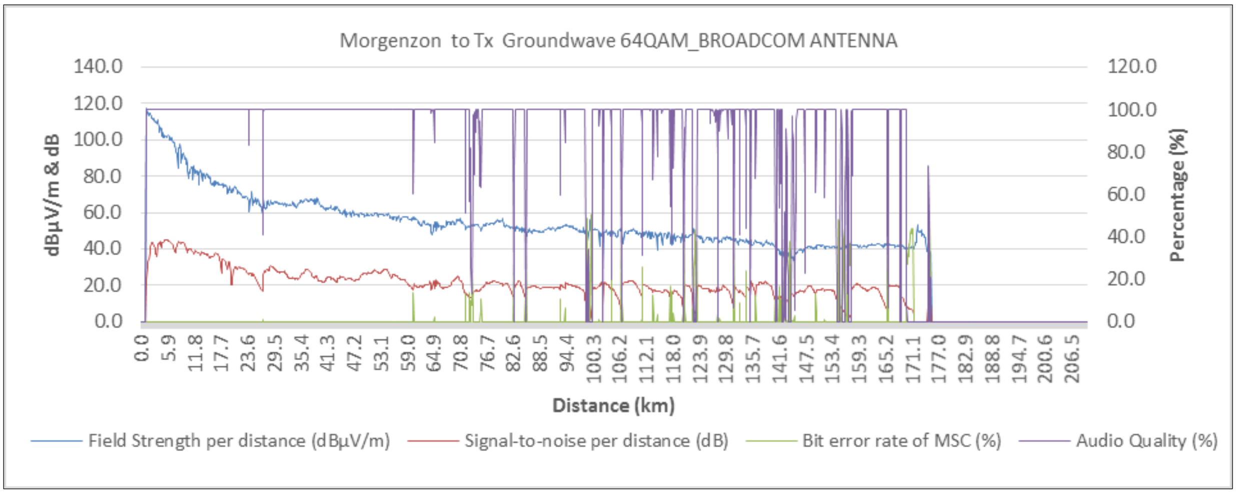
Graph 33: Broadcom Antenna north radial route – 64QAM



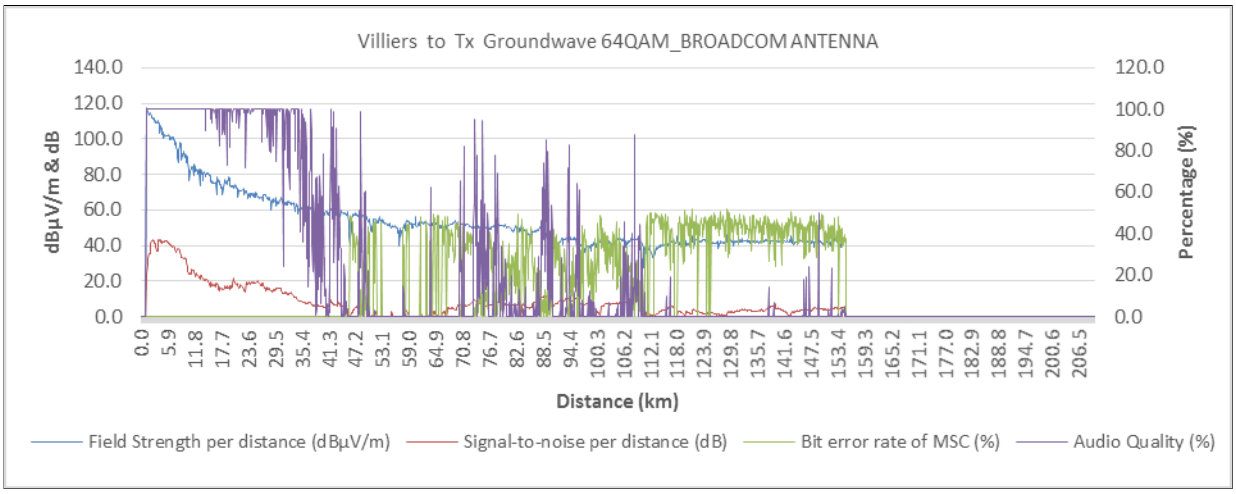
Graph 34: Broadcom Antenna north-east radial route – 64QAM



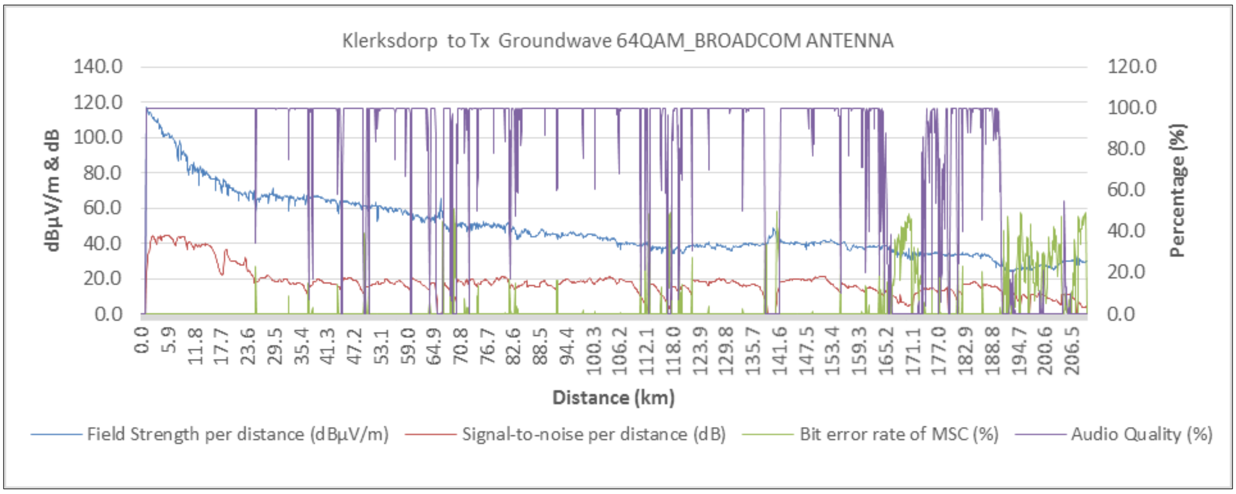
Graph 35: Broadcom Antenna east radial route – 64QAM



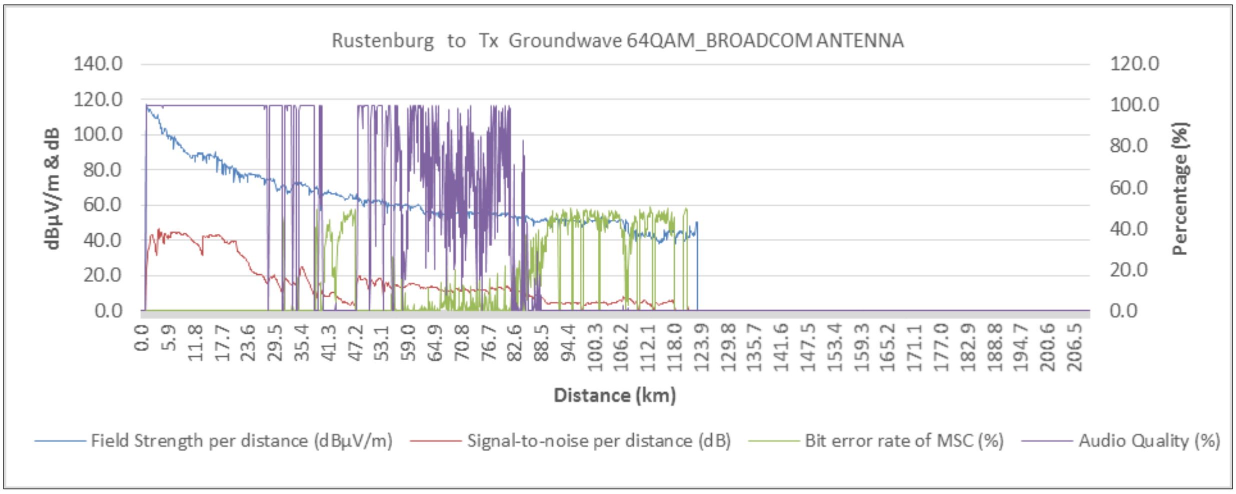
Graph 36: Broadcom Antenna south-east radial route – 64QAM



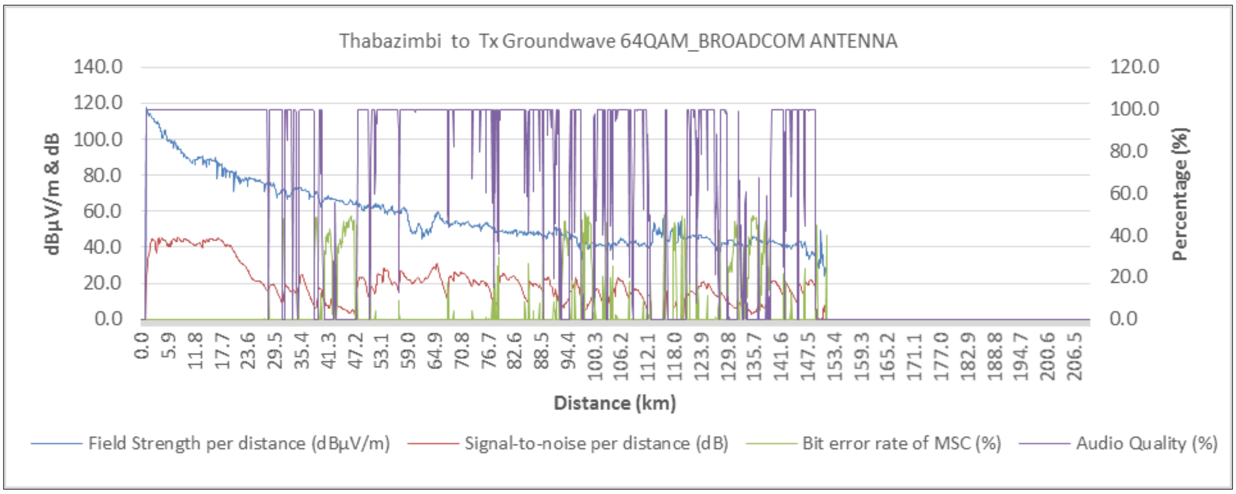
Graph 37: Broadcom Antenna south radial route – 64QAM



Graph 38: Broadcom Antenna south-west radial route – 64QAM

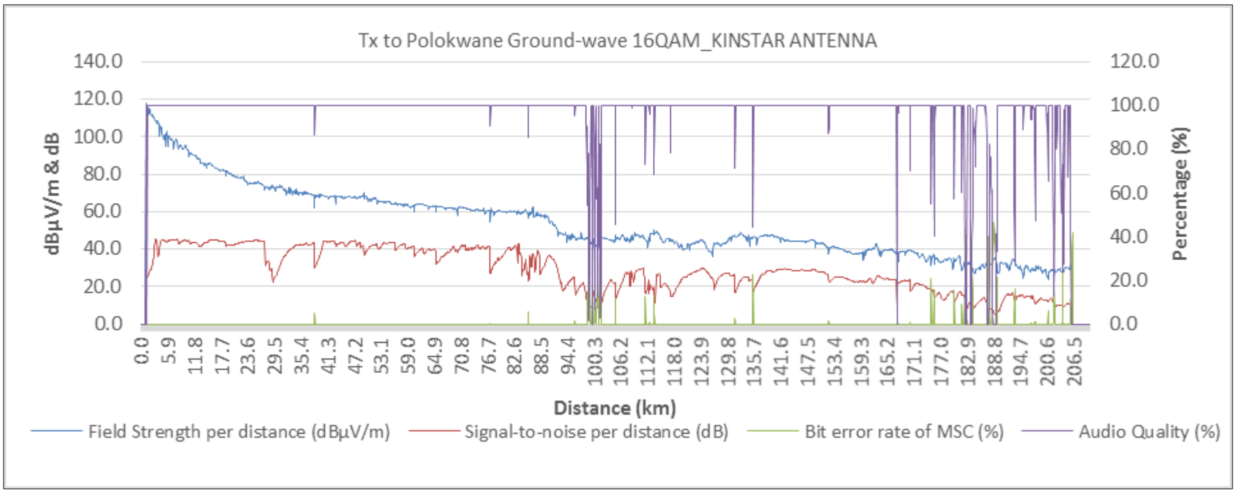


Graph 39: Broadcom Antenna west radial route – 64QAM

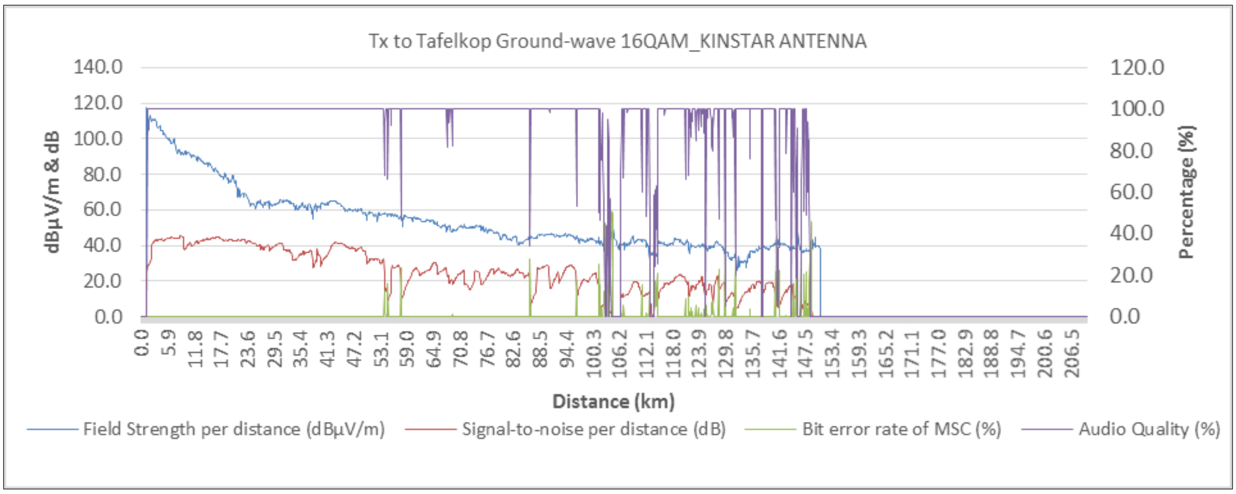


Graph 40: Broadcom Antenna north-west radial route – 64QAM

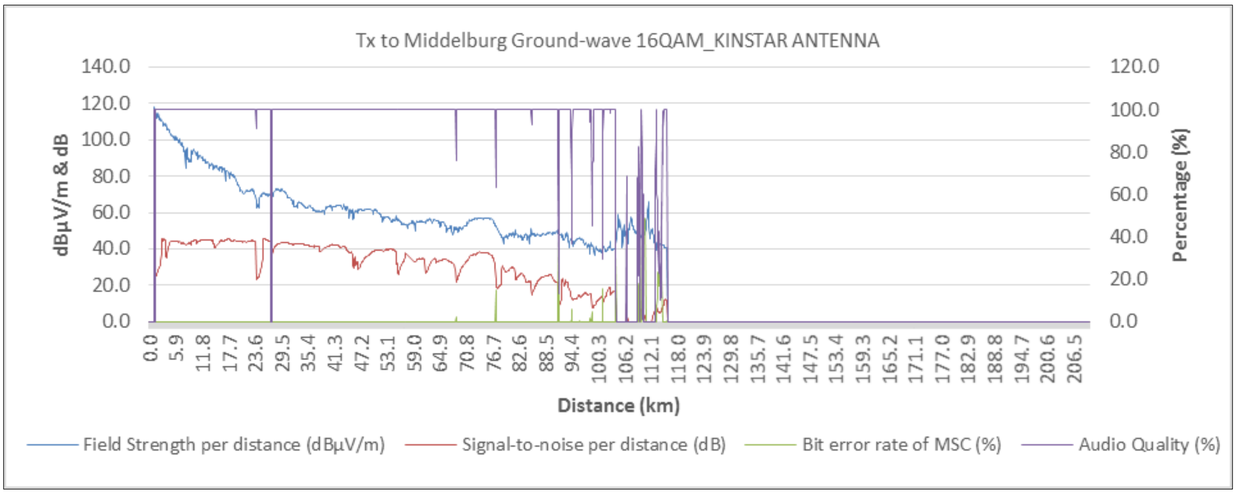
ANNEXURE C



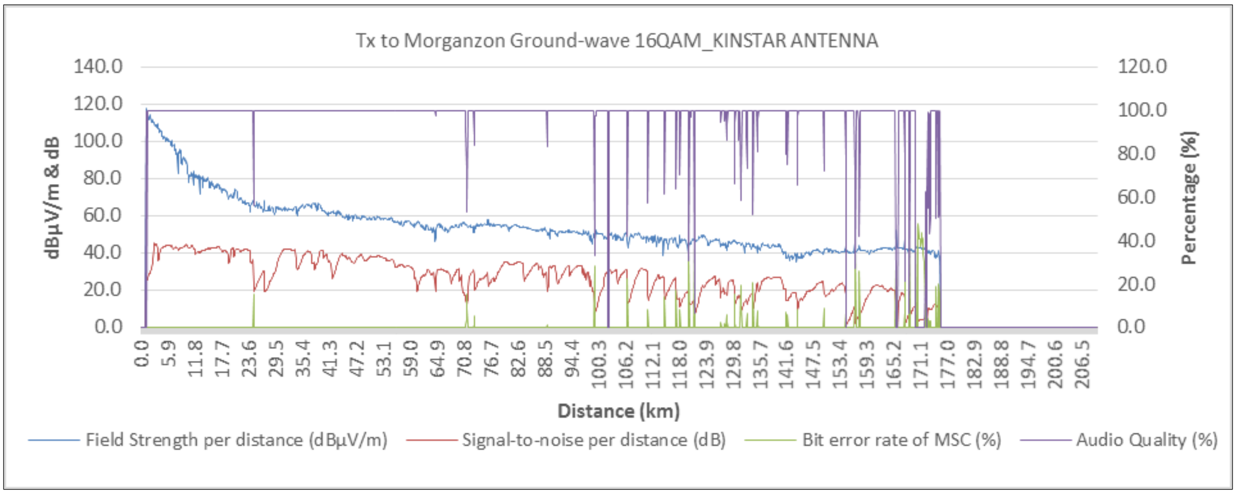
Graph 41: KinStar antenna north radial route – 16QAM



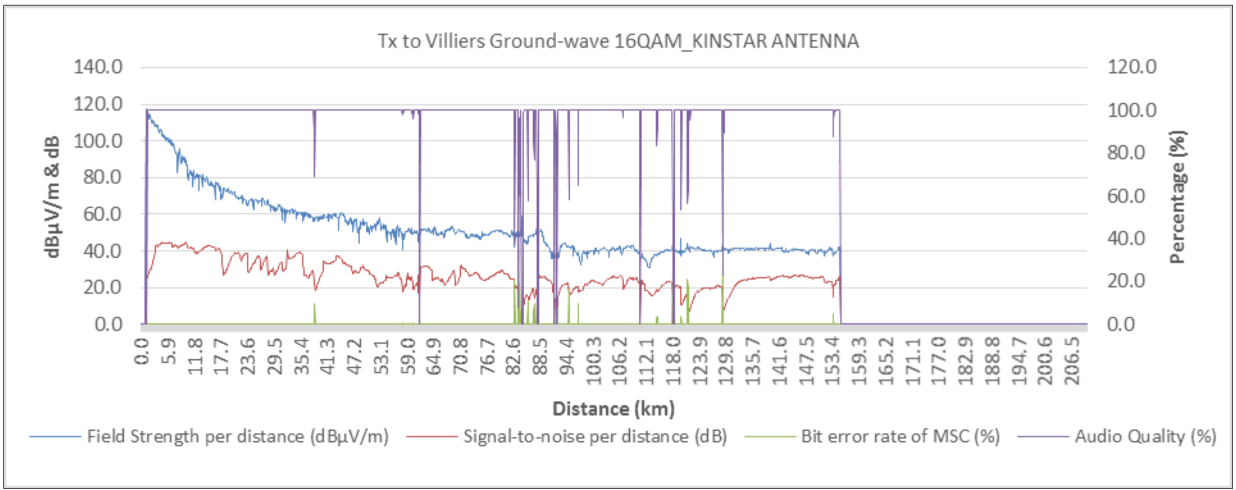
Graph 42: KinStar antenna north-east radial route – 16QAM



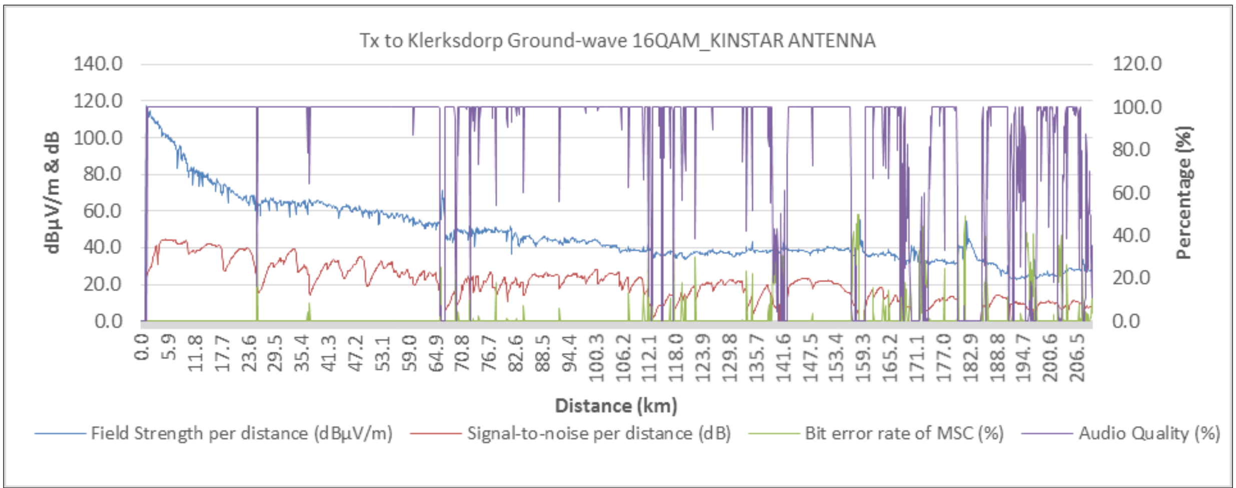
Graph 43: KinStar antenna east radial route – 16QAM



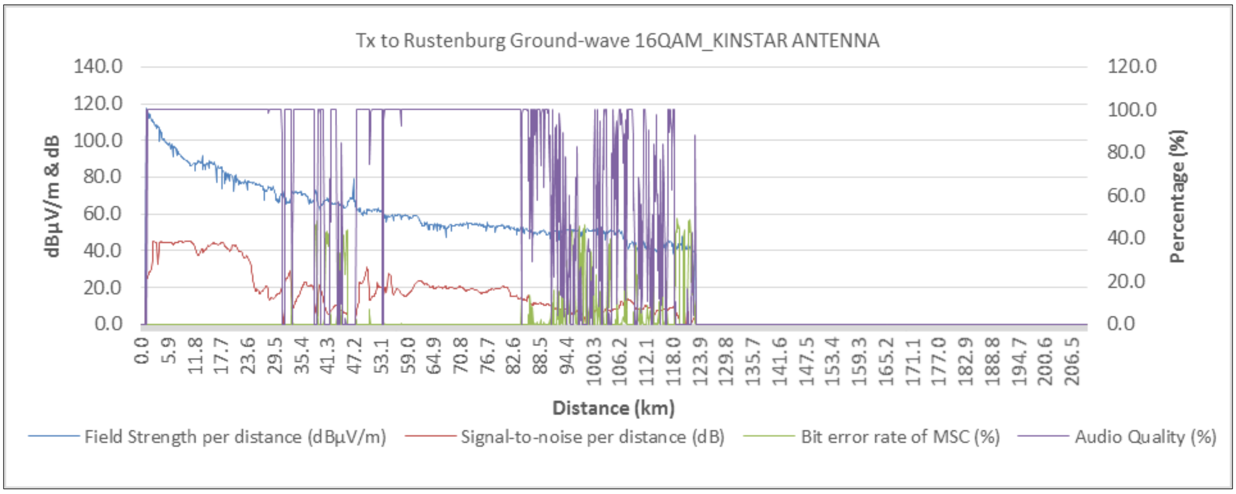
Graph 44: KinStar antenna south-east radial route – 16QAM



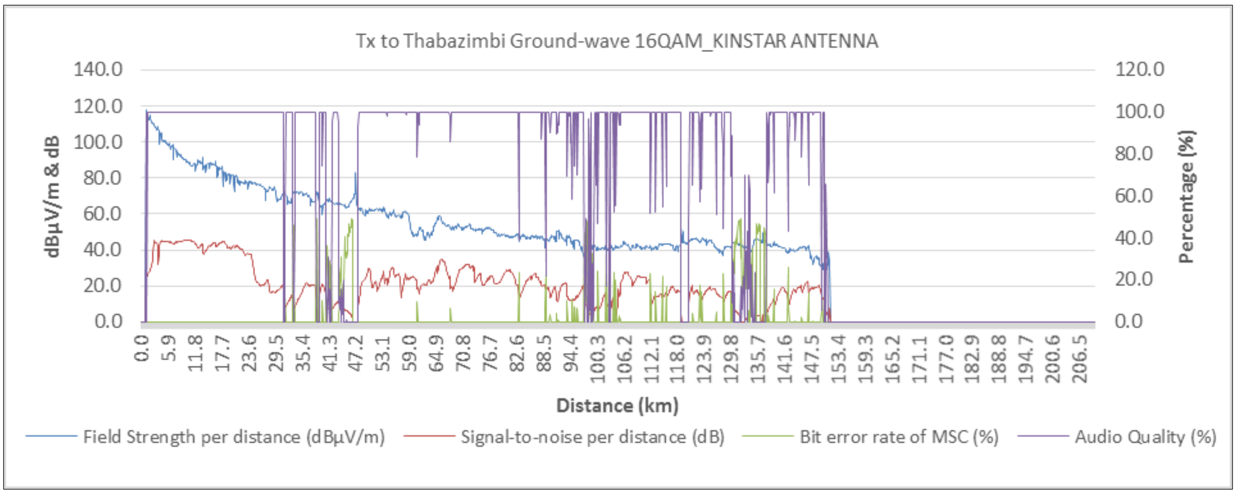
Graph 45: KinStar antenna south radial route – 16QAM



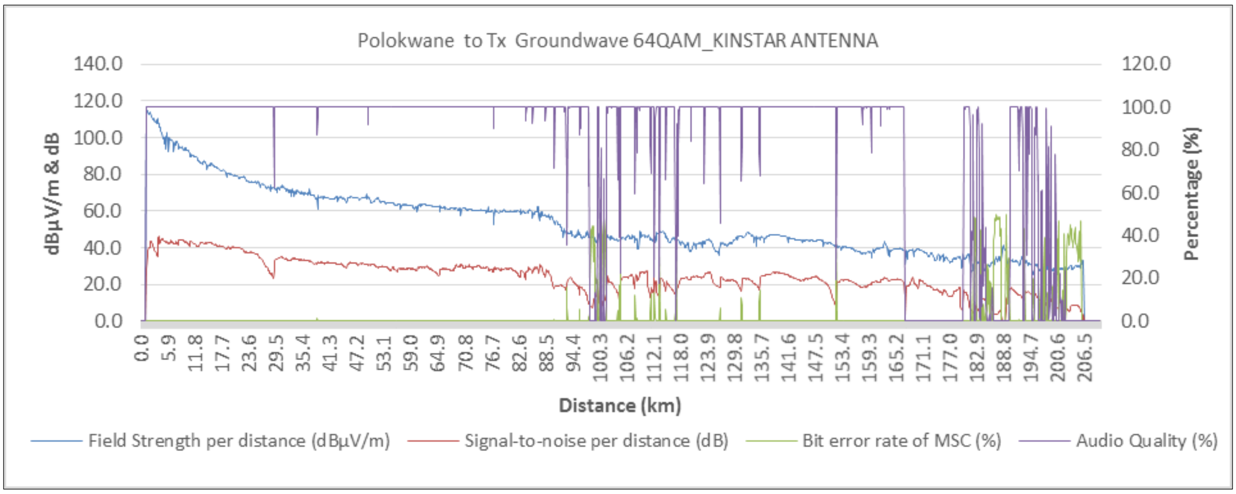
Graph 46: KinStar antenna south-west radial route – 16QAM



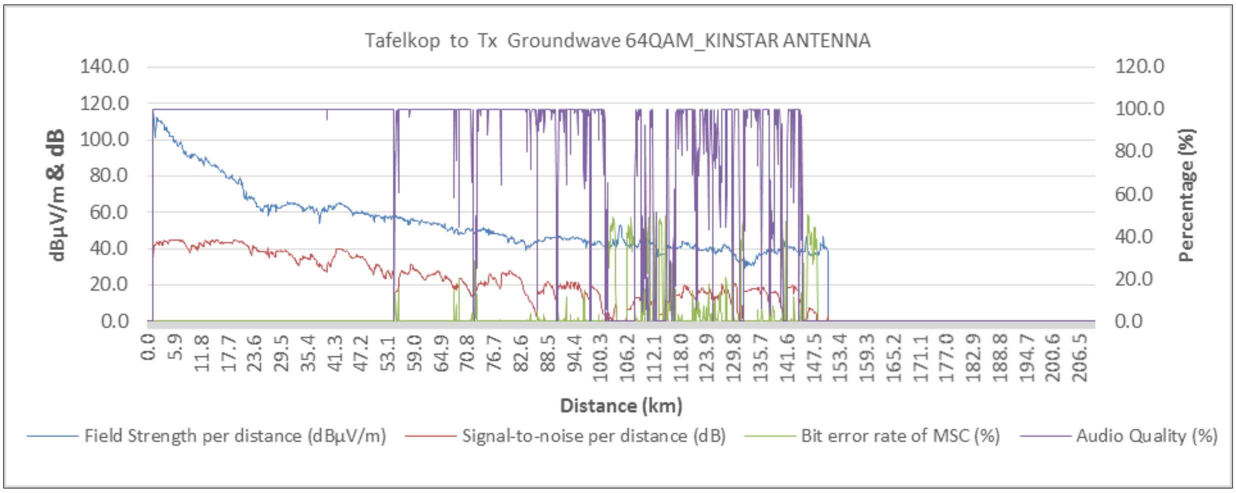
Graph 47: KinStar antenna west radial route – 16QAM



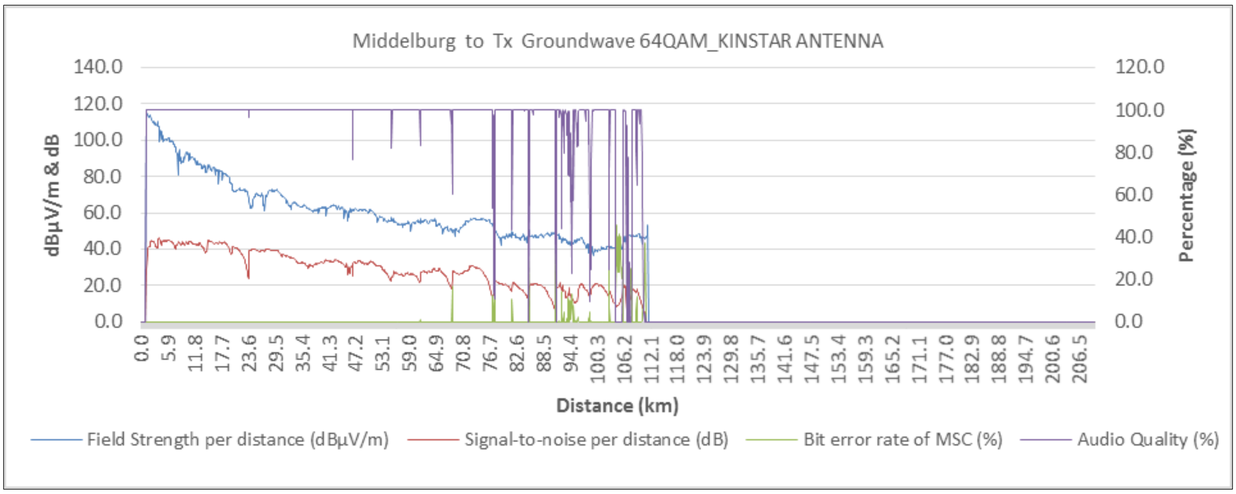
Graph 48: KinStar antenna north-west radial route – 16QAM



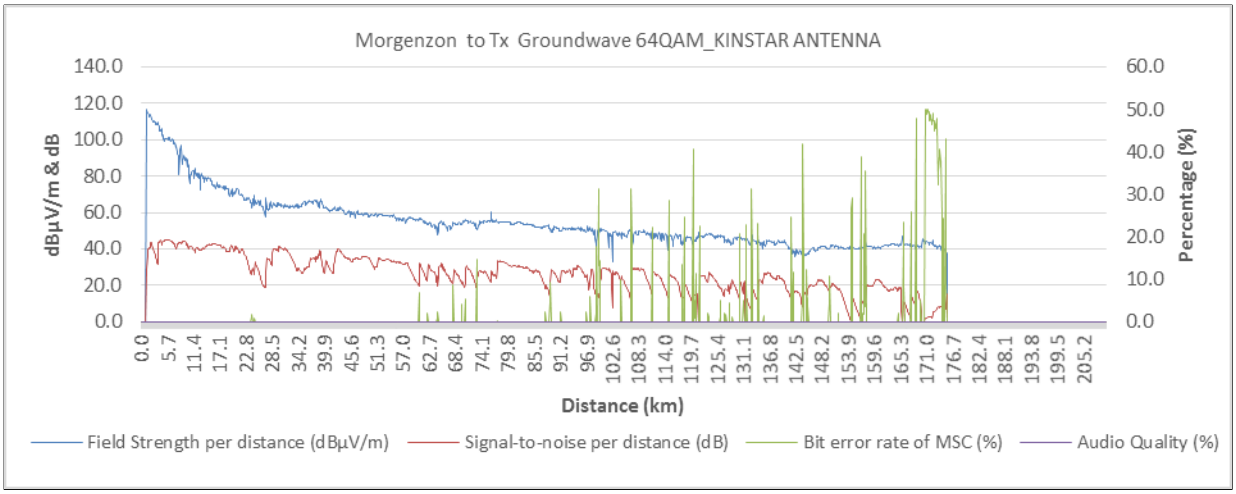
Graph 49: KinStar antenna north radial route – 64QAM



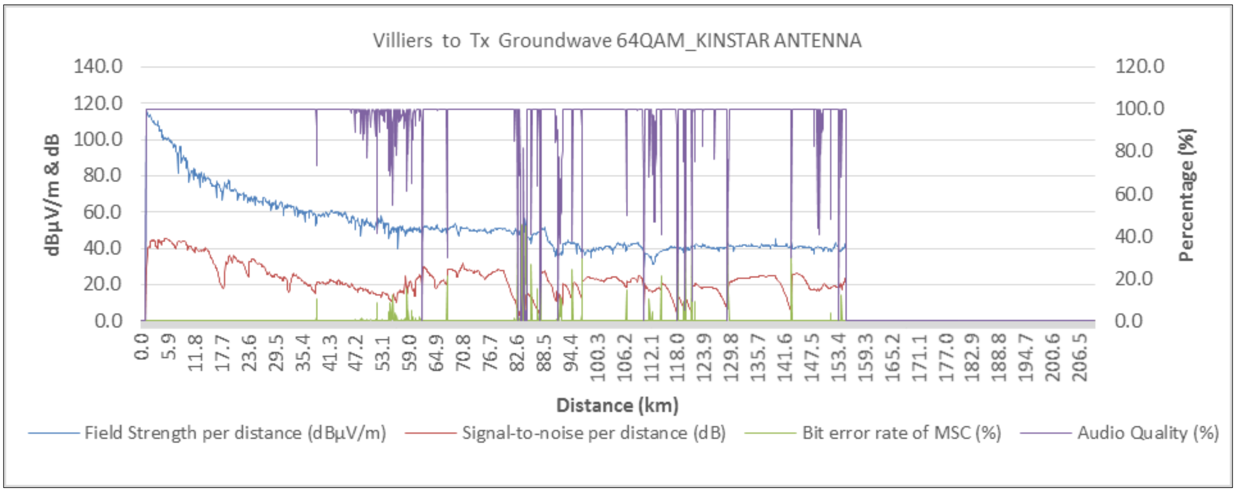
Graph 50: KinStar antenna north-east radial route – 64QAM



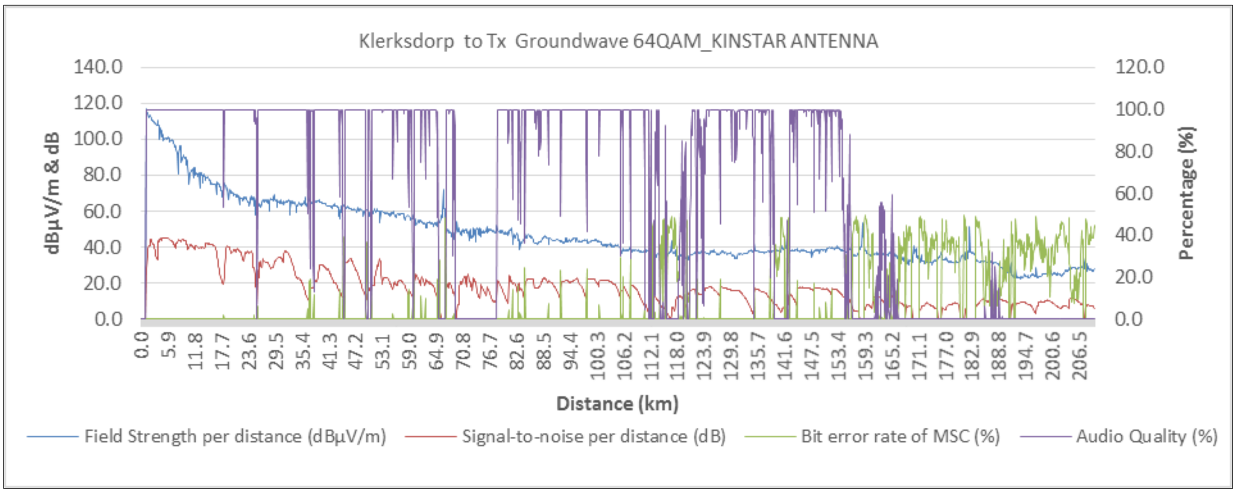
Graph 51: KinStar antenna east radial route – 64QAM



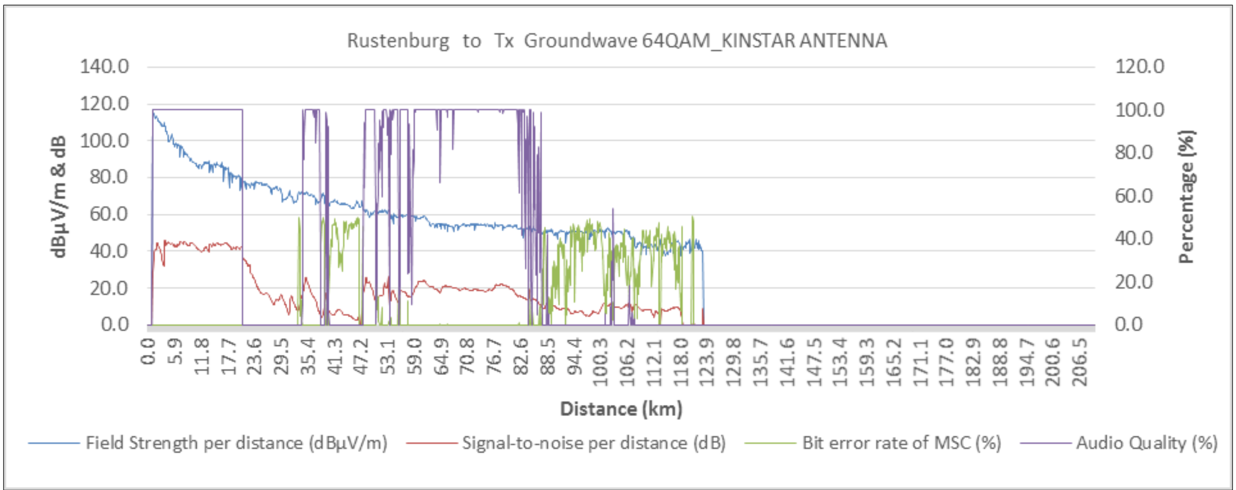
Graph 52: KinStar antenna south-east radial route – 64QAM



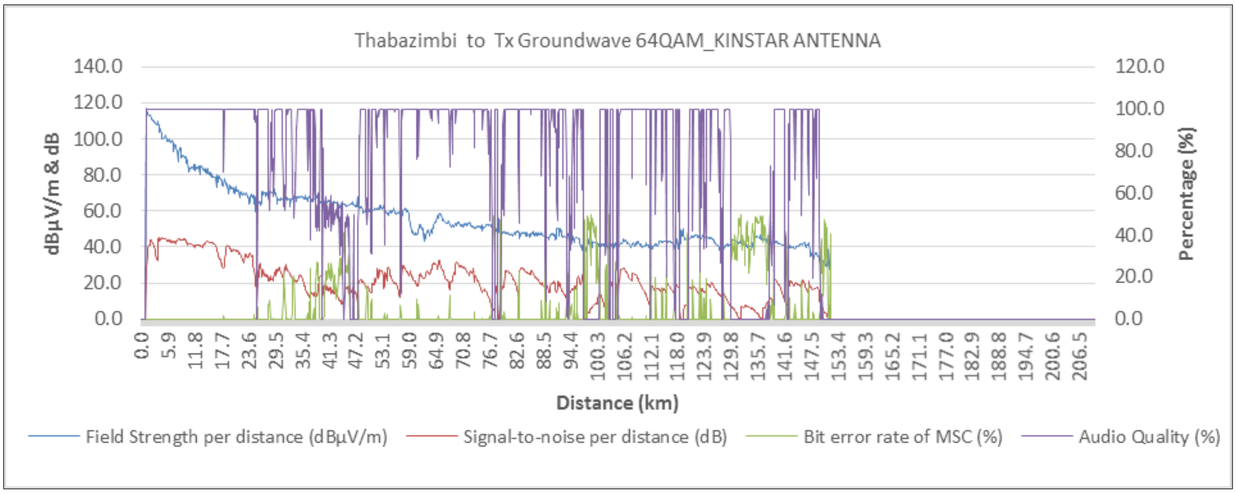
Graph 53: KinStar antenna south radial route – 64QAM



Graph 54: KinStar antenna south-west radial route – 64QAM

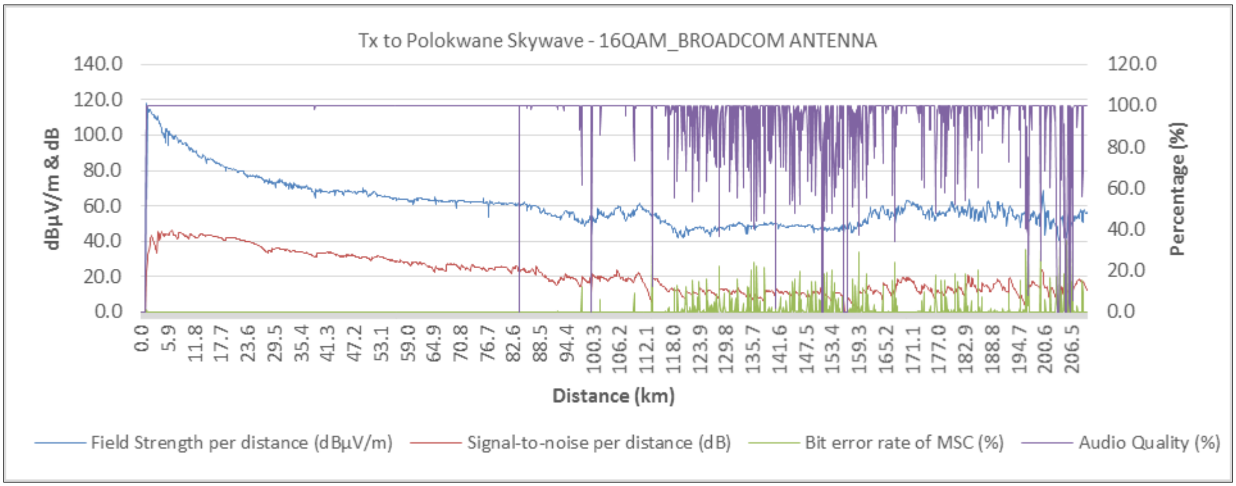


Graph 55: KinStar antenna west radial route – 64QAM

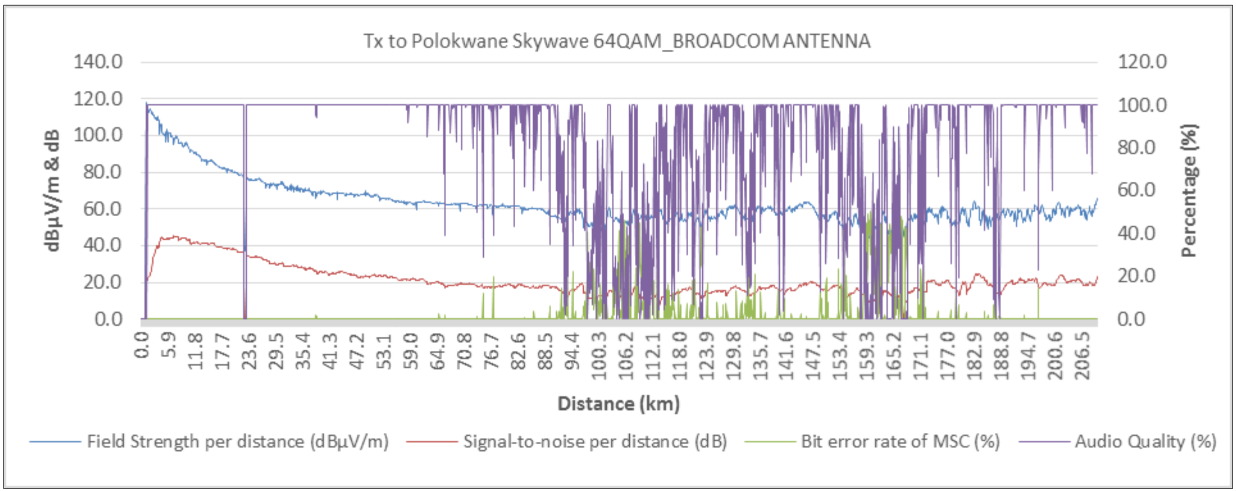


Graph 56: KinStar antenna north-west radial route – 64QAM

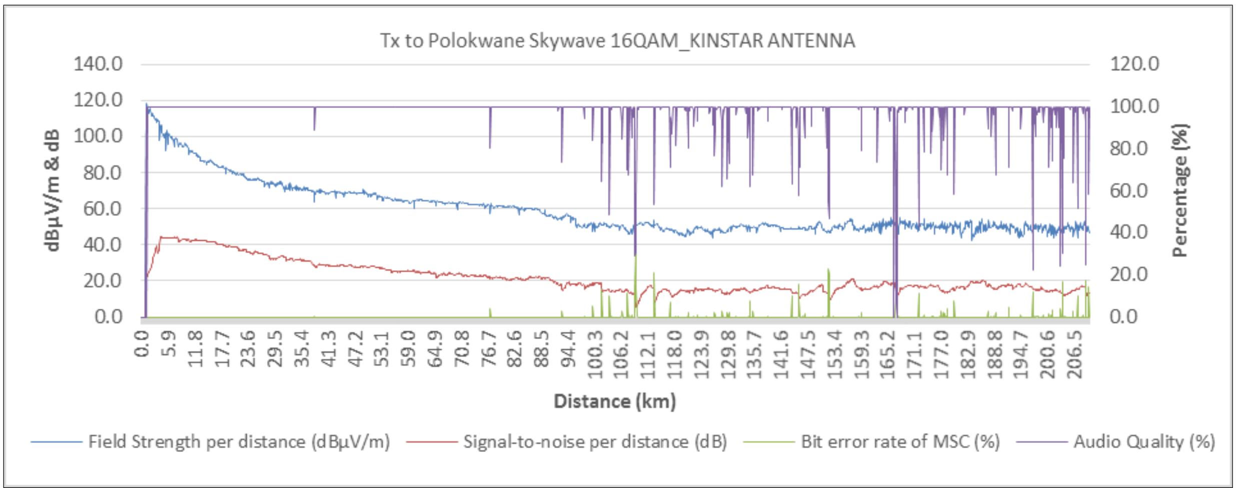
ANNEXURE D



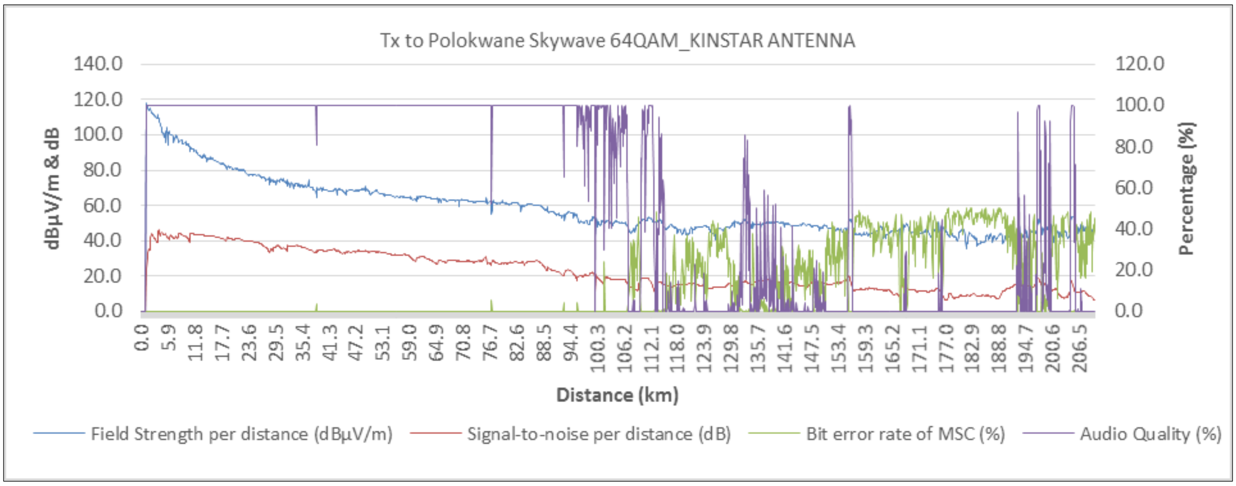
Graph 57: Broadcom Antenna north radial route – 16QAM



Graph 58: Broadcom Antenna north radial route – 64QAM

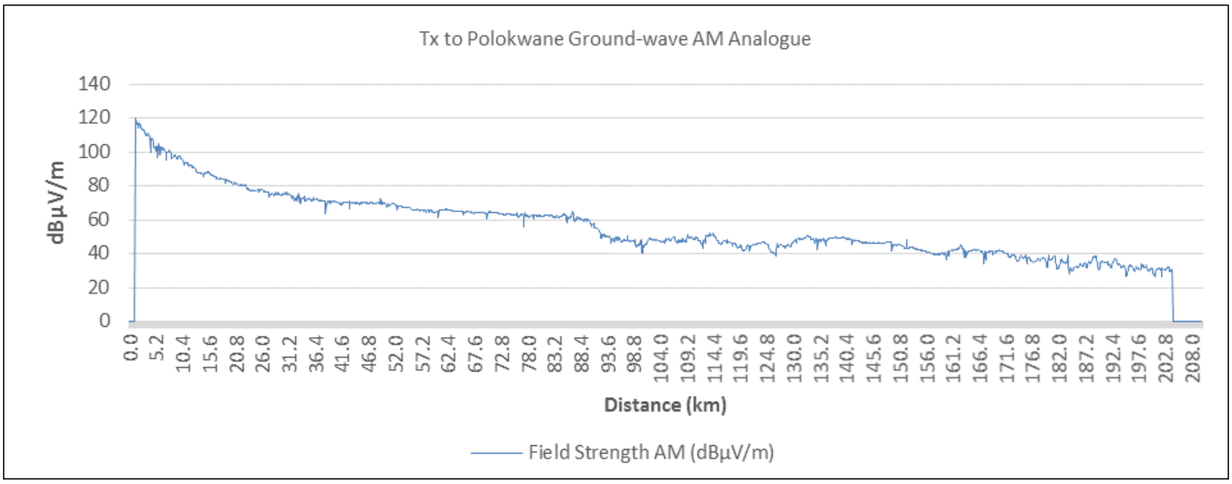


Graph 59: KinStar antenna north radial route – 16QAM

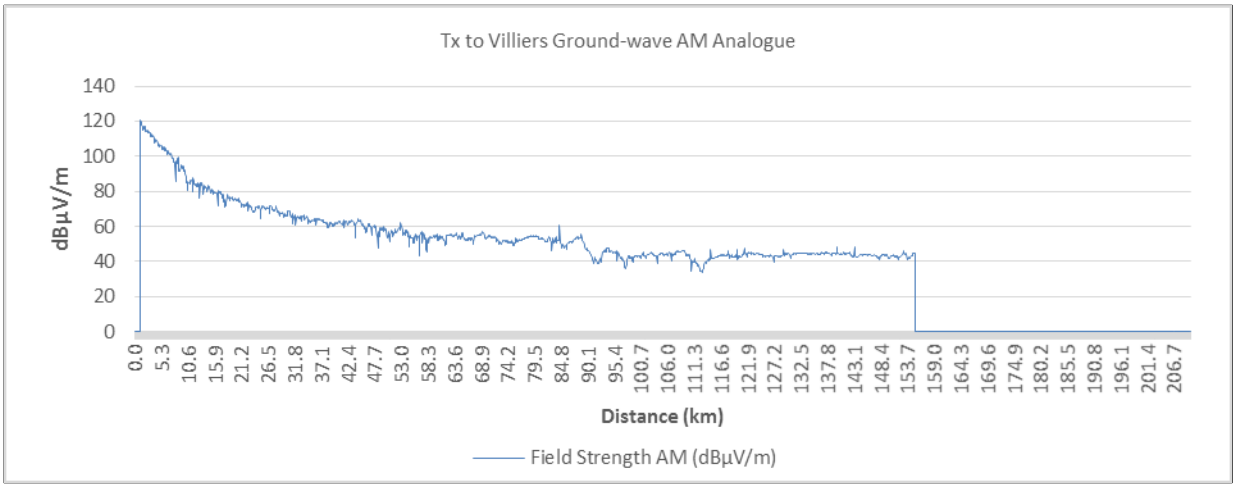


Graph 60: KinStar antenna north radial route – 64QAM

ANNEXURE E

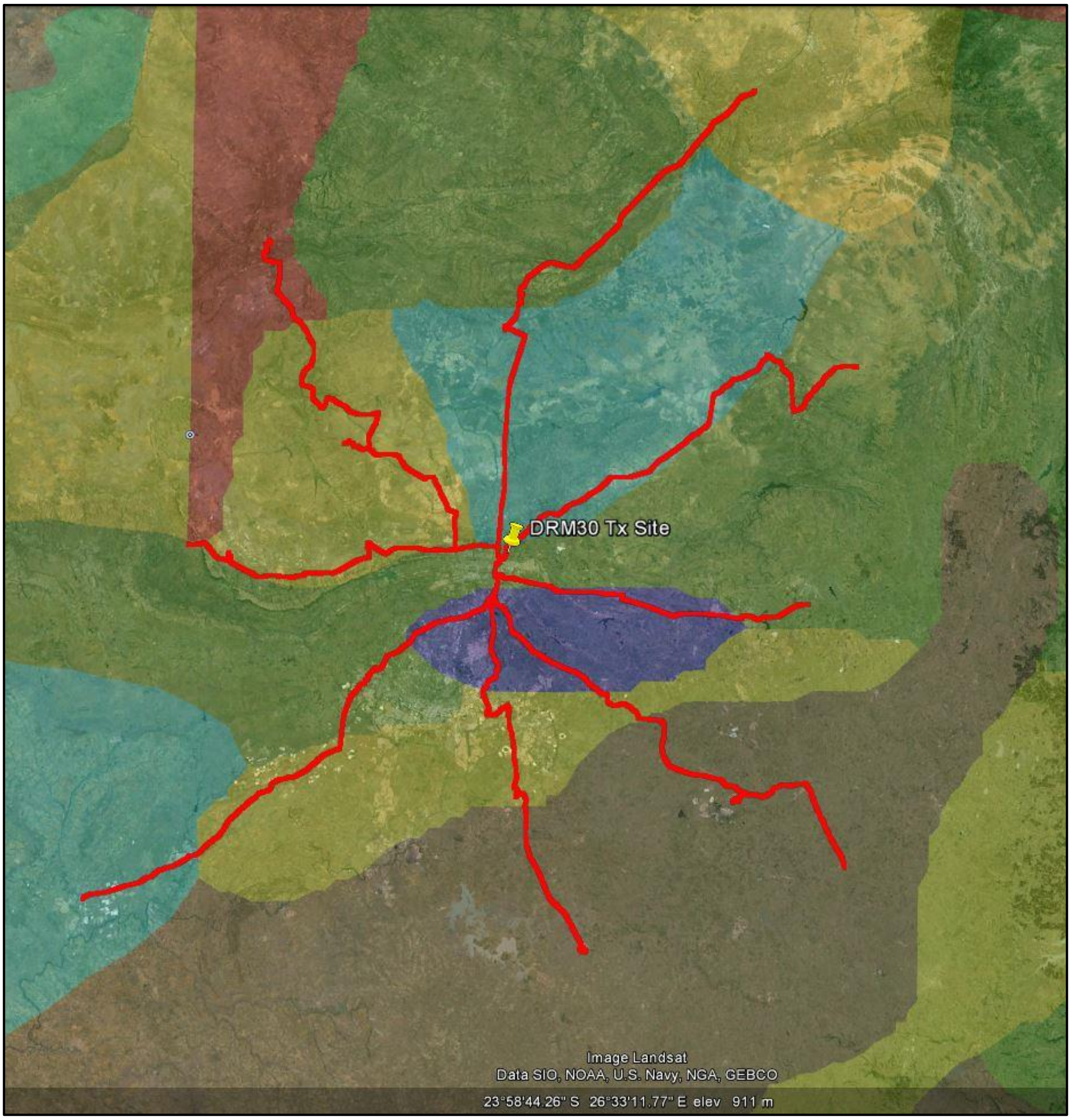


Graph 61: KinStar antenna north radial route – AM Analogue



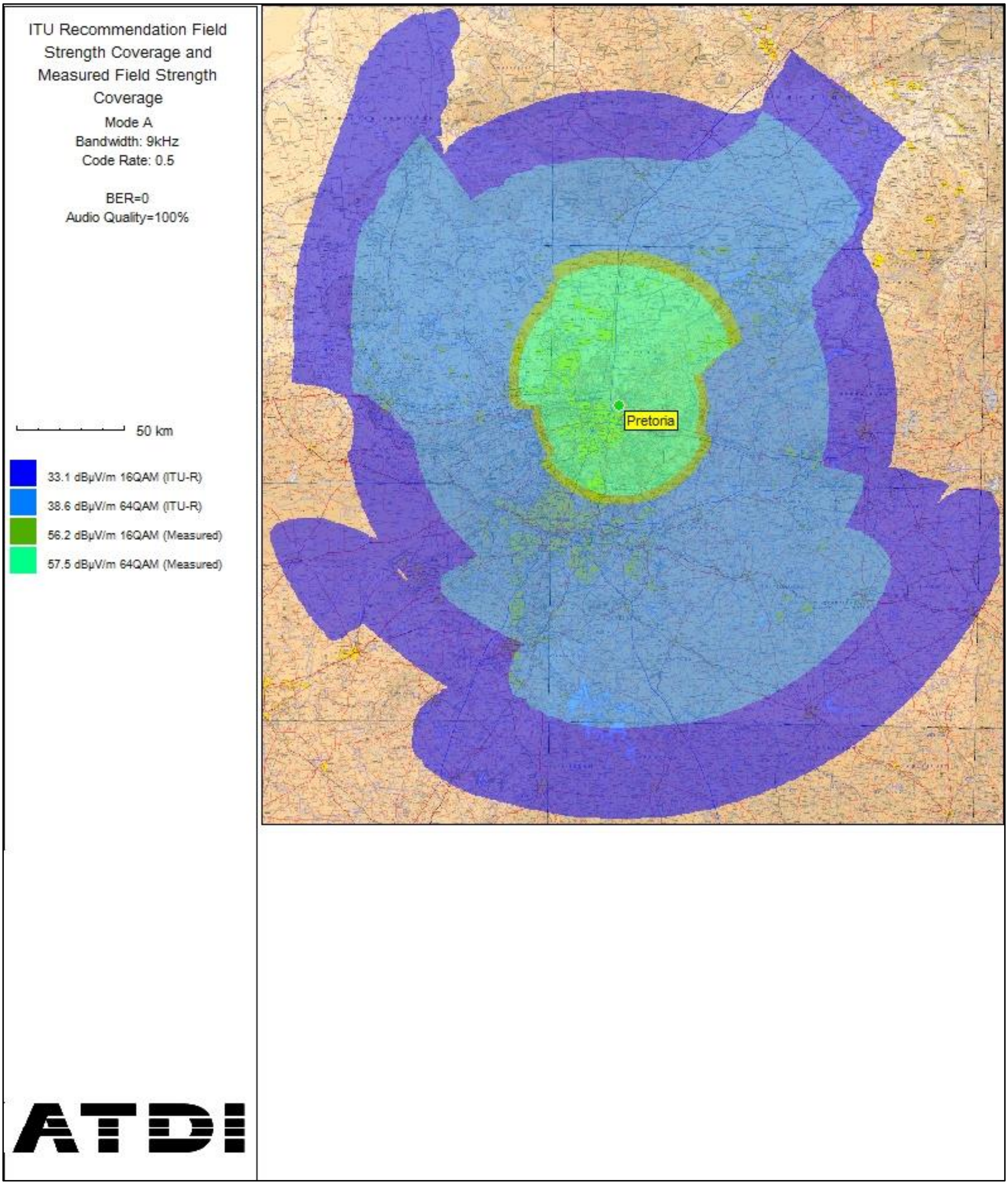
Graph 62: KinStar antenna south radial route – AM Analogue

ANNEXURE F



Map 21: Eight radial routes and conductivity layer

ANNEXURE G



Map 22: DRM30 ITU Recommendation Field Strength Coverage and Measured Field Strength Coverage.

END OF DOCUMENT