WIRED HAN CHARACTERIZATION CAMPAIGN - TEST REPORT

Test Report **TR_LAN12AF093 Ed.03**, dated **April 10, 2013**

Characterization of PLC channels

Customer	Equipment under test	Test package	LAN Ref. File
Energy UK	N/A	LAN121010.TD1 Ed011	LAN12AF093
Initiation	**Date**	**Description of modification**	**Ed.**
Guillaume SOUFACHE	March 29 2013	Creation of Test report	00
Guillaume SOUFACHE	April 10 2013	Updates addressing Energy UK comments	03

	Realized by	Checked by	Approved by
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Date	April 10, 2013	April 10, 2013	April 10, 2013

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1. INTRODUCTION

1.1 General Context

The Department of Energy and Climate Change (DECC) Smart Metering Implementation Programme (SMIP) has recently issued an Information Request to assess the availability of technologies for provisioning Home Area Network (HAN) connectivity to electricity and gas metering equipment, communications hub and in-home devices in cases where a 2.4GHz ZigBee wireless HAN will not work effectively.

Appendix: Wireless HAN Architecture describes the HAN topology based on 2.4GHz ZigBee wireless technology without repeaters. This request may be found at:

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/136105/Wired_HAN_Information_Request.pdf

In order to inform this information request, tests of performance of signals over the wiring of large buildings in GB have been commissioned by Energy UK. Access to properties has been arranged by Energy UK and its members, and Energy UK has commissioned LAN to carry out the measurement campaign.

1.2 Measurement Campaign

The Measurements have been conducted in a way that the evaluation of both Narrowband (*Cenelec Bands B, C, D*) and Broadband (*over 1 MHz*) point-to-point PLC technologies are possible. Typical targeted PLC technologies are G3-PLC, PRIME, HomePlug AV or GreenPHY.

Communication will be done between each smart meter and its related flat. This is assumed to be a Point-to-Point connection. Nevertheless, the number of flats per buildings may be high (100 or 200).

The Measurement Campaign done on the short listed buildings and flats that will be used to evaluate the maximum channel capacities of each technology.
Four parameters have been identified as of great interest for the study:

- The Insertion Loss of the channel, called "***Channel Gain***" in the sequel (*the module of the Transfer Function is enough for this study; i.e. the Phase is not required*),
- The **background noise**,
- The **crosstalk** (*interference with other apartments*),
- The **impedances**.

Note that it was not required to perform long term period measurements, which would help in detecting the fluctuating noise (*new source of noise appearing or disappearing during the day*) or the channel modification (*when a new device is powered on in the network*). It is assumed that the measurements were been done during open hours on working days.

1.3 Test Laboratory

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1.5 Document content

In this document the different types of measurement are introduced, the used equipments are described and its configuration detailed. The final part presents the results with global analyze and comments.

2. Measurements Methodologies

2.1 Introduction

The difficulty of the required measurements is related to the distance between the transmitter (*TX* at the smart meter location) and the receiver (*RX* in the flat), which requires to define and operate using a remote measurement methodology to estimate the channel attenuation.

2.2 General Setup

The general setup is described in figure 2 below.

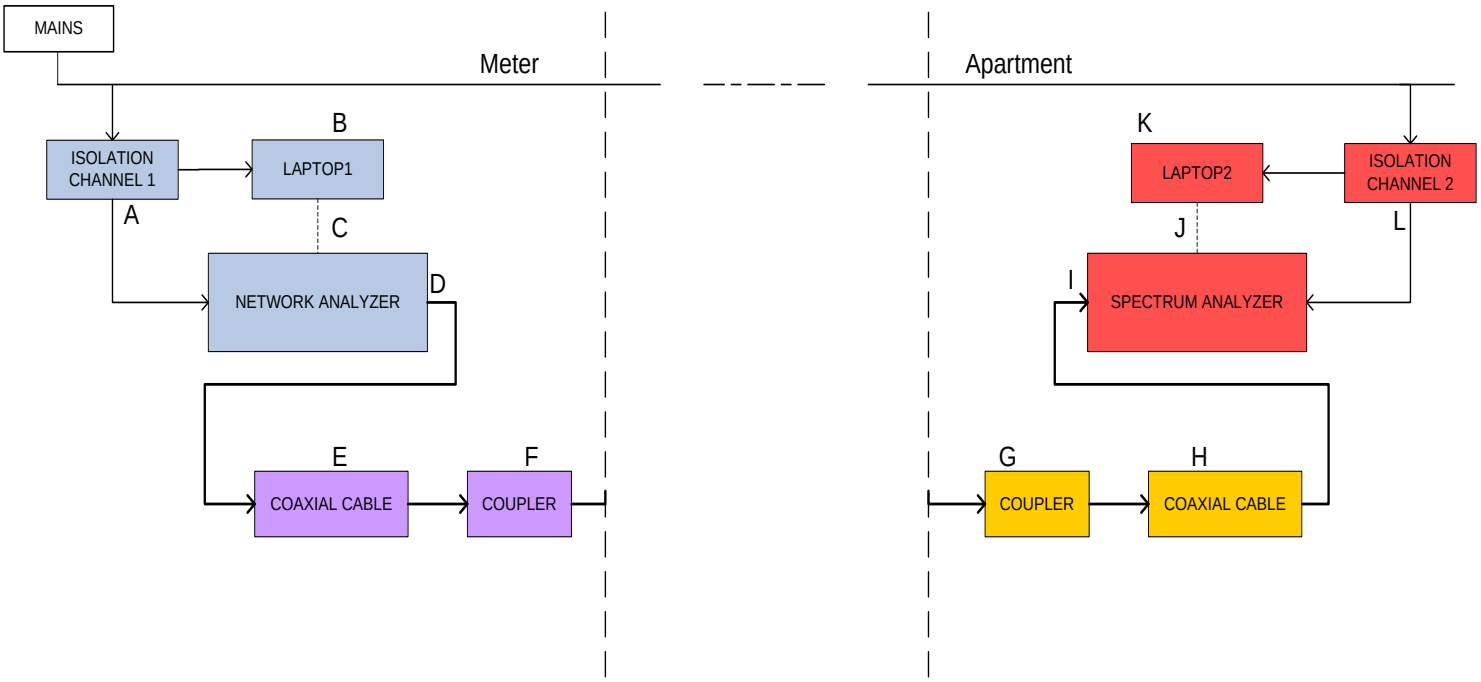


FIGURE 1 - GENERAL SETUP

2.3 Type of Measurements

The following measurements were been performed to identify PLC channels:

- Channel Gain measurements (see section 2.4) and Noise measurements (see section 2.5)
- Near End Cross Talk (NEXT) and Far End Cross Talk (FEXT) measurements (see section 2.7 and 2.8)
- Impedances measurements (see section 2.6)

2.4 Channel Gain - CG

2.4.1 Setup

The setup for Channel Gain measurement is the following:

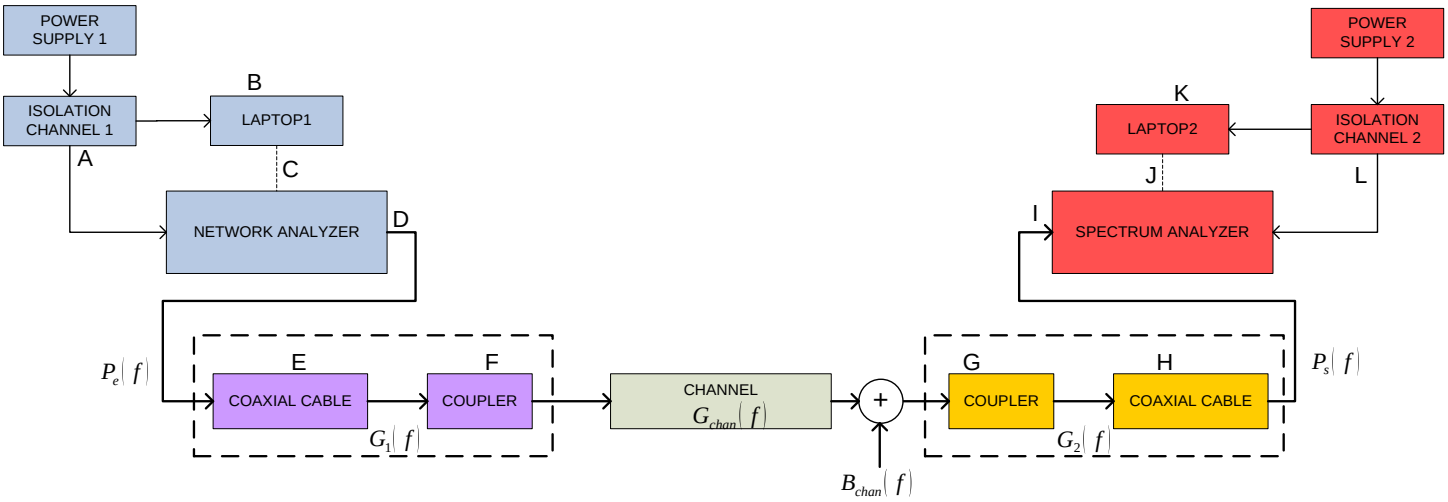


FIGURE 2 - SETUP FOR CHANNEL GAIN MEASUREMENT

The list of equipment used in this setup is given in the Table 1 - List of equipment for channel gain measurement (see section 2.4.3)

$$P_s(f) = P_e(f).|G_{chan}(f)|^2.|G_{cplr}(f)|^2 + B_{chan}(f).|G_2(f)|^2$$

$$|G_{chan}(f)|^2 = \frac{P_s(f) - B_{chan}(f).|G_2(f)|^2}{P_e(f).|G_{cplr}(f)|^2}$$

$$G_{chan,dB}(f) = 10.\log[P_s(f) - B_{chan}(f).|G_2(f)|^2] - P_{e,dBm}(f) - G_{cplr,dB}(f)$$

2.4.2 Principle

2.4.2.1 CHANNEL GAIN ESTIMATION

To retrieve the channel gain ($G_{chan}(f)$), the power received at the receiver end of the setup ($P_s(f)$) is measured and deduced by the following formulas:

Where :

$G_1(f)$ and $G_2(f)$ are the gains of the transmitting and receiving coupler respectively,

$G_{cplr}(f)$ is the resulting gain from the 2 measurement couplers ($G_{cplr}(f) = G_1(f) * G_2(f)$),

$P_e(f)$ is the transmitted power at the transmitter end of the setup,

And $B_{chan}(f)$ is the Noise resulting of the channel.

In the $G_{chan,dB}(f)$ formula, this resulting noise component is assumed to be negligible. This is especially the case when the signal noise ratio is high (see sections 2.5 and 2.4).

Thus the channel gain $G_{chan,dB}(f)$ can be deduced from the measured $P_s(f)$ and $G_{cplr}(f)$ and from the known transmitted power $P_e(f)$.

$$G_{chan,dB}(f) = P_{s,dB}(f) - P_{e,dB}(f) - G_{cplr,dB}(f)$$

2.4.2.2 COUPLERS CHARACTERIZATION

A characterization of the measurement coupler is needed to estimate the resulting gain when placed in serial. This is done through a S-parameter measurement using a network analyzer, as shown below.

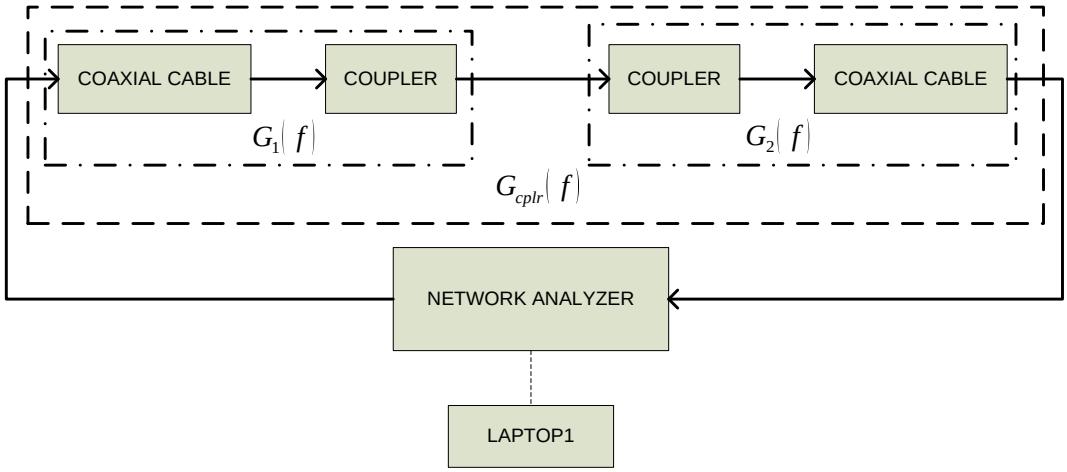


FIGURE 3 - SETUP FOR COUPLERS CHARACTERIZATION

$$G_{cplr,dB}(f) = S_{21,dB}(f) = G_{1,dB}(f) + G_{2,dB}(f)$$

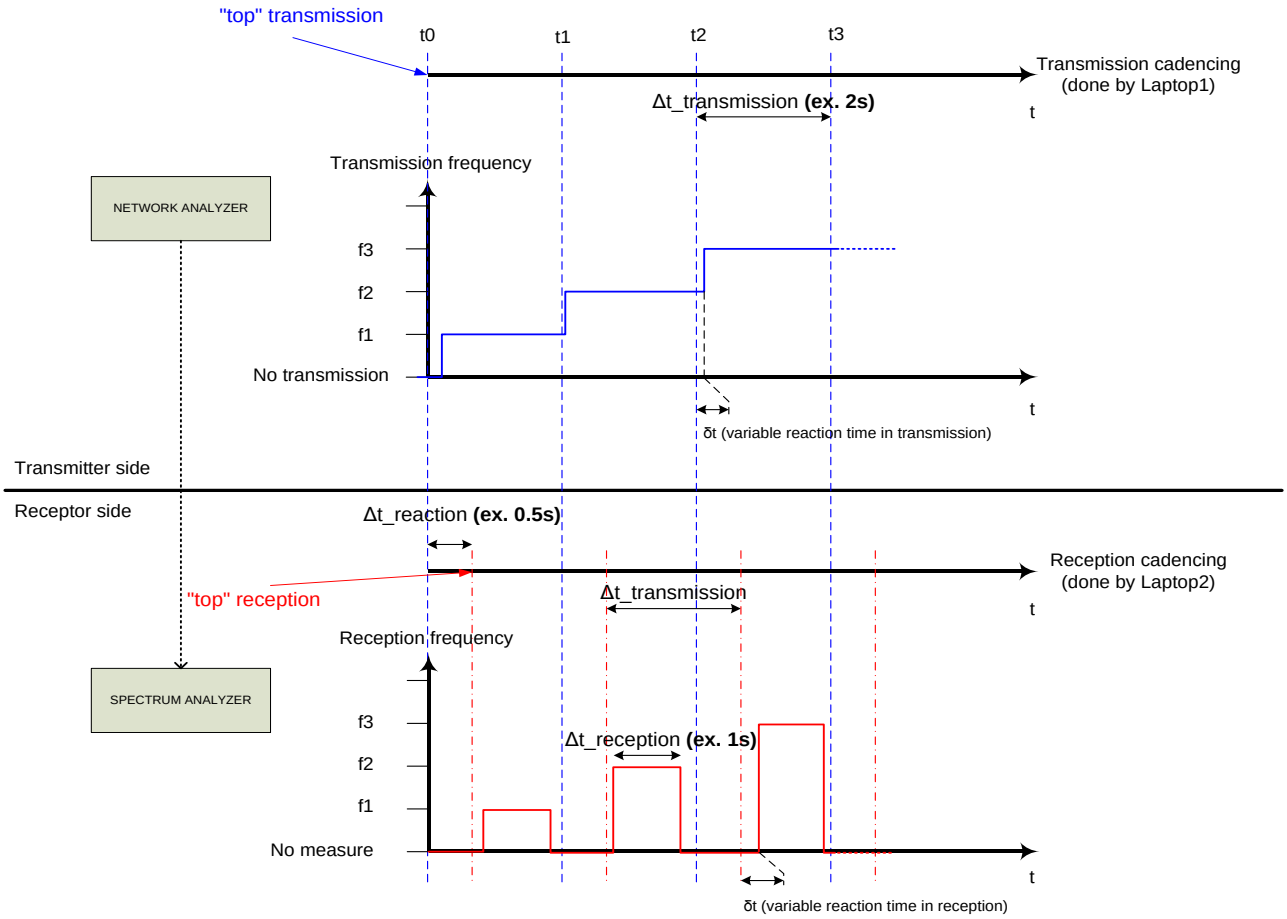
The same methodology was followed to estimate the gain of the receiver coupler $G_{2,dB}(f)$

These measurements were done at LAN laboratory prior to the campaign and the obtained values were included in global Excel files to allow the processing of the raw measurements after the campaign.

2.4.2.3 IMPLEMENTATION

Three different methods have been evaluated to implement the Channel Gain measurement. The selected method is named "Pseudo-Synchronization" methodology.

The following graph below shows the "Pseudo-Synchronization" developed for this measurement. It is based on a "manual" synchronization performed by operators at both end pressing a 'start' button almost at the same time to launch the transmission process as well as the reception process. Thus, a fixed time lag between the transmitter side and the receiver side occurs at the start of the measurement (*Δt_reaction*) and both transmission & reception processes operate with different fixed durations: Δt_transmission & Δt_reception, with Δt_transmission > Δt_reception to make sure the measurement is done during the transmission window.



Δt_transmission and Δt_reception have to be adjusted based on reaction time and δt

LF is used for [9kHz-150kHz] frequency range and HF is used for [1MHz-30MHz]. In HF, the results are recovered in a way where each result point corresponds to a HomePlug AV carrier. In LF, the results are recovered in a way where each result point corresponds to a PLC G3 carriers in the frequency range of [35kHz-91kHz] (we use the PLC G3 frequency step for the other frequencies in the band [9kHz-150kHz]).

Computers, network and spectrum analyzers are powered through filters and isolation transformers in order to avoid perturbations due to them on the PLC channel.

2.4.3 List of equipments

TABLE 1 - LIST OF EQUIPMENT FOR CHANNEL GAIN MEASUREMENT

Designation	Reference	Quantity	Location in the Setup
Isolating transformer	BLOCK TIM1000	2	A and L
Filter	LAN-FILTR TRIP-36A-F001/2	2	A and L
Filter	LAN-FILTR 36A-F001/2	2	A and L
Network analyzer	Agilent 4395A	1	D
Spectrum analyzer	Rhodes & Schwarz FSP	1	I
Computer	DELL VOSTRO 1000	2	B and K
Coaxial cable (5m)	Generic	2	E and H
USB-GPIB Adaptor	AGILENT 82357B	2	C and J

N-type adapter	Generic	2	D and I
High frequency coupler	LAN-CPLR rev.00	2	F and G
Low frequency coupler	LAN-IT800-CPLR rev00	2	F and G

2.4.4 Equipment configuration

TABLE 2 - HF: R&S FSP CONFIGURATION

Parameter	Value
Number of points	125
Number of sweep	3
Sweep Time (s)	0,1
Resolution bandwidth (RBW) (Hz)	10000
Video bandwidth (VBW) (Hz)	10000
Start frequency (Hz)	1806640.6
Stop frequency (Hz)	29980468.8
Attenuator (dB)	30

TABLE 3 - LF: R&S FSP CONFIGURATION

Parameter	Value
Number of points	125
Number of sweep	3
Sweep Time (s)	0,1
Resolution bandwidth (RBW) (Hz)	300
Video bandwidth (VBW) (Hz)	300
Start frequency (Hz)	9375,5
Stop frequency (Hz)	150000,5
Attenuator (dB)	30

TABLE 4 - TIME MEASUREMENTS

	Parameter	Value
High frequency	*Δt_transmission*	1558 ms
	Δt_reception	300ms
Low frequency	*Δt_transmission*	1978 ms
	Δt_reception	300ms

2.4.5 Measurement Procedure

See Annex A: Channel Gain Procedure

2.5 Noise – NOI and Signal to Noise Ratio - SNR

2.5.1 Setup at receiver side

The setup for Noise measurement at receiver side is the following:

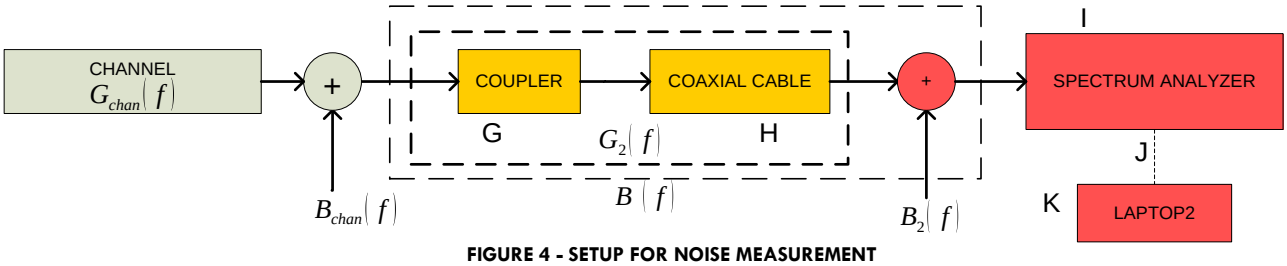


FIGURE 4 - SETUP FOR NOISE MEASUREMENT

The list of the equipment used is given in the Table 1 - List of equipment for channel gain measurement (see section 2.4.3)

2.5.2 Principle

2.5.2.1 NOISE ESTIMATION

Considering the great distance between the smart meters locations and the displays locations, it is assumed that the noise at each extremity of the channel can be very different. This is why the noise was measured at both ends. The measurements are conducted simultaneously by two operators on the two locations. The noise at the receiver side can be modelled as:

$$B(f) = B_{chan}(f).|G_2(f)|^2 + B_2(f)$$

If we neglect $B_2(f)$ then the noise before the receiver coupler $B_{chan}(f)$ is:

$$B_{chan}(f) = \frac{B(f)}{|G_2(f)|^2}$$

$$B_{chan,dBm}(f) = B_{dBm}(f) - G_{2,dB}(f)$$

Frequencies used during these measurements are the same ones than in Channel Gain measurements.

The setup is quite simple as we just measure power at each extremity of the channel using two spectrum analyzers (AGILENT 4395A in the meters location and Rohde & Schwarz FSP in the display locations) and two couplers (HF/LF). The results are then processed to convert the measured powers to PSD (Power Spectral Density). To be able to compare the 2 measurements the choice to use the attenuations which give the same noise floor on each side has been taken. This attenuation is useful to not underestimate the noise level.

2.5.2.2 SNR ESTIMATION

The Signal to Noise Ratio (SNR) is estimated using the measured power and the measured noise power at the receiver side.

$$SNR_{dB}(f) = P_{S,dBm}(f) - B_{dBm}(f)$$

2.5.3 List of equipments

The used equipments are the ones used for Channel Gain measurement. See section 2.4.3.

2.5.4 Equipment configuration

TABLE 5 - HF: R&S FSP CONFIGURATION.

Parameter	Value
Number of points	2001
Sweep type	Average on 20 sweeps
Resolution bandwidth (RBW) (Hz)	10000
Video bandwidth (VBW) (Hz)	10000
Start frequency (Hz)	1806640.6
Stop frequency (Hz)	29980468.8
Attenuator (dB)	Variable (30, 40 or 60dB)

TABLE 6 - HF: AGILENT 4395A CONFIGURATION (STEP 1).

Parameter	Value
Number of points	801
Sweep type	Average on 20 sweeps
Resolution bandwidth (RBW) (Hz)	10000
Video bandwidth (VBW) (Hz)	10000
Start frequency (Hz)	1806640.6
Stop frequency (Hz)	21337890.6
Attenuator (dB)	Variable (20, 30 or 50dB)

TABLE 7 - HF: AGILENT 4395A CONFIGURATION (STEP 2).

Parameter	Value
Number of points	354
Sweep type	Average on 20 sweeps
Resolution bandwidth (RBW) (Hz)	10000
Video bandwidth (VBW) (Hz)	10000
Start frequency (Hz)	21362304.7
Stop frequency (Hz)	29980468.8
Attenuator (dB)	Variable (20, 30 or 50dB)

TABLE 8 - LF: R&S FSP CONFIGURATION.

Parameter	Value
Number of points	91
Sweep type	Average on 20 sweeps
Resolution bandwidth (RBW) (Hz)	300
Video bandwidth (VBW) (Hz)	300
Start frequency (Hz)	9375.5
Stop frequency (Hz)	150000,5
Attenuator (dB)	Variable (30, 40 or 60dB)

TABLE 9 - LF: AGILENT 4395A CONFIGURATION.

Parameter	Value
Number of points	91
Sweep type	Average on 20 sweeps
Resolution bandwidth (RBW) (Hz)	300
Video bandwidth (VBW) (Hz)	300
Start frequency (Hz)	9375,5
Stop frequency (Hz)	150000,5
Attenuator (dB)	Variable (20, 30 or 50dB)

2.5.5 Measurement Procedure

See ANNEX B: Noise Procedure

2.6 Impedance – IMP

2.6.1 Principle

After a calibration stage, a measurement of the power reflection (S_{11}) allows to calculate the access Impedance.

2.6.2 List of equipments

TABLE 10 - LIST OF EQUIPMENT FOR IMPEDANCE MEASUREMENT

Material	Reference	Quantity
Network analyzer	Agilent 4395A	1
S-parameters extension	Agilent 87511A	1
Reflection extension	Agilent 87512A	1
Isolating transformer	BLOCK TIM1000	1
Computer	DELL VOSTRO 1000	1
USB-GPIB Adaptor	AGILENT 82357B	1
Filter	LAN-FILTR TRIP-36A-F001/2	1
Filter	LAN-FILTR 36A-F001/2	1
Coaxial cables (1m)	Generic	2
N-type adapter	Generic	2
Coupler calibration kit	LAN	3
Low frequency couplers	LAN-IT800-CPLR rev00	2
High frequency couplers	LAN-CPLR rev.00	2

2.6.3 Equipment configuration

TABLE 11 - HF: AGILENT 4395A CONFIGURATION (STEP 1)

Parameter	Value
Number of points	801
Start Frequency (Hz)	1806640,6
Stop Frequency (Hz)	21337890,6
Sweep time (ms)	1834
Sweep type	Continuous
Source Power (dBm)	15
IF Bandwith (Hz)	10000

TABLE 12 - HF: AGILENT 4395A CONFIGURATION (STEP 2)

Parameter	Value
Number of points	354
Start Frequency (Hz)	21362304,7
Stop Frequency (Hz)	29980468,8
Sweep time (ms)	810,7
Sweep type	Continuous
Source Power (dBm)	15

IF Bandwith (Hz)	10000

TABLE 13 - LF: AGILENT 4395A CONFIGURATION

Parameter	Value
Number of points	91
Start Frequency (Hz)	9375,5
Stop Frequency (Hz)	150000,5
Sweep time (ms)	4625
Sweep type	Continuous
Source Power (dBm)	15
IF Bandwith (Hz)	300

2.6.4 Measurement Procedure

See Annex C: Impedance Procedure

2.7 Near End Cross Talk - NEXT

2.7.1 Principle

To obtain a NEXT measurement between different customer's homes, the Channel Gain and Noise measurement methodologies are used (see Channel Gain - CG and Noise – NOI and Signal to Noise Ratio - SNR).

The measurement is done between 2 different flats or 2 different meters. At the transmitter side, the network analyzer is connected to one flat. At the receiver side, the Spectrum analyser is connected to the second flat.

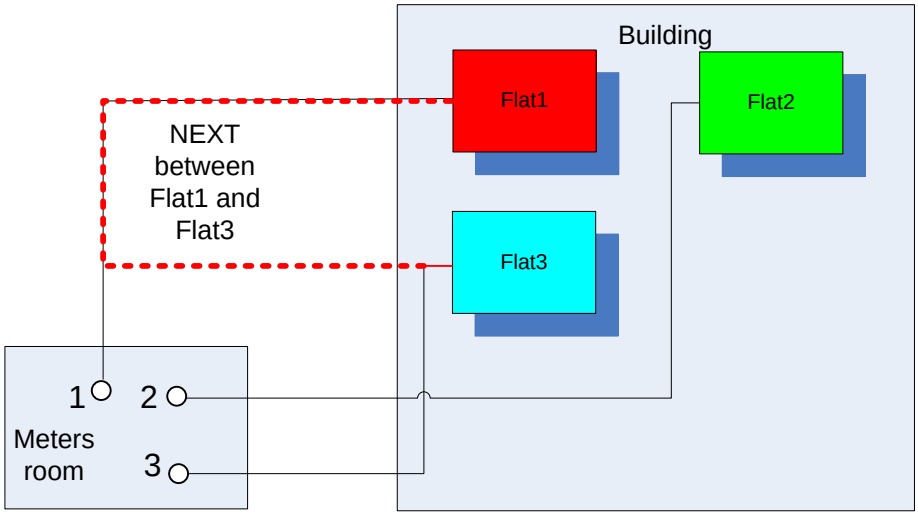


FIGURE 5 - OVERVIEW OF NEXT MEASUREMENT

Note : Note that the Flat1 and 3 might be feeded by a same phase or not. Thus the NEXT effect might be contributed by direct electrical propagation and/or by radiated coupling on the cables.

2.7.2 List of equipments

The used equipments are the ones used for Channel Gain measurement. See section 2.4.3.

2.7.3 Measurement Procedure

The used procedure is Channel Gain procedure See Annex A: Channel Gain Procedure.

2.8 Far End Cross Talk - FEXT

2.8.1 Principle

To obtain a FEXT measurement between different customer's homes, the Channel Gain and Noise measurement methodologies are used (see sections 2.4 and 2.5).

The measure is done between a flat (ex: FlatA) and a meter (ex: MeterB) which are not directly connected together. As in the original methodology, the transmitter side (in the smart meters location) is connected to the network analyzer. But at the other side (the receiver side), the measured socket isn't in the corresponding flat, but in another one. This is linked to Spectrum analyser.

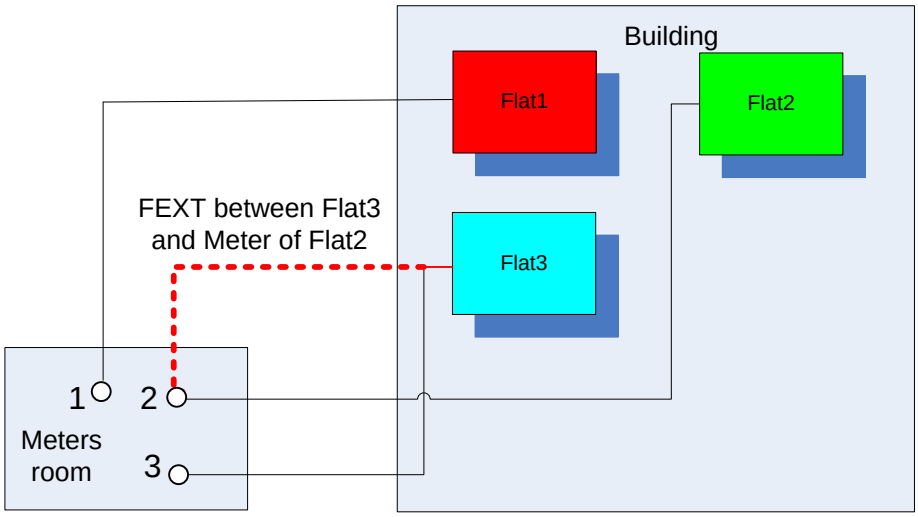


FIGURE 6 - OVERVIEW OF FEXT MEASUREMENT

2.8.2 List of equipments

The used equipments are the ones used for Channel Gain measurement. See section 2.4.3.

2.8.3 Measurement Procedure

The used procedure is Channel Gain procedure See Annex A: Channel Gain Procedure.

2.9 Test Equipment Details

Network Analyzer	
Manufacturer's Name	Agilent
Trade name/mark/model	NETWORK / SPECTRUM /
Serial No.(s)	MY41101280
Calibration Date	July-12
S-parameters extension	
Manufacturer's Name	Agilent
Trade name/mark/model	87511A
Serial No.(s)	MY43100263
Option. (s)	001
Reflection extension	
Manufacturer's Name	Agilent
Trade name/mark/model	87512A
Spectrum Analyzer	
Manufacturer's Name	Rohde & Schwarz
Trade name/mark/model	FSP
Serial No.(s)	100508
Option. (s)	FS-K73 / FSP-B15
Calibration Date	29-oct-12

RFI Filter	1	2	3	4
Name	LAN-FLTR 36A	LAN-FLTR 36A	LAN-FLTR TRIP-36A	LAN-FLTR TRIP-36A
Manufacturer's Name	LAN	LAN	LAN	LAN
Serial No.(s)	F0001	F0002	F0001	F0002
Option.(s)	rev. 00	rev. 00	rev. 00	rev. 00

Isolating Transformer	1	2
Name	TIM1000	TIM1000
Manufacturer's Name	BLOCK	BLOCK
Serial No.(s)	1	2

Computer	1	2
Model Name	VOSTRO 1000	VOSTRO 1000
Manufacturer	DELL	DELL
HW Characteristics	AMD Turion 64 X2 mobile 1.79 GHz 1GB of RAM	AMD Turion 64 X2 mobile 1.79 GHz 1GB of RAM
Operating System	Microsoft Windows XP version 2002, Service Pack2	Microsoft Windows XP version 2002, Service Pack2

High Frequency PLC Coupler	1	2
Name	LAN-CPLR rev. 00	LAN-CPLR rev. 00

Manufacturer's Name	LAN	LAN
Serial No.(s)	#0001	#0002

Low Frequency PLC Coupler	1	2
Name	LAN-IT800-CPLR rev00	LAN-IT800-CPLR rev00
Manufacturer's Name	LAN	LAN
Serial No.(s)	#0003	#0004

Cables		
Designation	**Reference**	**Quantity**
Coaxial cable	AGILENT 8120-4387	4
Coaxial cable (1m)	Generic	2
Coaxial cable (5m)	Generic	2
N-type adapter	Generic	4
Type N Calibration kit (GREMAN)	AGILENT 85032F	1
Coupler calibration kit	LAN	3
USB-GPIB Adaptor	AGILENT 82357B	2
S-Parameters extension cable	FUJIKURA-T E49075	1
Power strip	Generic	2
UK-euro adapters	Generic	6
Power cords	Generic	3

3. TEST CAMPAIGN INFORMATION

3.1 Building and Flat information

The detailed list of buildings and flats and its survey is given from section 6.4 and following.

Data	CAR1	SWA1	POR1	MAN1
Address	Cardiff	Swansea	Porthcawl	Mqnchester
Number of floor	10	28	2	16
Number of flat	80	122	60	90
Date of construction	1990s	2008	1976	1970s
Number of Lift(s)	2	4	1(Service)	2
Tested flat	F275 (5th floor) F262 (10th floor)	F111 (20th floor) F120 (23th floor)	F42 (1st floor) F40 (2nd floor) F24 (2nd floor)	F47 (9th floor) F54 (10th floor) F64 (12th floor) F85 (16th floor) F88 (16th floor)

3.2 Measurement Coverage

3.2.1 Channel Gain + Noise

	Building			
Channel Gain	CAR1	SWA1	POR1	MAN1
Meter ➔ Flat	M262_F262 M275_F275	M111_F111 M120_F120	HF_M40_F40	M47_F47 M64_F64 M85_F85 M88_F88
Flat ➔ Meter		F120_M120	F40_M40	F85_M85 F88_M88

3.2.2 Crosstalk + Noise

	Building			
Crosstalk	CAR1	SWA1	POR1	MAN1
between Flats (same phases)			F40_F42_sp	F88_F54_sp
between Flats (different phases)			F40_F24_dp	F85_F47_dp
between Meters (different phases)	M262_M275_dp	F120_F111_dp		
Meter ➔ Flat (different phases)		M111_F120_dp		

3.2.3 Impedance

	Building			
Impedance	CAR1	SWA1	POR1	MAN1
Meter	M262	M120 M111	M40	M85 M47 M64 M54 M88
Flat		F120	F40	F85 F88

3.3 Detailed Results & Records (File Tree)

3.3.1 Delivery

All the data are grouped in: LAN12AF093-PLC_Characterization tests-Measurement_Results Ed01.zip

3.3.2 Naming

3.2.2.1 FOLDERS

There are four levels of folders:

- **Level 1** – Building:
  - o CAR1 = CARdiff #1 (*first building in Cardiff*),
  - o SWA1 = SWAnsea #1 (*first building in Swansea*),
  - o POR1 = PORthcawl #1 (*first building in Porthcawl*) and
  - o MAN1 = MANchester #1 (*first building in Manchester*).
- **Level 2** – Frequency band:

HF and LH folders separate the frequency band used for the measurements:

- o HF: High Frequency band [1MHz-30MHz],
- o LF: Low Frequency band [9kHz-150kHz].

Note that a subfolder called "pics" is also included in this level. It contained all the pictures of the flats, meter rooms and measurement setups.

- **Level 3** – Type of measurement:
  - o CG (Channel Gain + Noise)
  - o IMP (Impedances)
  - o XT (Crosstalk + Noise)

- **Level 4** – Transmitter and Receiver for Channel Gain and Crosstalk measurements

For Channel Gain, the folders are named following this rule:

- Transmitter_Receiver
  - o Transmitter and Receiver are named using the following rule:
    - F (*for Flat*) or M (*for Meter*) followed by its number.

For Crosstalk, the folders are named following this rule:

- Transmitter_Receiver_sp (*or dp*)
  - o Same rules than above for Transmitter and Receiver names.

o The suffix "sp" or "dp" indicates if the crosstalk is measured on the same phases or on different phases.

For Impedances, the measurements of a building are all grouped in a single excel file. Each sheet of the file is referring to the Flat and to the side of the measurement (*F for Flat side or M for Meter side*).

At the last level (*Level 4 for Channel Gain and Crosstalk; Level 3 for Impedance*), the folders contain:

- the raw measurements (*row data collected from the spectrum analyzers*) gathered in subfolders, and
- the results files (*data post-threaten to compensate the cabling and coupling attenuations ; graphs displaying the results are also included in these files*).

3.2.2.2 RESULTS FILES

The results files are named using same rules than above but in a different order to facilitate the analysis:
- First letters: Type of measurement (*CG, IMP or XT*),
- Following letters: Frequency band (*HF or LF*),
- Following letters: Building (*CAR1, SWA1, POR1 or MAN1*),
- Transmitter and Receiver + suffix in case of measurement on different phases.

All the Result files are also gathered in the "_Results Files" folder to allow a more comfortable and direct analysis.

4. MEASUREMENTS SYNTHESIS

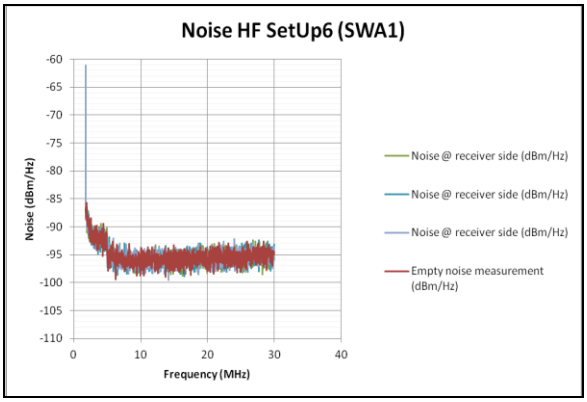
4.1 Important Notes

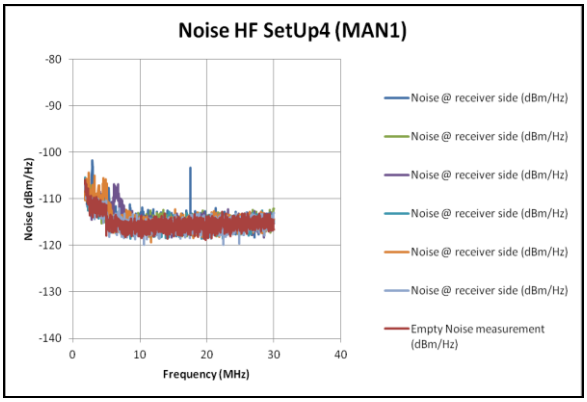
Prior to the exploitation and the use of the **Channel Gain** measurements, great care should be taken for each specific measurement about the fact that the assumption on the low noise and high SNR is verified. Such a verification can be done by using and verifying the SNR measurements performed in the same context as for the channel gain measurement.
It shall also be noted that in the cases of MAN1 and SWA1 buildings, the attenuations settings used are different between the Channel Gain measurement and the Noise Measurement.

- For SWA1 :
  - Attenuation used for the noise measurement at receiver side was 60dB
  - Attenuation used for the Channel Gain measurement at receiver side was 30dB
- For MAN1 :
  - Attenuation used for the noise measurement at receiver side was 40dB
  - Attenuation used for the Channel Gain measurement at receiver side was 30dB

For these buildings, one can thus consider that the measured noise is thus overestimated compared to the real noise encountered on the Channel during the Channel Gain measurement. This explains the case of some Cross Talk measurements in the Swansea building (SWA1) where the SNR has some negative values.

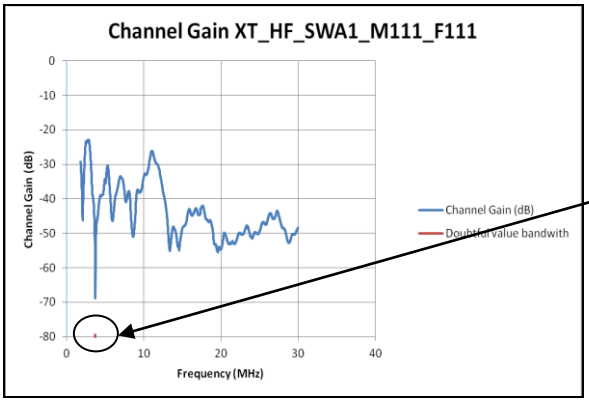
To help in the analysis, we have charted the noise level of an "empty" noise measurement on the Spectrum analyzer for the SWA1 and MAN1 setups (no connection on the spectrum analyzer to get the background noise for the same setting). This gives the minimum achievable level of noise for the selected measurement configuration (the "noise floor").





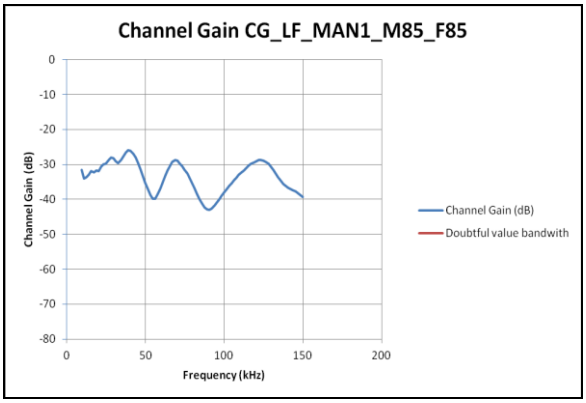
As one may on these charts, the measured noise levels roughly match the "empty" noise case for a specific setup, so one may conclude with confidence that the noise is overestimated in such cases.

For all measurements, we have underlined, on the Channel Gain chart, **by a red chart**, the frequency bandwidths where the measured SNR values are weak and thus where the Channel Gain measurements might not be reliable. In the example below, a threshold of SNR of 10dB was selected to identify the less "reliable" measurement areas. Such a threshold can be however set to different values in the Excel files (see excel cell (F,2) in the first sheet of the excel files).



This frequency presents a low SNR value which is under the threshold (10dB).
The low noise assumption is thus not met, making the Channel Gain estimation for this frequency band less reliable.

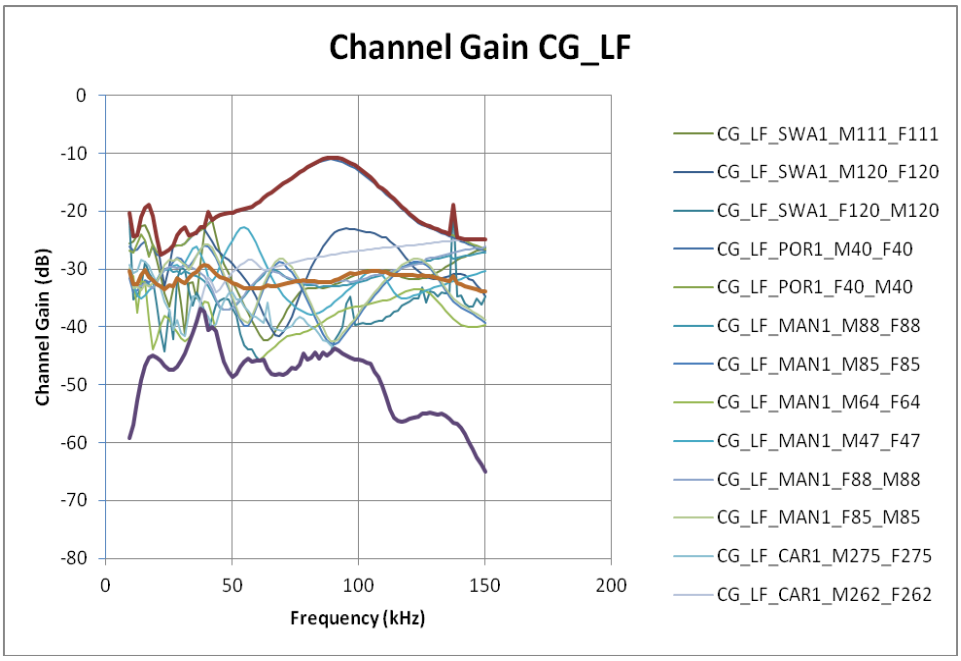
The Channel Gain charts where no red appears are totally validated by the physical conditions (as shown below for the Manchester flat 85 channel gain measurement):



The following sections below, without detailing every single measurements performed and setup tested, aims at identifying the most challenging situations, and the most easiest ones, met during the campaign. This is to allow solutions providers to elaborate about their ability to meet these situations with their solutions and to demonstrate these solutions are fitted to handle with some of the mains

4.2 Channel Gain synthesis

Channel gain values collected over all the building and flats configurations are shown in a single chart below for the Low Frequencies (LF) first, and for the High Frequencies (HF). These are measurements performed either for a transmission going from the meter to the corresponding flat (Mxxx_Fxxx), or, going in the reverse direction, that is from the flat to the related power meter (Fxxx_Mxxx).



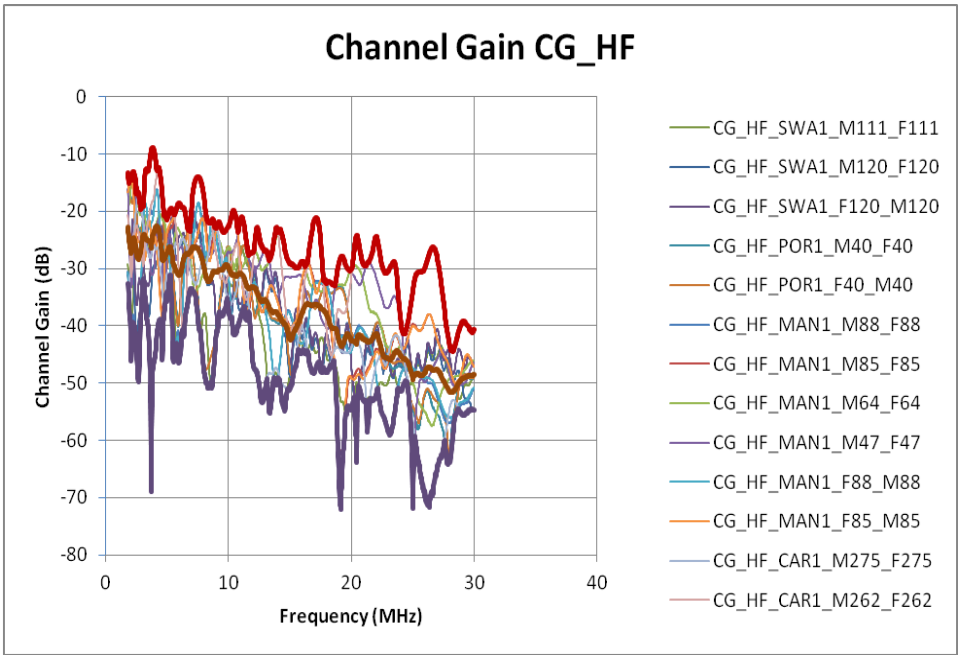


FIGURE 7 : CHANNEL GAIN SYNTHESIS (LF AND HF)

The maximum, minimum and average curves (vs frequencies) are also shown on each of these charts, giving an insight of the range of attenuations the powerline solutions may face when deployed in such configurations. The table below displays the minimum and maximum spread that can be met between theses MIN and MAX curves:

	LF	HF
min (MAX-MIN)	**14 dB**	**8 dB**
max (MAX-MIN)	**40 dB**	**60 dB**

4.2.1 Frequency Responses Selectivity and Variability

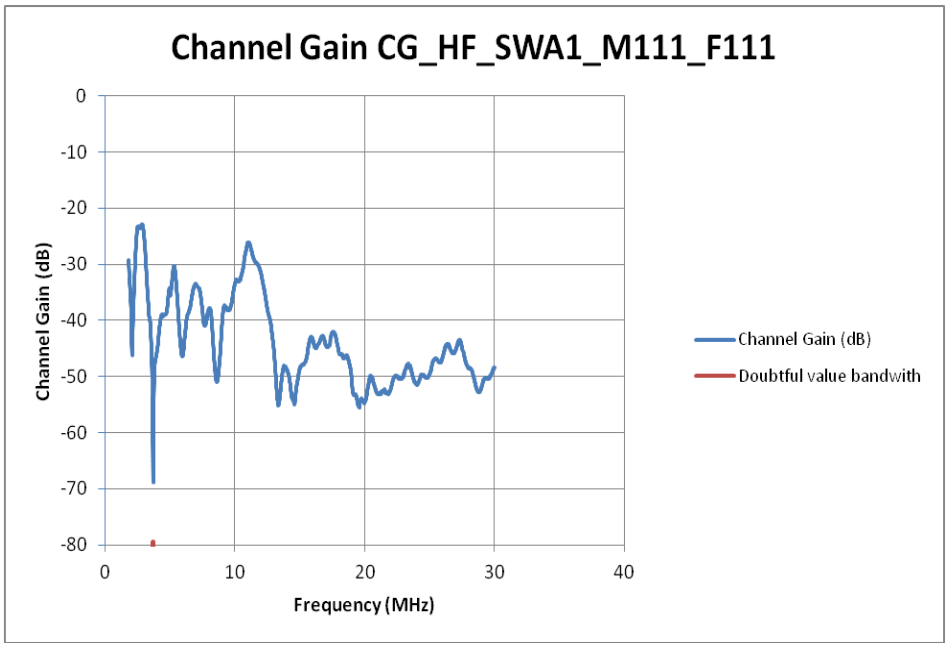
The above channel gains measurements show the great variablity and selectivity of the channel responses among the building and the flats. Selectivity is illsutrated by the fact that the channel responses are not flat (ie constant over the band) and rather show large losses for some specific frequencies. **In the HF band, Large losses (up to 70 dB) may be encountered for some specific frequencies while the rest of the channel response is rather located around an average gain value whose range is from -22 dB to -51dB. In the LF band from, losses up to 60 dB may be encountered for some specific frequencies, while the rest of the channel response is rather located around an average gain value whose range is from -29 dB to -34 dB.** These values may not represent an exhaustive panel of what could be met in the field of building the UK, but these are typical values met during the measurement campaign. As such, potential powerline solutions should demonstrate that they are able to cope with such values.

Variability among the responses (see above table) appears to be more important in the high frequencies (up to 60dB) than in the low frequencies (up to 40dB), but still remains within the same order for both frequnecy ranges. Such a variability in the attenautions will have a direct impact on the dynamic and sensitivity the of the potential powerline solutions which will aslo have to deal with such various attenuations profil over the frequency bands.

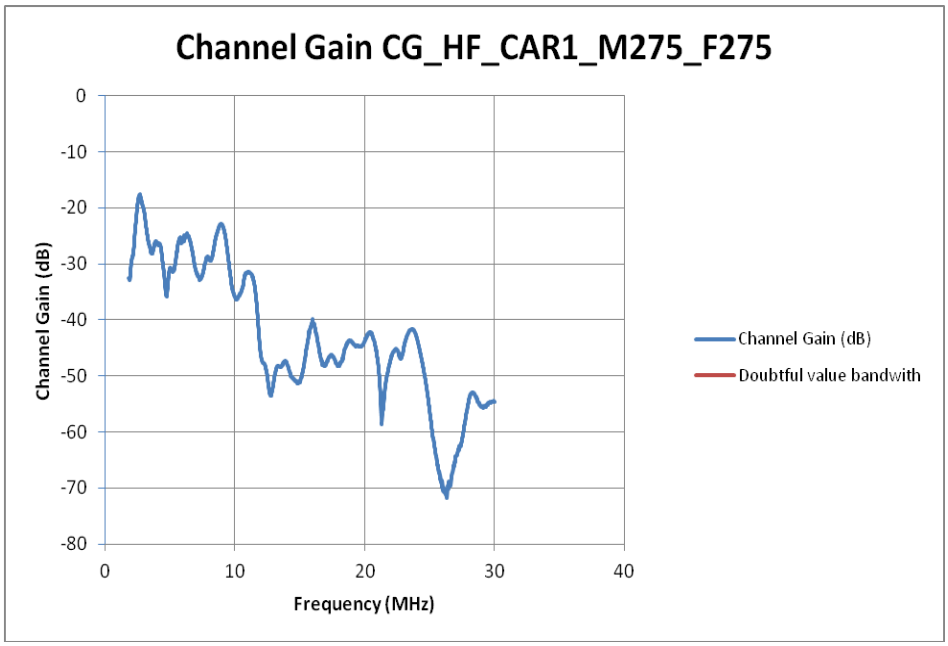
The following situations below have been specifically identified as the most challenging and the easiest ones in terms of channel gains. These are :

4.2.2 Channel Gain – Highest attenuation situation (HF)

- SWA1_M111_F111

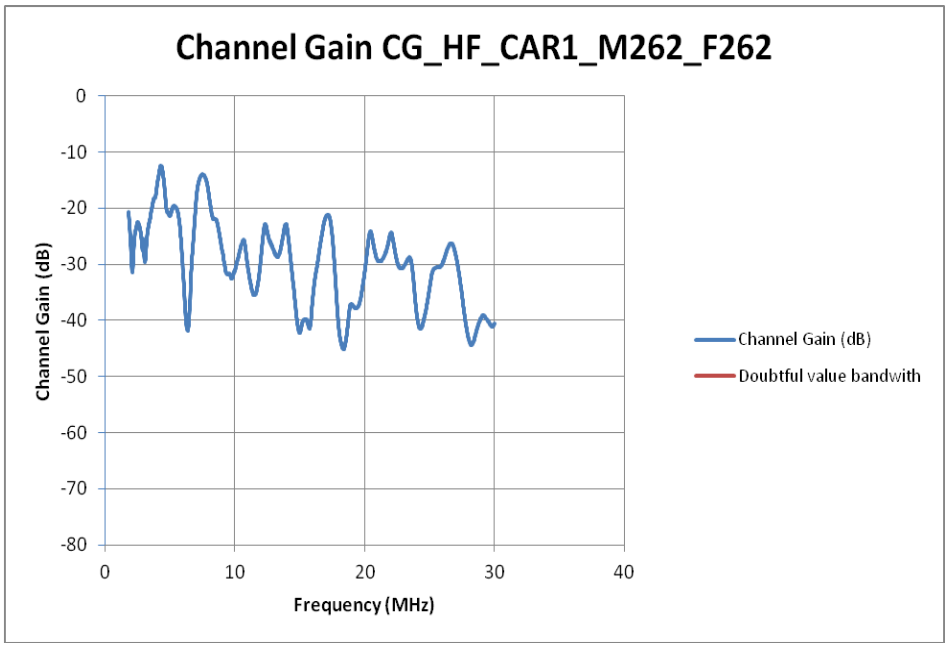


- CAR1_M275_F275

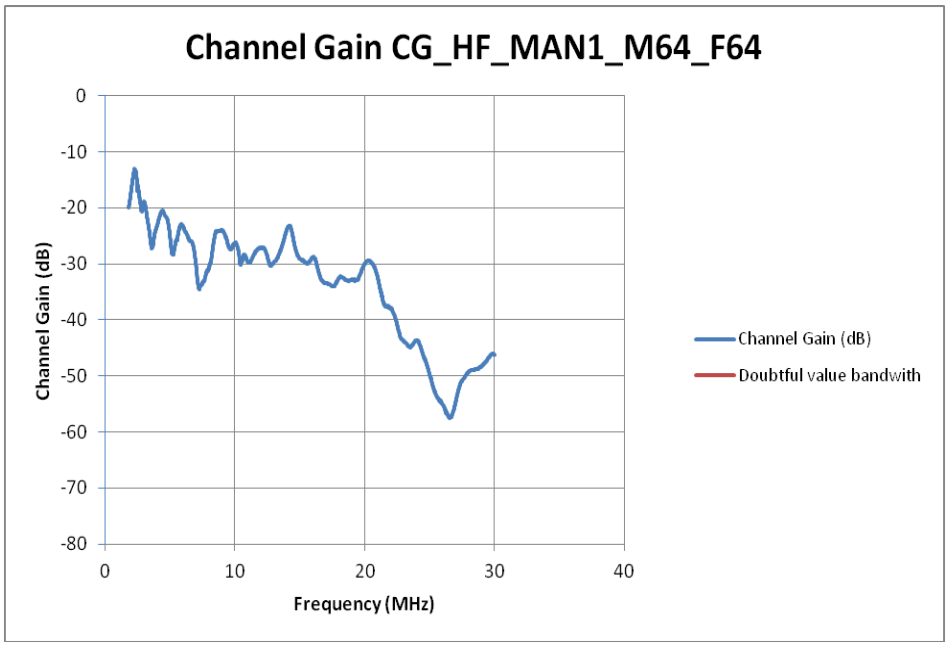


4.2.3 Channel Gain – Lowest attenuation situation (HF)

- CAR1_M262_F262

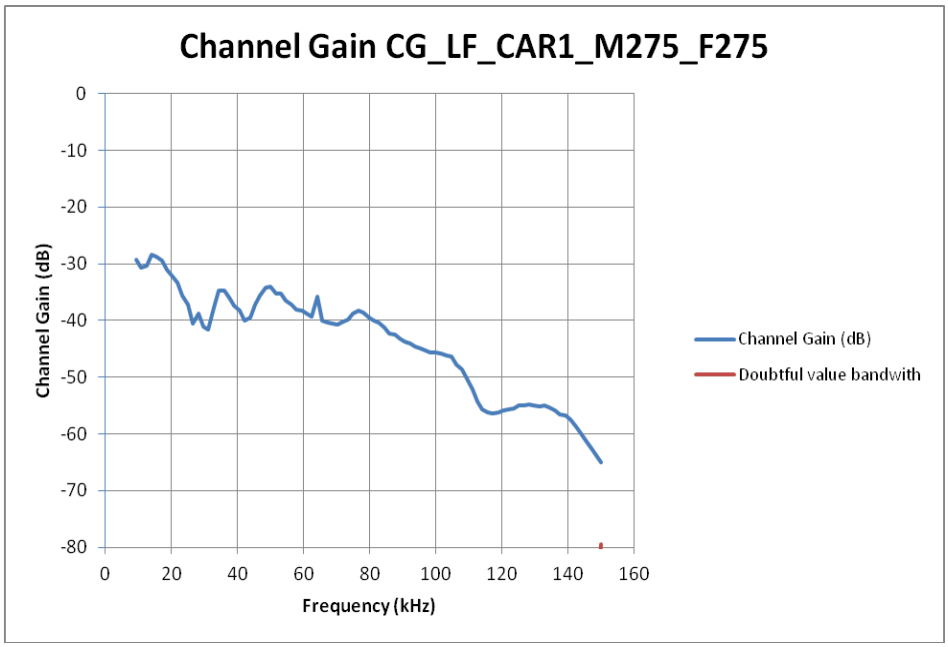


- MAN1_M64_F64

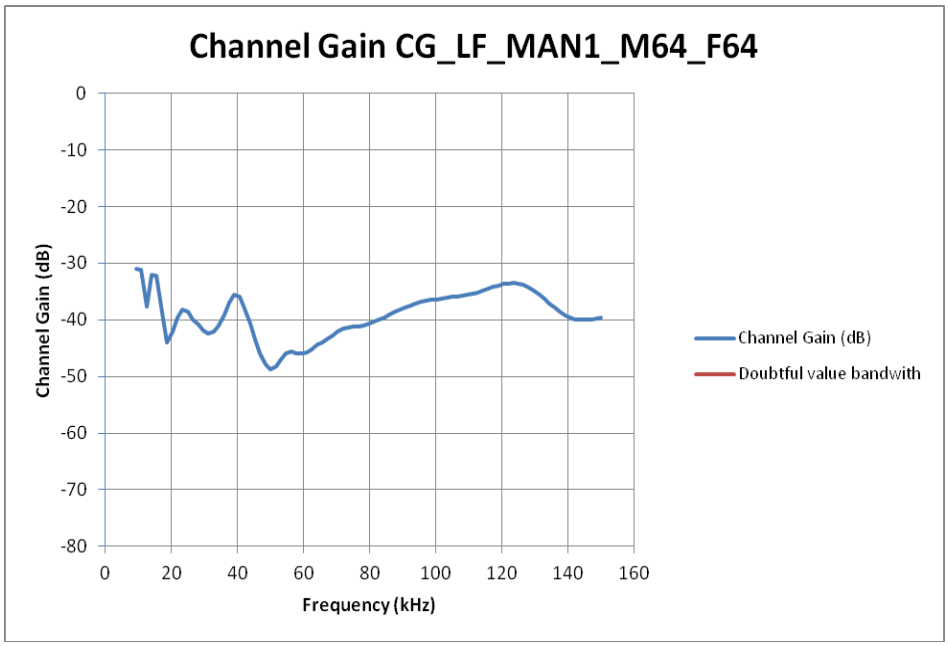


4.2.4 Channel Gain - Highest attenuation situation (LF)

- CAR1_M275_F275

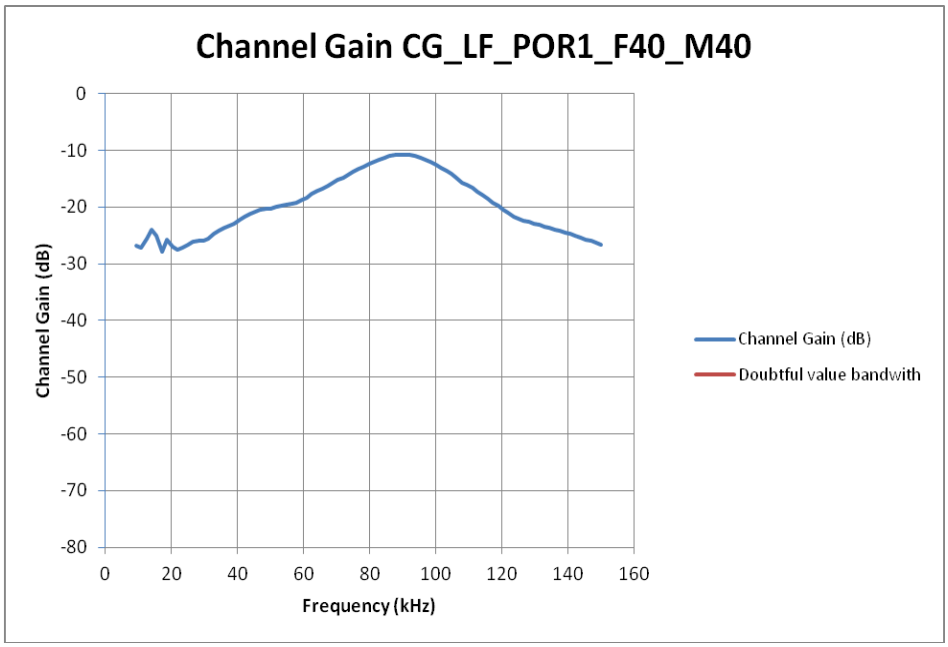


- MAN1_M64_F64

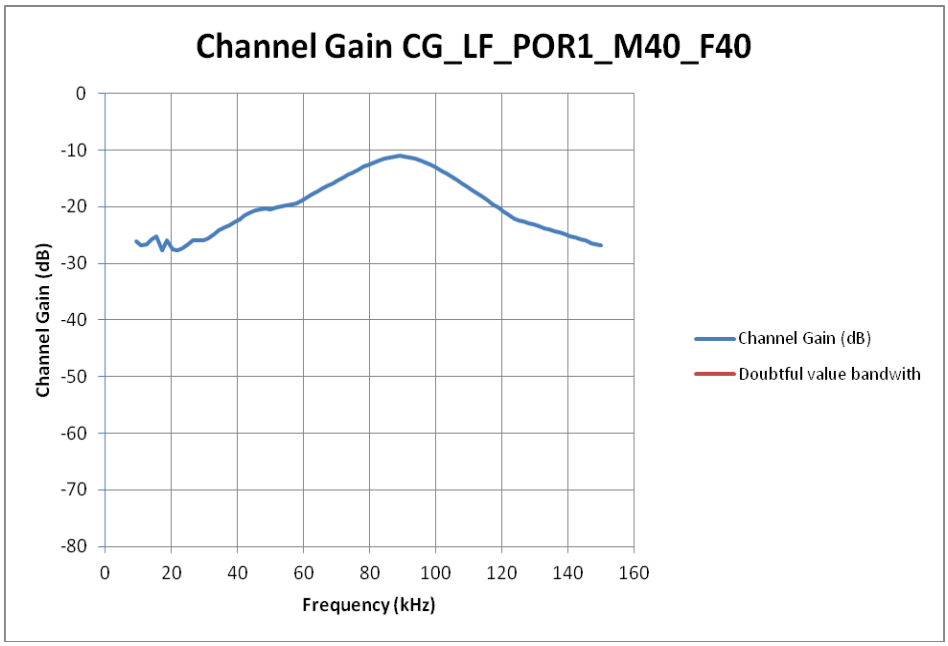


4.2.5 Channel Gain – Lowest attenuation situation (LF)

- POR1_F40_M40



- POR1_M40_F40



Note that these attenuation curves may be used by solution providers along with the related noise files to derive the capacity of their solutions in these different configurations. They could thus demonstrate the solution providers ability to meet the HAN network requirements in terms of capacity and robustness.

4.3 Crosstalk synthesis

The crosstalk denomination is used and defined in the sequel as the signal received on one end when transmitted from another end and where both ends are not supposed to communicate directly between

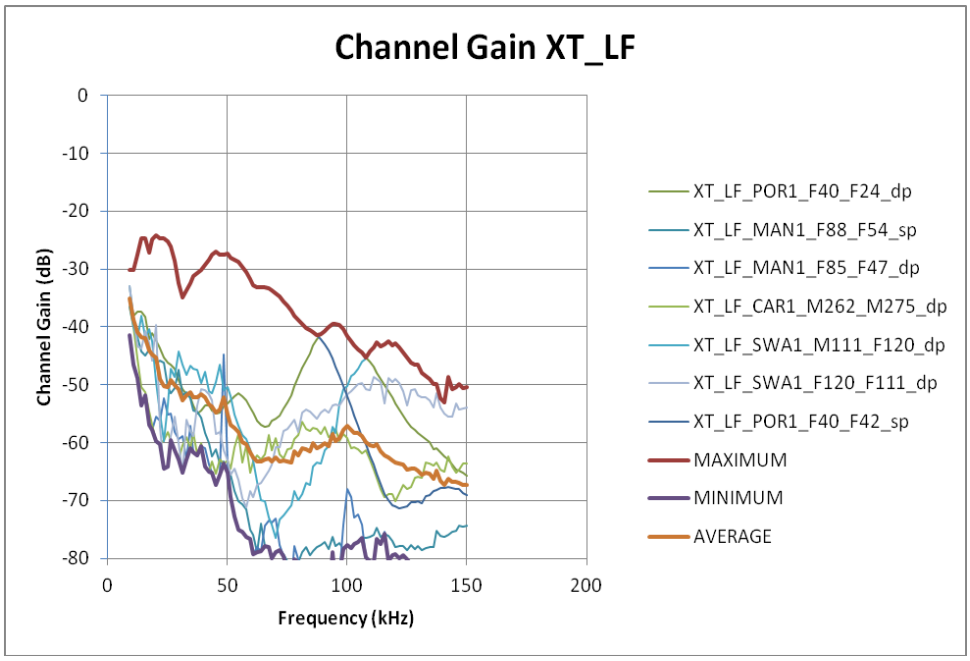
each others. Such an approach gathers different situations where the transmission medium may be shared while no direct communication between ends is however intended:

- from a Flat to another Flat
  - located on a same phase (measurements with "_sp" extensions)
  - located on a different phase (measurements with "_dp" extensions)
- from a flat to a different meter (a meter which is not the flat's meter)
  - on a same phase
  - on a different phase
  - also, all these situations with the reverse direction (from meter to the flat)

The crosstalk characterization is however a key aspect of the measurement campaign as it may address crucial questions that may raise about the electrical medium and the deployment of a powerline network, such as:

- will all the powerline nodes be visible from each others in a same building or not ? is this required, needed and how shall it be managed?
- shall the physical access to powerline medium be shared among all flats and nodes at the same time?
- are there any potential hidden nodes in the network?
- are there part of the network that may be hidden from a single node?
- would different but neighbor powerline networks easily coexist without any dedicated mechanisms?

The following figures display the synthesis of the crosstalk measurements performed across all the buildings:



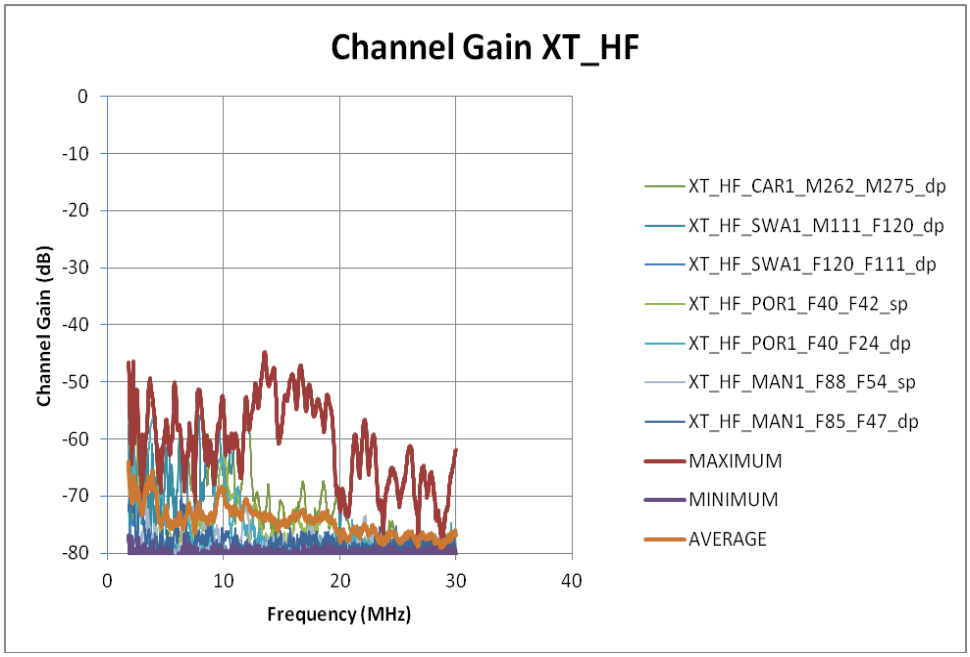


FIGURE 8 : CROSS TALK SYNTHESIS (LF AND HF)

These results & measurements question solution providers about distinct challenging situations: **hidden nodes** and **neighborhood networks,** as described below.

4.3.1 Hidden Nodes

There are situation where some flats and/or meters in a same building are "hidden" from each others in the HF and in the LF. This is the case for instance for flats F120 and F111 in the Swansea building (**CG_HF_SWA1_F120_F111_dp** and **CG_LF_SWA1_F120_F111_dp)** where the channel gain measurements between these flats show very high attenuations in the High and Low frequencies, which may prevent any communication or signalling between these flats. In such measurements (see below) the transmitted signal was attenuated by more than 75dB over the whole HF band. Note that, in these

measurements, the noise was measured with a too high input attenuation value (60dB, to avoid LF saturations) making the SNR in the HF band not meaningful (SNR is indeed measured negative over the band).

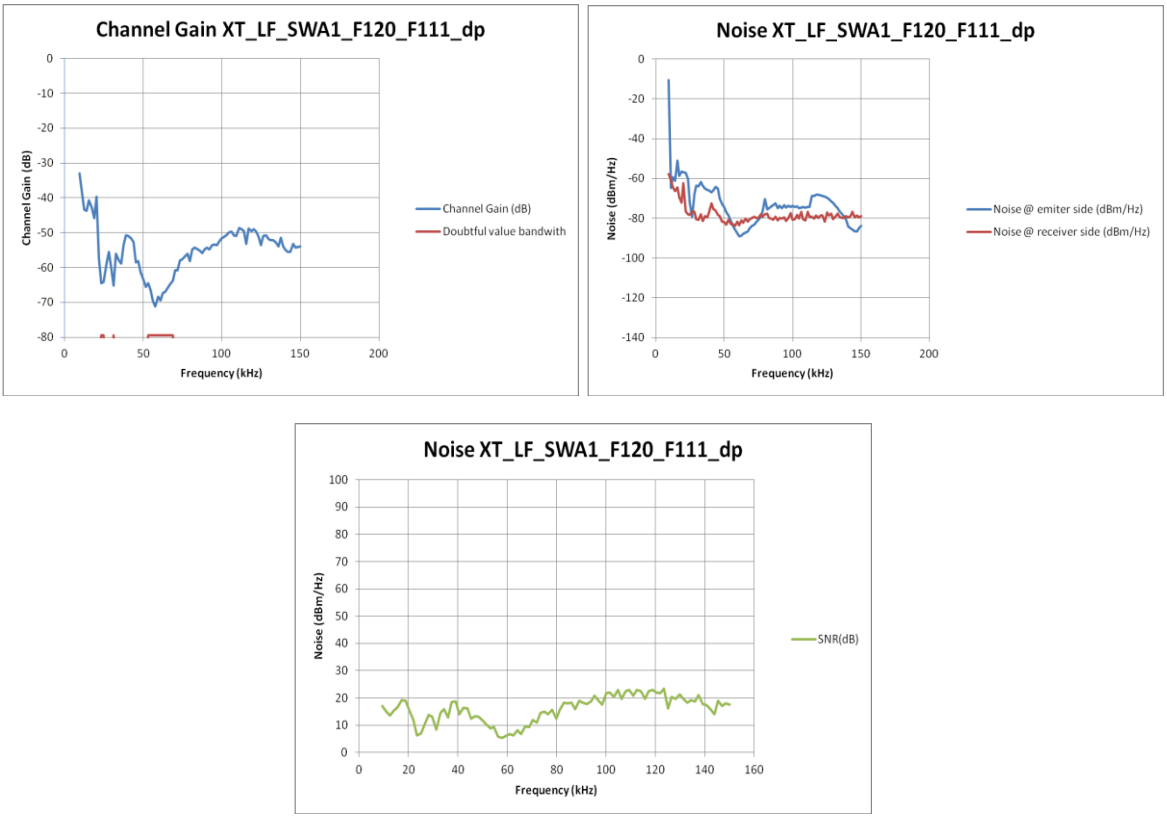
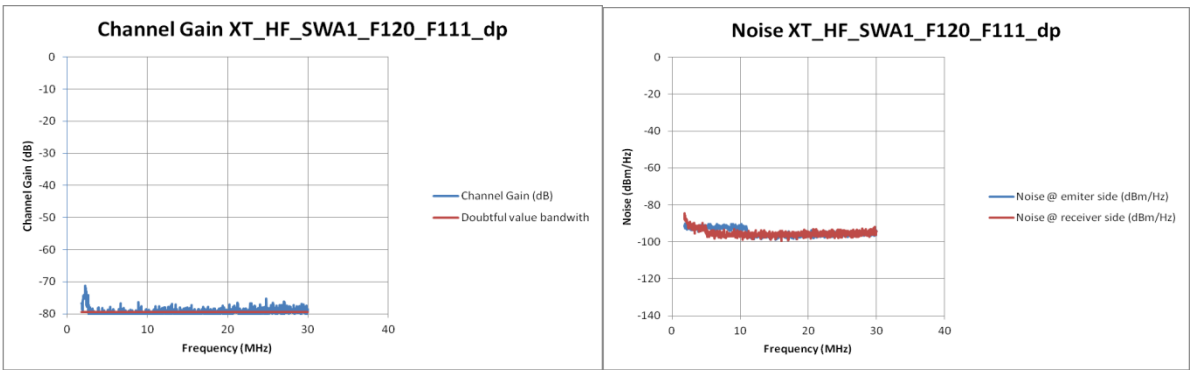


FIGURE 9 : CROSSTALK - CG_LF_SWA1_F120_F111_DP



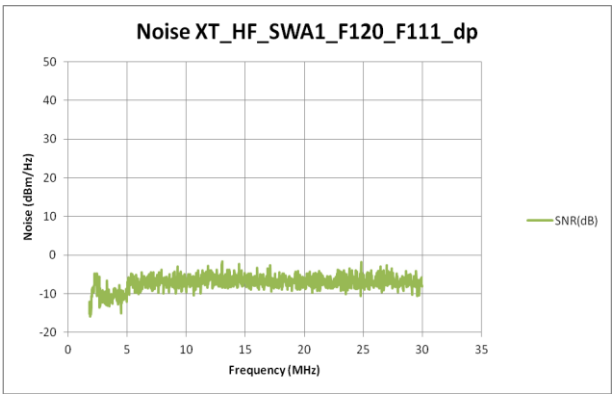
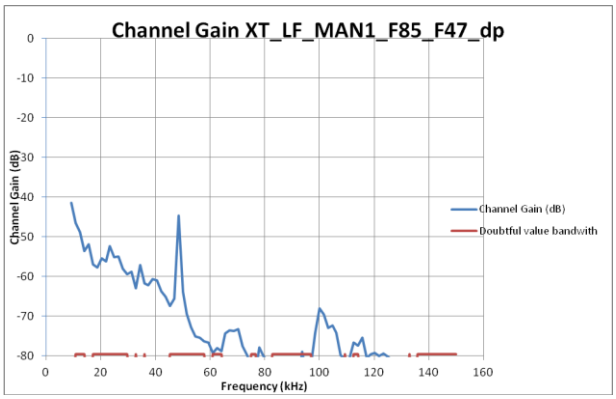
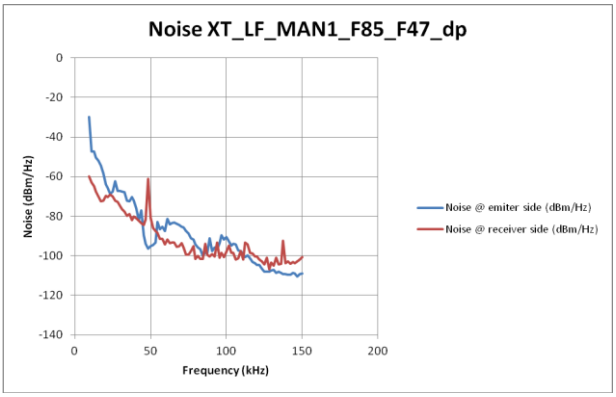


FIGURE 10 : CROSSTALK - CG_HF_SWA1_F120_F111_DP

Other hidden nodes situations were identified such as:





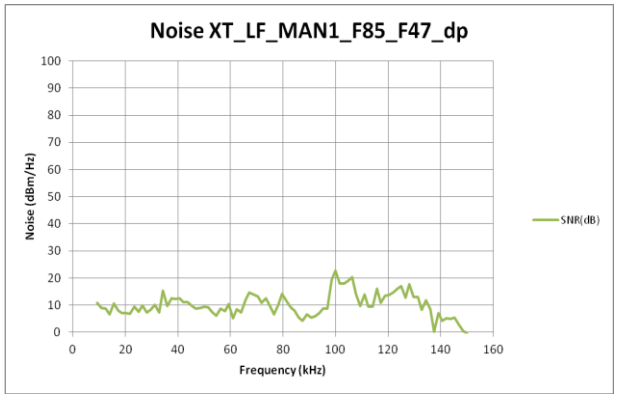


FIGURE 11 : CROSSTALK - CG_LF_MAN1_F85_F47_DP (LF)

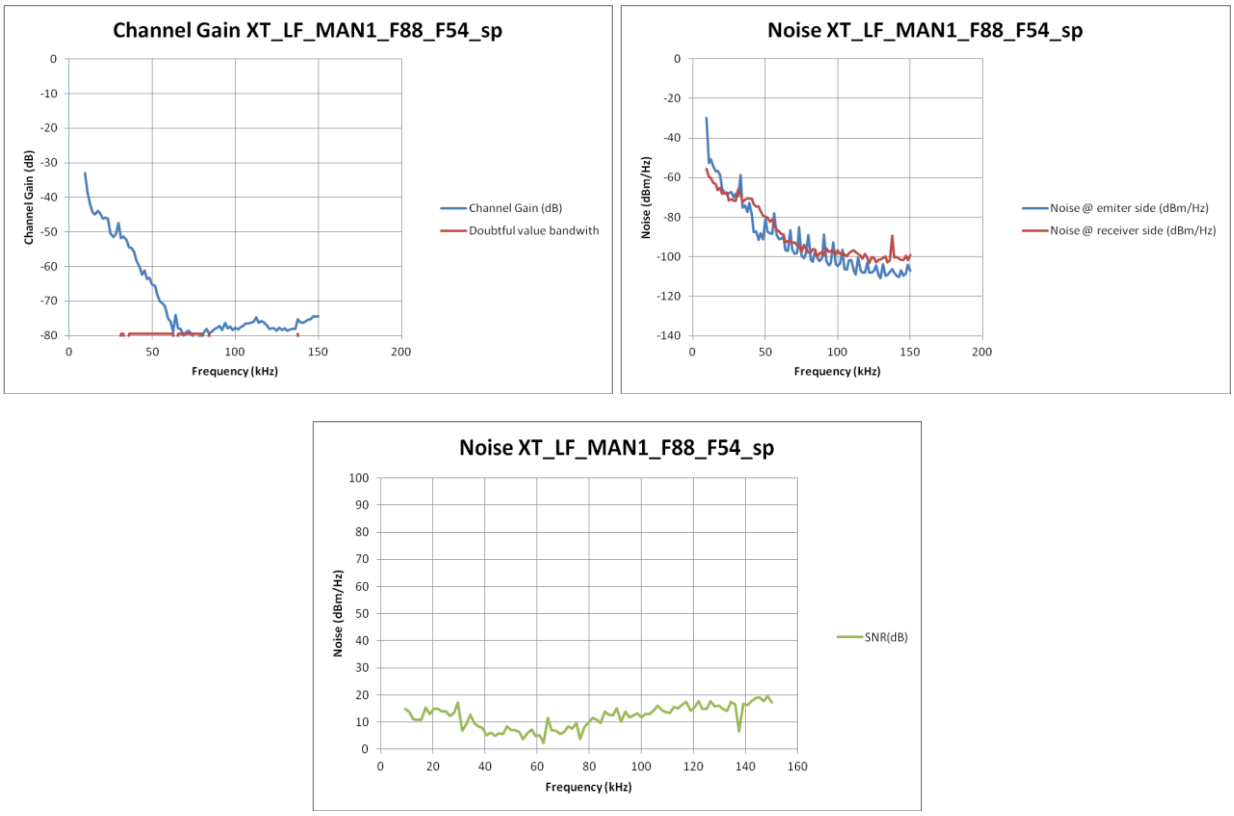


FIGURE 12 : CROSSTALK - CG_LF_MAN1_F88_F54_SP (LF)

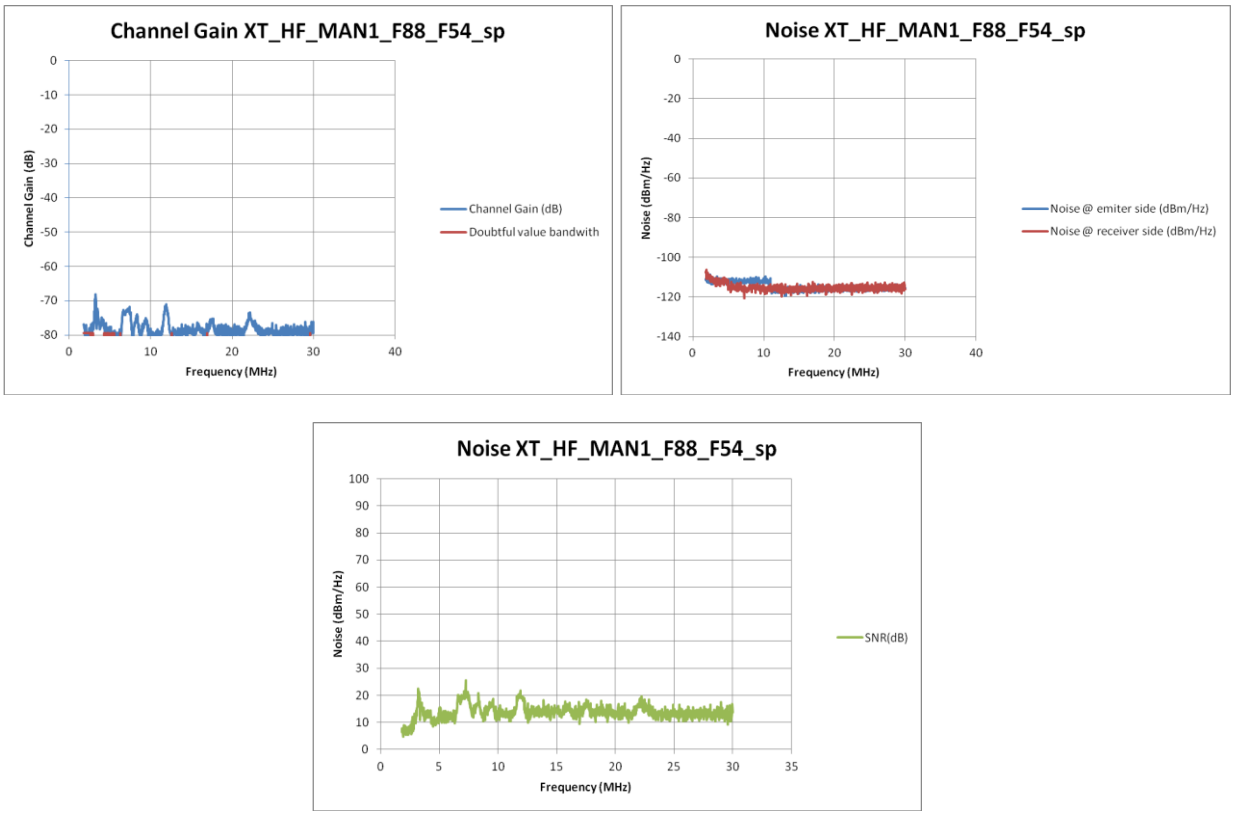


FIGURE 13 : CROSSTALK - CG_HF_MAN1_F88_F54_SP (HF)

It is important to note that, in the MAN1_F88_F54 above case, the hidden nodes issue concerns **flats that are on a same phase, and not only flats that are feeded by different phases.**

The main issue in having hidden (flat) nodes, is not really in the fact that such flats cannot communicate. Such a flat-to-flat communication is not really intended nor needed for the purpose of the IHD application, the smart metering applications is indeed rather about meter-to-flats transmissions (and vice versa). Such drastic propagation conditions between flats are not really surprising as the electrical path between flats may be very long : flats F88 and F54 are respectively located on the 16th and the 10th floors (out of 16) and several hundreds of meters of electrical wires may be encountered in some situations. Moreover, when flats are fed with different phases, the signals from one flat may reach the other flat by radio coupling only.

The issue of the hidden nodes may have a deep impact from the meter point of view and may raise 2 main questions:

1. **how will a specific meter and its related flat behave in presence of a bidirectional communication from a meter and a flat that are on a same phase and where flats are unable to "hear" each other ?** The channel access mechanism managing the transmission over the medium **shall indeed prevent the 2 flats from "talking" (or signaling) at the same time** towards their respective meter, otherwise one flat may interfere onto the other meter, polluting its communication with its flat. **This hidden node issue is a critical issue that solution providers shall answer and details shall be given about the mechanisms allowing the management of such situations.** Answers shall be documented on the implemented mechanism, and shall not only demonstrate how they address the hidden nodes issue, but also how this mechanism still allows a smooth deployment within the building, and how it impacts the whole capacity or the capacity of the deployed powerline network.

2. **The same question raises when the 2 meters (and their respective flats) are not on the same phase**. The next section below indeed illustrates how "**neighbor networks**" feeded by different phases may interfere on each others.

4.3.2 Neighbor Networks

If we consider again the Swansea building example shown above, about flats F120 and F111, which are hidden nodes for each others, one may observe that their meters may see each of the other flat. This is illustrated by the crosstalk measurements between meter M111 and flat F120 **CG_HF_SWA1_M111_F120_dp (HF)** and **CG_LF_SWA1_M111_F120_dp (LF, showing channel gain values of -50dB (HF) or -40db (LF)**.

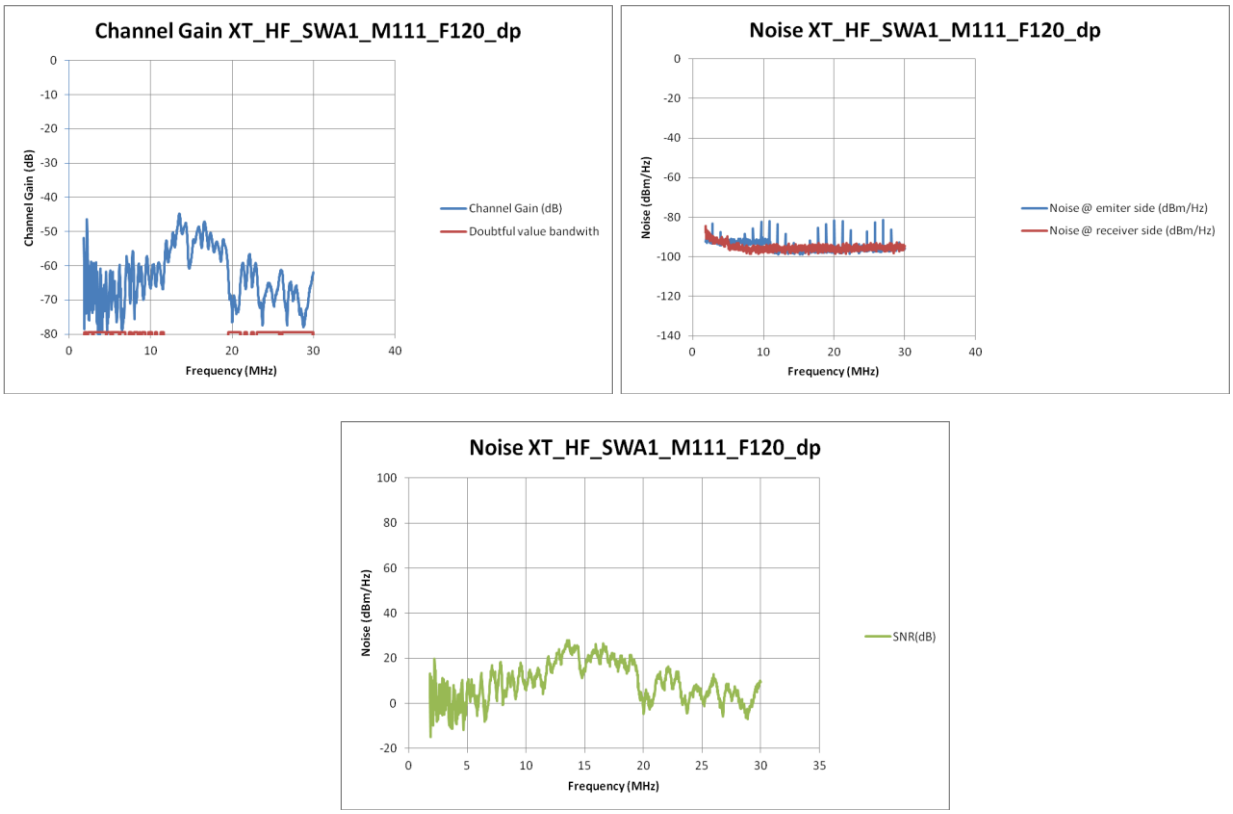


FIGURE 14 : CROSSTALK - XT_HF_SWA1_M111_F120_DP (HF)

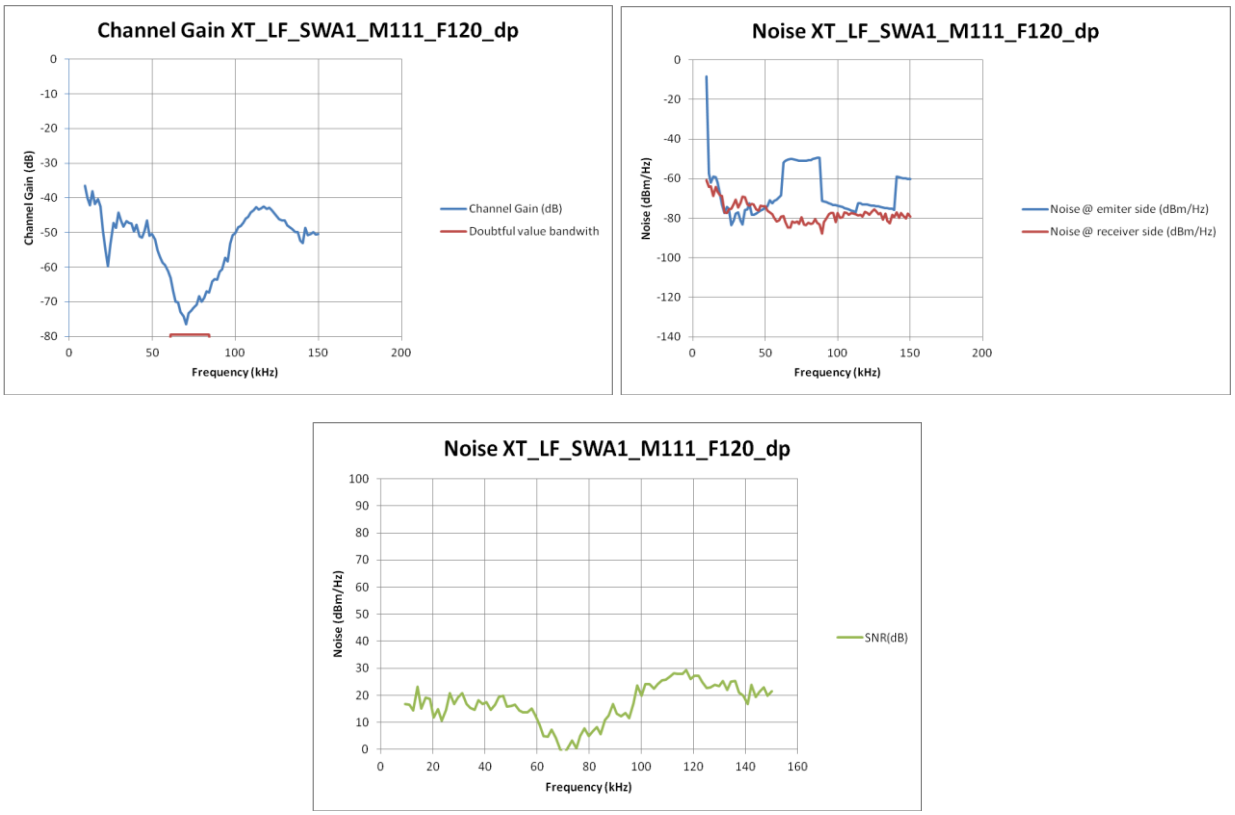
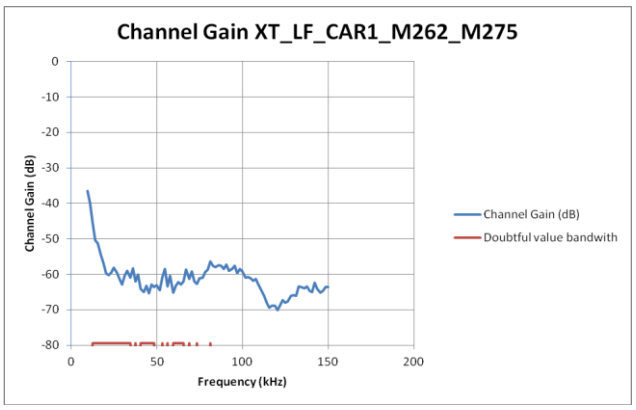


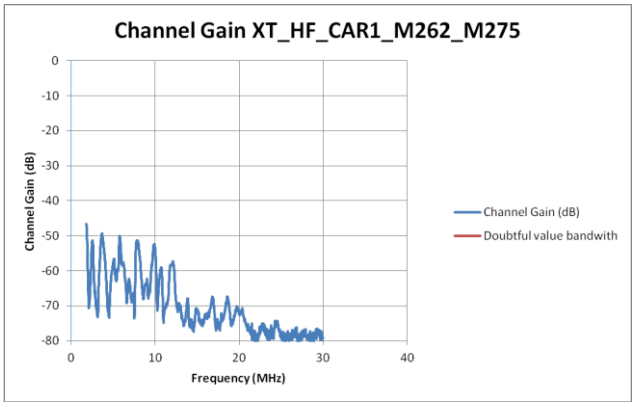
FIGURE 15 : CROSSTALK - XT_LF_SWA1_M111_F120_DP (LF)

Other typical crosstalk paths from a meter to another meter on a different phase ("_dp" extension) are shown in the following measurements:

- CG_LF_CAR1_M262_M275_dp (LF)



- CG_HF_CAR1_M262_M275_dp (HF)



Definitively these measurements show that different phases are not a barrier against cross-signaling (cross-talk) of flats or meters located on different phases. **In such neighbor networks situations, schemes of deployment and/or coexisting mechanisms for neighbor networks and the mitigation of these shall be proposed by solution providers to insure the reliability of the powerline networks.**

4.4 Noise synthesis

The electrical noise may take a large number of various aspects. While the purpose of the characterization campaign was not to capture every single type of noise, some assumptions were made about the nature of the noise which was supposed stationary and non-impulsive. Such an assumption was not always met when executing all the measurements, but such an approach allowed the capture typical noise levels in the buildings and in the residential environments.

The following figures give an insight of all the noise measurements performed in the HF and in the LF bands for the different buildings.

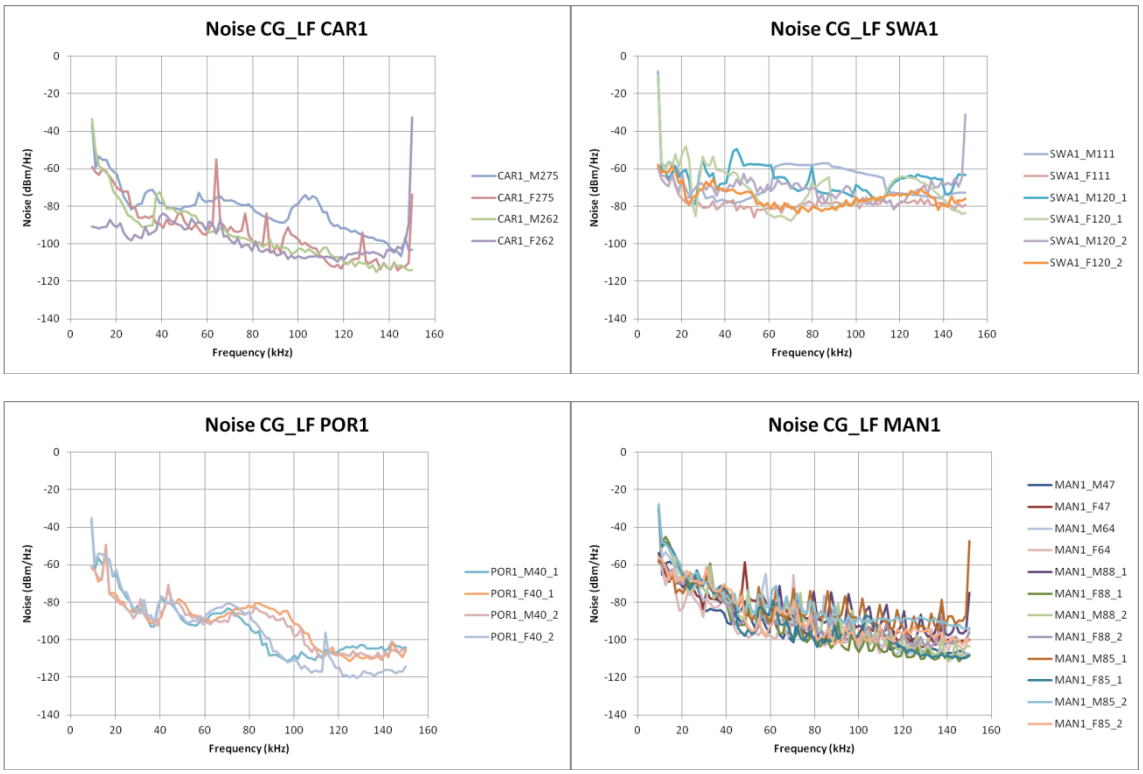


Figure 16 : Noise synthesis – LF band

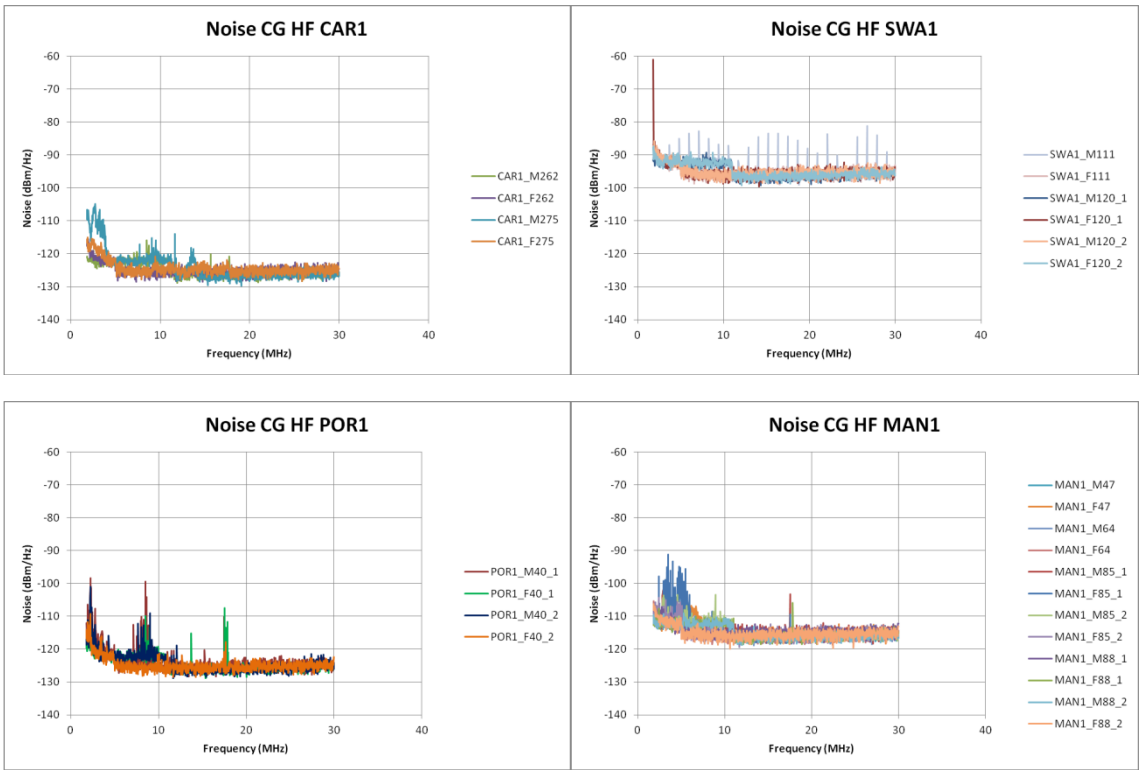


Figure 17 : Noise synthesis – HF band

4.4.1 Noise power and profiles - LF band

The above noise measurements in the LF band do not allow to derive a typical noise floor level. Indeed, noise power levels are shown to be too dispersive to extract a noise floor level. The noise power levels were indeed calculated and derived for each measurement. They are given in the table below for the HF band.

TABLE 14 - LF NOISE POWER (DBM)

	Meter	Flat
SWA1_M111_F111	23,71	-21,59
SWA1_M120_F120	22,47	-18,52
SWA1_F120_M120	0,92	22,00
CAR1_M262_F262	-1,66	-0,61
CAR1_M275_F275	-3,80	-18,96
MAN1_F85_M85	-14,05	1,53
MAN1_F88_M88	-18,30	2,21
MAN1_M88_F88	3,67	-19,74
MAN1_M85_F85	4,18	-18,76
MAN1_M47_F47	4,01	-20,88
MAN1_M64_F64	2,97	-21,25
POR1_F40_M40	-17,88	-2,89
POR1_M40_F40	-4,02	-17,02

The noise power table given above shall put into perspective with the noise measurements graphs (see above) which show the presence of potential high power peaks noises in the LF band. This is the case for instance for the different situations in the above table which have been highlighted in pink. The above power levels table also shows that a same flat (or a same meter) could be investigated twice (at its noise level): for instance flat F40 in POR1 building was measured twice (see last 2 lines of the table). **The two measurements show that the levels can vary drastically between 2 measurements from -2.89 dBm to -17,02 dBm in the LF band.** This is also true for other situations depicted in the table : SWA1_M111_F111, SWA1_M120_F120, MAN1_F88_M88.

Additionnally to this power variability, in the LF band, the noise appear to be very heteregenous among the buildings. Various and heteregenous noise shapes may be as well encountered within a same building, among the flats themselves or among the meters.

Such a dispersion in the noise measurements and shapes tends to confirm that the electrical noise in the LF band has a relatively fast variation versus time and / or versus the position in the electrical network. It is

indeed expected that the electrical interferences and impairments are varying faster in the low frequencies than in the high frequencies, due to the variability of the power network and all the electrical devices connected to it (variations of the impedances and electrical characteristics of the network may vary fast while devices are switched/powered ON/OFF, etc).

Solution providers shall demonstrate that such noise conditions in the LF band are manageable and that their solution is able to manage with such noise conditions.

4.4.2 Noise power and profiles - HF band

The above noise measurements also show that the typical noise floor level in the powerline network is round -124 dBm/Hz in average (CAR1 and POR1 measurements) in the HF band. The measurements in the other buildings display levels that are lower. This is due to the different attenuation settings used during the measurements for the different buidings (input attenuation was set high in some buildings to avoid saturation in the spectrum analyzer). Indeed, some buildings (SWA1) were inspected with an input attenuation setting at the receiver side of 60dB (SWA1) while the input attenuation setting was 40dB for MAN1 building and 30dB for the CAR1 and POR1 buidlings. For these MAN1 and SWA1 buildings, therefore, the measured noise floors are less accurate than in the other buildings (respectively -114 dbM/hz and -94 dBm/Hz).

The noise power levels were also calculated and derived for each measurement and are given in the table below for the HF band:

TABLE 15 - HF NOISE POWER (DBM)

	Meter	Flat
SWA1_M111_F111	-19,48	-20,25
SWA1_M120_F120	-20,10	-20,25
SWA1_F120_M120	-20,18	-19,75
CAR1_M262_F262	-49,89	-50,01
CAR1_M275_F275	-45,01	-49,19
MAN1_F85_M85	-39,06	-35,60
MAN1_F88_M88	-39,81	-39,76
MAN1_M88_F88	-39,91	-40,13
MAN1_M85_F85	-39,22	-39,33
MAN1_M47_F47	-39,90	-39,26
MAN1_M64_F64	-39,79	-40,14
POR1_F40_M40	-44,80	-48,85
POR1_M40_F40	-47,01	-49,39

The values displayed in the above graphs show that the levels of the noise are very consistent between flats and meters sides in the HF band. The measured noise powers highly depends on the considered building for the same reasons as given above about the input attenuation setting: while POR1 and CAR1 buildings (set with 30dB attenuation) show a noise power around -50 dBm, the 2 other buildings (MAN1 and SWA1) show power levels which are 10dB and 30dB above due to the input attenuation value which is respectively 10dB and 30dB higher.

Therefore a **realistic noise power level is -50dBm in the HF band** (flat or meter side, see above in green in the table).

In the HF band, no typical or characteristic noise profile could be observed, despite the fact that some basic characteristics may be drawn from the different buildings:

- Some spread spectrum perturbations of several MHz may appear (see buildings CAR1, POR1, MAN1) making probable the presence of electrical / radio disturbers in the HF band (below and around 5 MHz, around 7 and 14 MHz) at levels ranging from -90dBm/Hz to -110 dBm/Hz. These levels are however not too drastic given their levels.

- Harmonics of a specific frequency may also be encountered in some buildings. For instance, the noise measurement of the SWA1 building displays a strong peak at 1.8 MHz (-60 dBm/Hz) and its harmonics at 1.15 MHz -85 dBm/Hz or so. This denotes from the presence of a potential disturber that may cause impairment to the powerline communication in the HF. So far, it is not easy to determine whether such a noise is impulsive or not, and stationary or not. The noise measurement is an average measurement over 80 msec for each frequency and it is relatively "easy" to catch some impulsive noise during a measurement.

Among all the HF situations however, **the most stressfull situation resides in the SWA1_M111 above measurements** where a strong peak and its harmonics are met. This situation is good example of what solution providers shall consider to describe their ability to mitigate HF noises in the buildings.

Solution providers shall demonstrate that such noise conditions are not too drastic for the powerline solution they propose and, even if these noise measurements are not exhaustive, that their solution is able to manage with such interference and/or noise conditions.

4.5 Impedance synthesis

All the measured impedances are compiled in the charts below for the Low Frequencies (LF) for all the meters and all the different flats.

Impedances at Meters – LF band

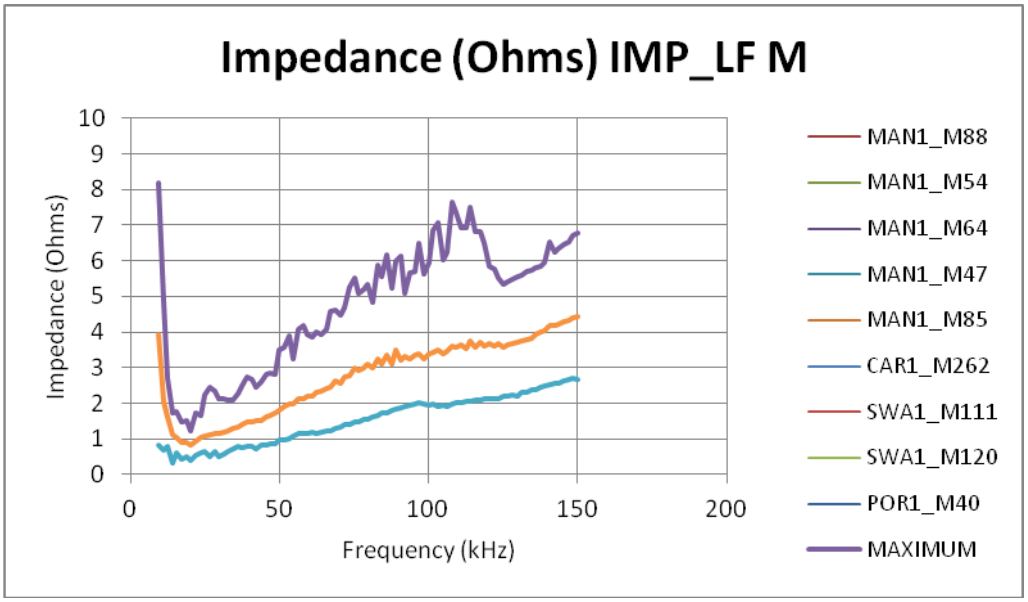


Figure 18 : Impedance synthesis at Meters – LF band

Impedance at Flats – LF band

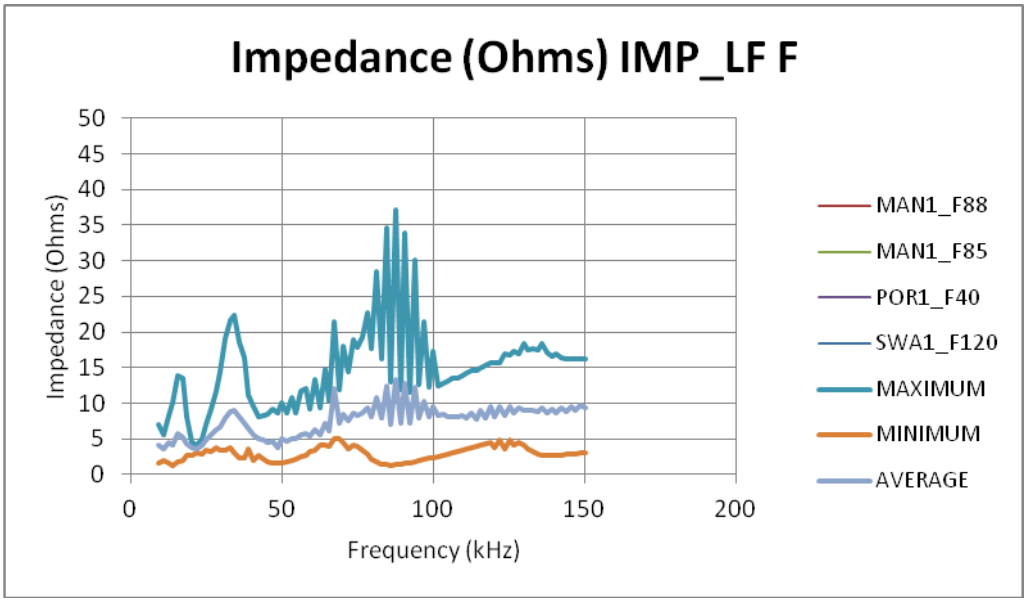


Figure 19 : Impedance synthesis at Flats – LF band

Same chart of all the measured impedances in the High Frequencies (HF) is given below for all the meters and all the different flats:

Impedances at Meters – HF band

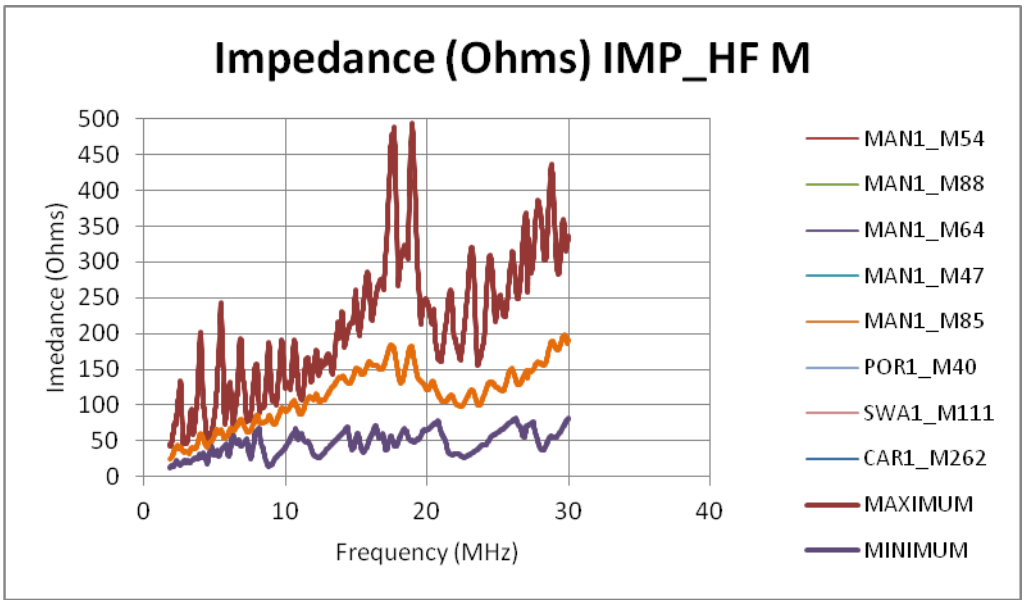


Figure 20 : Impedance synthesis at Meters – HF band

Impedance at flats – HF band

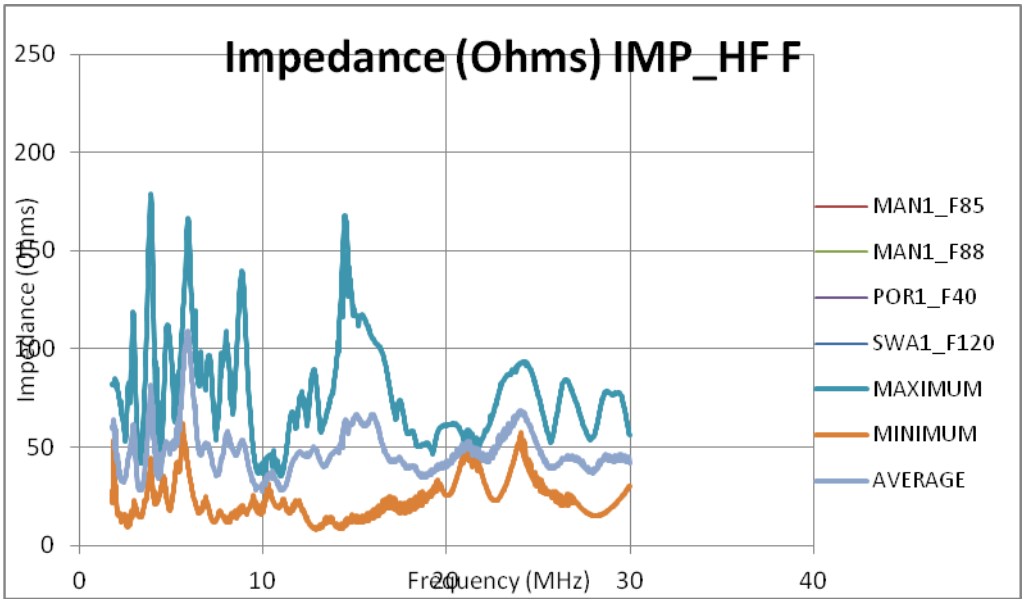


Figure 21 : Impedance synthesis at Flats – HF band

These figures giving a global view of the impedance values met at the meter side and at the flat for both rnages of frequencies. The measurement "Impedance_M120" in IMP_HF_SWA looks like to be inconsistent. Indeed this measurement contains a wrong value measured of more than 2000 Ohms and the global shape of the first part of the chart doesn't meet at all the shape measured in the other impedance measurements. An issue during the measurement execution is suspected here.

Typical values for meters and flats are listed in the table below:

	LF – Meter side	**LF - Flat side**	**HF – Meter side**	**HF – Flat side**

Min value (Ohms)	**0.3**	**1.2**	**12**	**8**
Average value (Ohms)	**2.7**	**7.5**	**113**	**47**
Max value (Ohms)	**8**	**37**	**494**	**179**

The electrical network shows very low impedances at the meter side, especially in the lower band. Solution providers shall demonstrate they can address and adapt such a variety of impedances with their solutions over the different band.

5. CONCLUSION

The behavior of the electrical line propagation has been characterized for Low and High frequencies for 4 UK typical buildings and 12 different flats. This characterization campaign was performed between the power meters and flats by a measurement of the channel gain, the noise power. Side parameters such as SNRs and cross-talk levels were also investigated during the characterization campaign.

A first analysis and overview of all the physical measurements show that no real obstacle to the propagation of the powerline signals is met either in the low, or in the high, frequencies from a meter to its related flat. The encountered and measured line attenuations do not drastically impact the HF or the LF signals (30-60dB are values that technologies shall manage easily), except in some narrow areas.

Solution providers shall however demonstrate that their solutions is reliable and robust enough when facing the variety of attenuation and noise levels met in the HAN network, especially they shall demonstrate how their solution copes with potential effects met on the electrical medium, such as hidden nodes and neighbour networks situations. They shall characterize how their solutions will manage with noise interferers or disturbers, impulsive or not, narrow or wide bands, and shall demonstrate that their solution implement specific mechanisms that address such drastic situations (error correcting codes, retransmission, etc).

It is important to note that the field trial did not address the potential impact of impulsive electrical noises which were not investigated here. This may be for further study or even addressed in a field trial dedicated to the evaluation of candidate technologies.

6. APPENDICES

6.1 ANNEX A : Channel Gain Procedure

Connections

CONNECTING NETWORK ANALYZER TO THE CHANNEL

1. Plug a coaxial cable on the "RF OUT" of the network analyzer (a type N adapter must be used)
2. Plug the other extremity of the coaxial cable to HF/LF coupler serial#0001
3. Plug the coupler on the channel to be measured (use a Euro/UK adapter if required).

CONNECTING SPECTRUM ANALYZER TO THE CHANNEL

1. Plug a coaxial cable on the "RF INPUT" of the spectrum analyzer (a type N adapter must be used)
2. Plug the other extremity of the coaxial cable to HF/LF coupler serial#0002
3. Plug the coupler on the channel to be measured (use a Euro/UK adapter if required).

Computers configuration

1. Boot up the computers on Windows XP
2. Open the "DECC" folder on desktop
3. Open Net/Spectrum-analyzer-script.xls file depending on the equipment connected on the computer.
4. Open task manager (CTRL+ALT+F1)
5. In the "Process" tab, search "EXCEL.EXE"
6. Right-click on it
7. *Select "define priority" -> "Real-Time"*

Measure launch

NETWORK ANALYZER SIDE

1. On the Excel sheet, click on the button labelled "LAUNCH HF/BF EMISSION" (see **Erreur ! Source du renvoi introuvable.**8)
2. A message box appears (see **Erreur ! Source du renvoi introuvable.**9)
3. Call the operator of the spectrum analyzer
4. When he's ready say "1…2…3…TOP !" and click OK right after saying "TOP"

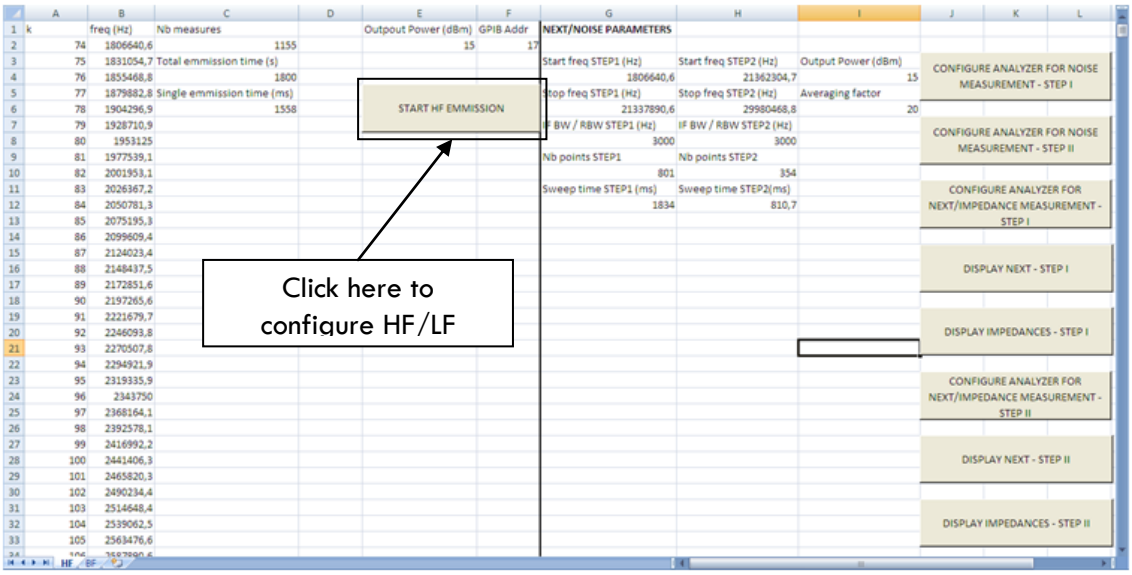


FIGURE 8 - CONFIGURE HF/LF TRANSMITTER.

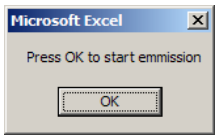


FIGURE 9 - PRESS OK TO START EMMISSION DIALOG.

SPECTRUM ANALYZER SIDE

1. On the Excel sheet, click on the button labelled "START HF MEASUREMENT" (see **Erreur ! Source du renvoi introuvable.**10)
2. Select the path corresponding to the flat where measures take place (see **Erreur ! Source du renvoi introuvable.**11)
3. Press OK
4. A message box appears (see **Erreur ! Source du renvoi introuvable.**12)
5. Wait for the call of the network analyzer operator
6. Click OK when **earring the "P"** of the "TOP" of the network analyzer operator

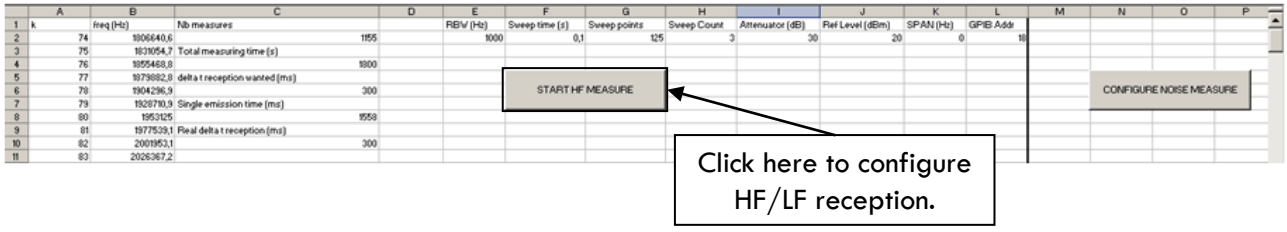


FIGURE 10 - CONFIGURE RECEPTOR.

FIGURE 11 - PATH TO FLAT SELECTION DIALOG.

FIGURE 12 - PRESS OK TO START MEASURE DIALOG.

6.2 ANNEX B : Noise Procedure

Connections

NETWORK ANALYZER (AGILENT 4395A) SIDE:

4. Plug a coaxial cable on the **PORT R** of the network analyzer (a type N adapter must be used)
5. Plug the other extremity of the coaxial cable to HF/LF coupler serial#0001
6. Plug the coupler on the channel to be measured (use a Euro/UK adapter if required).

SPECTRUM ANALYZER (R&S FSP) SIDE:

4. Plug a coaxial cable on the "**RF INPUT**" of the spectrum analyzer (a type N adapter must be used)
5. Plug the other extremity of the coaxial cable to HF/LF coupler serial#0002
6. Plug the coupler on the channel to be measured (use a Euro/UK adapter if required).

Measure launch

HF

AGILENT 4395A side:

1. Open the tab "HF" in the Excel document
2. Click on the button labelled "CONFIGURE ANALYZER FOR NOISE MEASUREMENT - **STEP I"**
3. Select the right setup in order to avoid overload on the equipment (the setup must be the same on the two equipments).
4. Wait for the 20 sweeps to be done
5. Press "OK" on the computer
6. Specify the path to the folder corresponding to the measured flat (under HF folder) by clicking on the "browse" button
7. Save the measure.

8. */!\ Click "CONFIGURE ANALYZER FOR NOISE MEASUREMENT – **STEP II**" and repeat from step 3 to 7 /!*

R&S FSP side:

1. Open the tab "HF" in the Excel document.
2. Click on the button labelled "CONFIGURE NOISE MEASURE".
3. Select the right setup in order to avoid overload on the equipment (the setup must be the same on the two equipments).
4. Wait for the 20 sweeps to be done
5. Press "OK" on the computer.
6. Specify the path to the folder corresponding to the measured flat (under HF folder) folder by clicking on the "browse" button.

LF

AGILENT4395A side:

1. Open the tab "HF" in the Excel document
2. Click on the button labelled "CONFIGURE ANALYZER FOR NOISE MEASUREMENT"
3. Select the right setup in order to avoid overload on the equipment (the setup must be the same on the two equipments)
4. Wait for the 20 sweeps to be done
5. Press "OK" on the computer

6. Specify the path to the folder corresponding to the measured flat (under LF folder) by clicking on the “browse” button
7. Save the measure.

R&S FSP side:

1. Open the tab “HF” in the Excel document.
2. Click on the button labelled “CONFIGURE NOISE MEASURE”.
3. Select the right setup in order to avoid overload on the equipment (the setup must be the same on the two equipments).
4. Wait for the 20 sweeps to be done.
5. Press “OK” on the computer.
6. Specify the path to the folder corresponding to the measured flat (under LF folder) by clicking on the “browse” button.

6.3 ANNEX C : Impedance Procedure

HF

STEP 1

1. Put the Agilent 87511A S-parameters extension on the Agilent 4395A network analyzer
2. Press the PRESET button on the network analyzer
3. On the Excel file "Net-analyzer-script", select the "HF" tab
4. Click on "CONFIGURE ANALYZER FOR NEXT/IMPEDANCE MEASUREMENT – STEP I"
5. Perform a "Full two ports" calibration by means of the LAN coupler calibration kit (see calibration procedure document)

Impedances: For each couple of outlets:

1. On the Excel file, click on "DISPLAY IMPEDANCES – STEP I"
2. Wait for the measurement to be stable on the network analyzer script, then press OK on the computer (see **Erreur ! Source du renvoi introuvable.**13)
3. Select the path corresponding to the building where measures take place
4. Indicate which flat is on port 1 and which flat is on port 2 (set them to the same number if the impedance of only one flat is measures – *on this case, the flat's outlet should be linked to port 1*)
5. Follow the steps indicated in figures 14, 15, 16 and 17 to save the measure.

STEP 2

1. Click on "CONFIGURE ANALYZER FOR NEXT/IMPEDANCE MEASUREMENT – STEP II"
2. Perform a "Full two ports" calibration by means of the LAN coupler calibration kit (see calibration procedure document)
3. On the Excel file, click on "DISPLAY NEXT – STEP II"

Impedances: For each couple of outlets:

1. On the Excel file, click on "DISPLAY IMPEDANCES – STEP II"
2. Wait for the measurement to be stable on the network analyzer script, then press OK on the computer (see **Erreur ! Source du renvoi introuvable.**13)
3. Select the path corresponding to the building where measures take place
4. Indicate which flat is on port 1 and which flat is on port 2 (set them to the same number if the impedance of only one flat is measures – *on this case, the flat's outlet should be linked to port 1*)
5. Follow the steps indicated in figures 14, 15, 16 and 17 to save the measure.

LF

1. Put the Agilent 87512A Reflection extension on the Agilent 4395A network analyzer
2. Press the PRESET button on the network analyzer
3. On the Excel file "Net-analyzer-script", select the "HF" tab
4. Click on "CONFIGURE ANALYZER FOR NEXT/IMPEDANCE MEASUREMENT"
5. Perform a "One path two ports" calibration by means of the LAN coupler calibration kit (see calibration procedure document)
6. On the Excel file, click on "DISPLAY NEXT"

Impedances: For each outlet:

1. On the Excel file, click on "DISPLAY IMPEDANCES"
2. Wait for the measurement to be stable on the network analyzer script, then press OK on the computer (see figure 13)
3. Select the path corresponding to the building where measures take place
4. Indicate which flat is on port 1
5. Follow the steps indicated in figures 14, 15, 16 and 17 to save the measure.

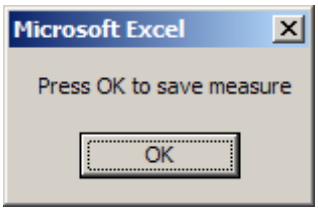


FIGURE 13 - PRESS OK TO SAVE MEASURE DIALOG.

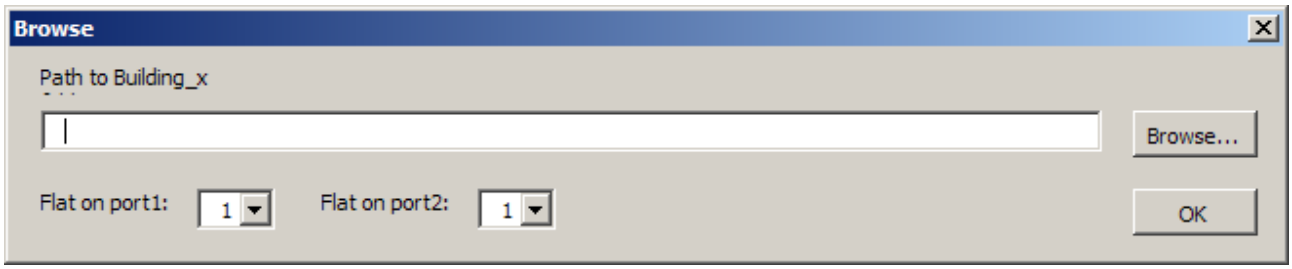


FIGURE 14 - PATH SELECTION DIALOG.

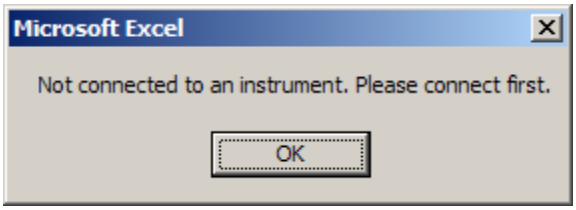


FIGURE 15 - SCRIPT LOADS AGILENT INTUILINK TOOL.

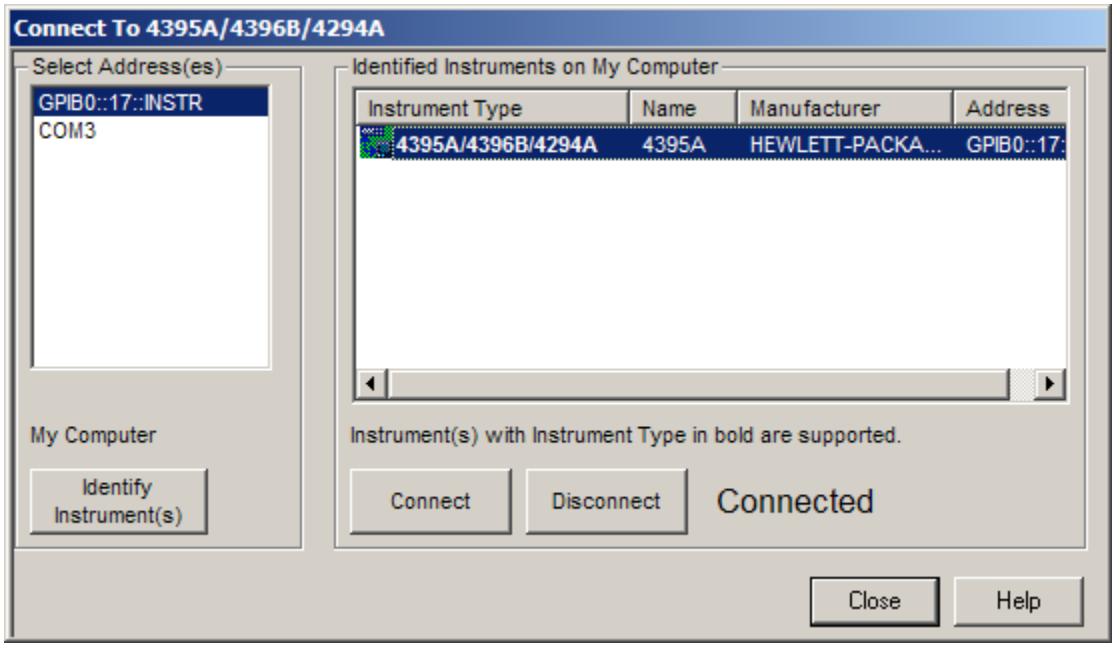


FIGURE 16 - CONNECTION TO AGILENT 4395A: DOUBLE CLICK ON THE HIGHLIGHTED FIELDS AND CLOSE.

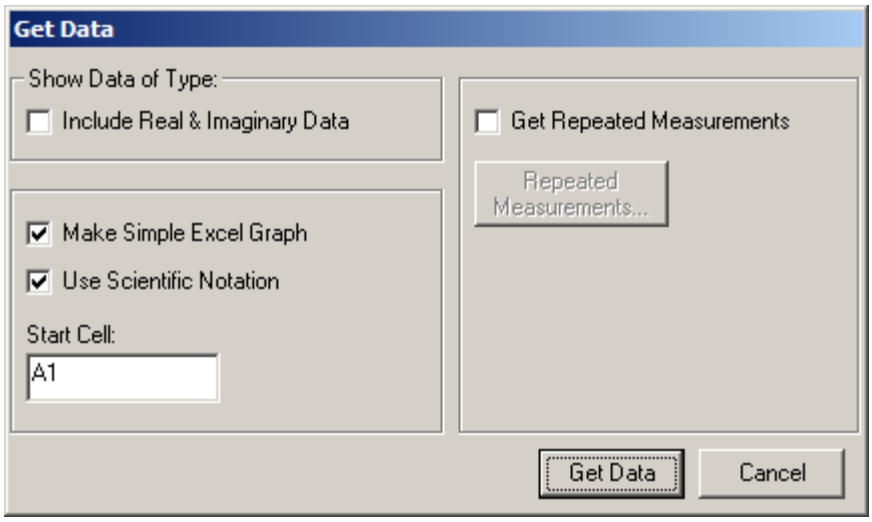


FIGURE 17 - PRESS "GET DATA" AND CLOSE THE EXCEL DOCUMENT AUTOMATICALLY CREATED.

6.4 ANNEX D : Building Information CAR1

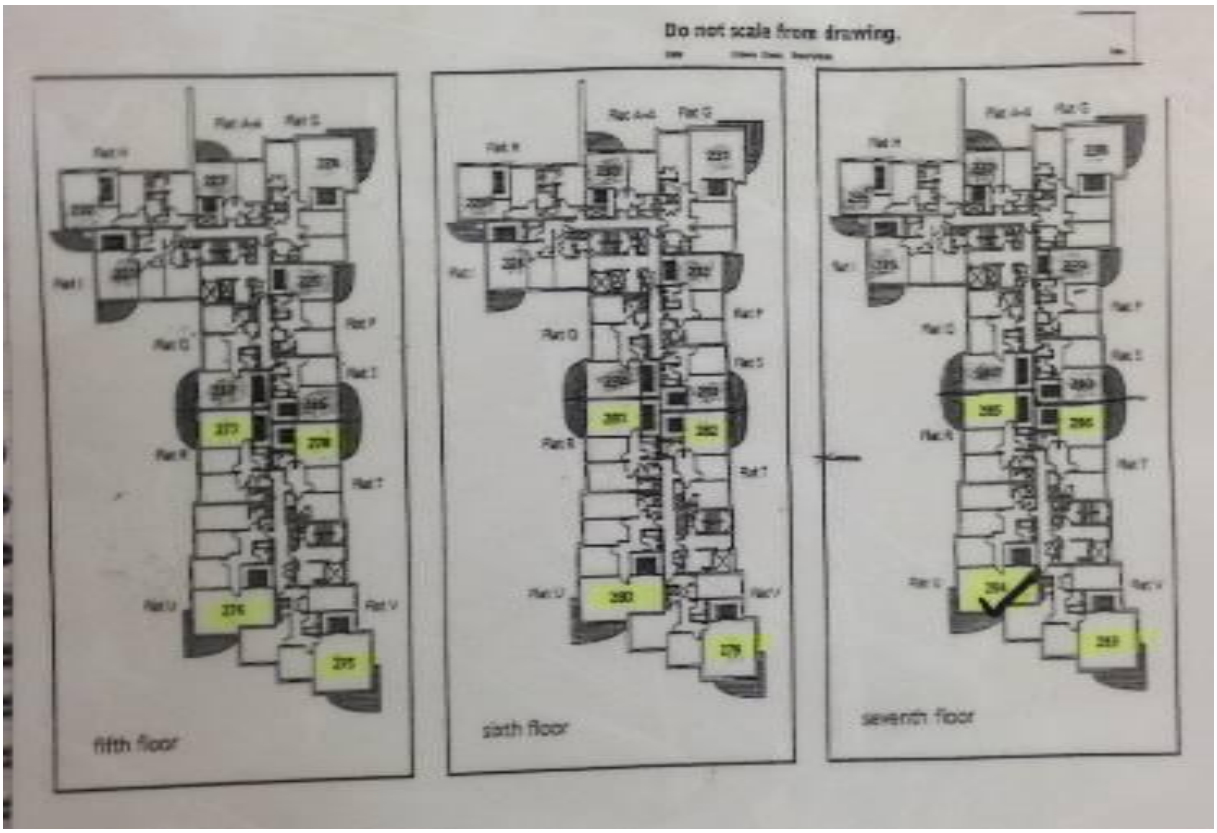
Building Survey

Cardiff

27 February 2013

Address	
Street Address	Picton House Victoria Wharf Watkiss Way Cardiff
Postcode	CF11 0SH
City	Cardiff
Approximate date of construction	1990s
Building Topology	
Number of apartments	c80
Size of apartments	One and two bedroom flats
Number of floors	10 Floors
Apartments per floor, for each floor	8 Appts per floor

sketches of the building



- Location of the electricity meters

2 Meter Rooms on first floor in centre of building

No gas metering

- Apartment numbering scheme

See above

Building

Approx

60m long.

20 m wid

Each floor 3.5 m

Building photograph (external view, whole building)

Picton House is top left

Building Wiring	
Describe the general wiring scheme: • Cable entry • Cable trunking • Distribution of phases • Lengths of cables from meter through to flat • Cable junctions	Individual feeders from meters to flats. Likely to be concentric cables. Cable within meter room on open racking. Consumer unit in flats immediately inside flat.
Meter Room(s)	

Describe the meter rooms, and provide photographs

Two meter rooms in the building

Both located on the first floor

Very close to each other

Wiring in metal boxes back to risers

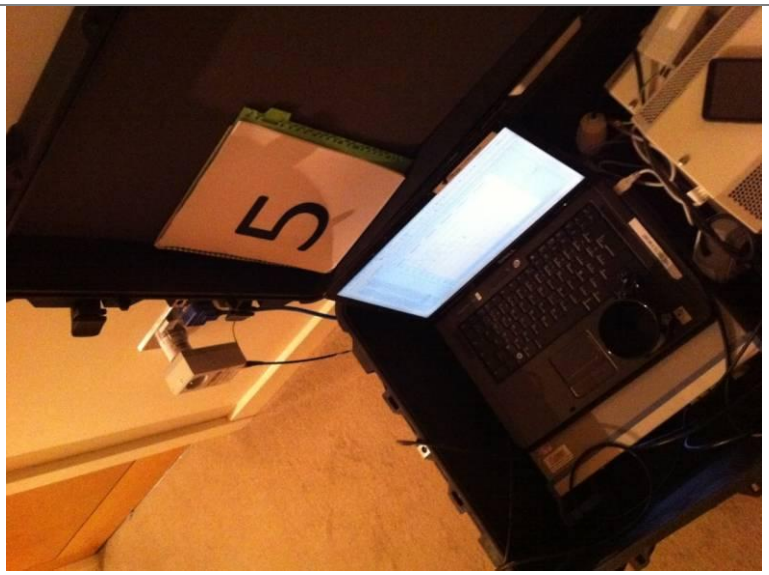
The meter rooms very spacious.

Meter layout

Dummy Meter In place

How many meters have been relocated to individual flats?	None

Flats



Test equipment in flat

Photograph examples of circuit breakers / fuses

Noise Sources	
Record potential noise sources such as:	

• Inverters connected to solar panels or other micro-generation equipment • Inverters controlling pumps • Cable TV equipment • Lift motors and controllers	No generation or special equipment Lift motors – Two lifts in building In centre near meter room and on east end of building
Low Impedance Sources	
Record potential low impedances such as: • Power factor correction equipment (e.g. for lift controllers) • Cable TV equipment	None seen
Gas	
Is the building heated by gas?	No Gas supply
Is the building heating centralised, or local to each flat?	local
Test Locations	
Record ranges of flat numbers which would be good candidate test locations	Testing at Meter Room and Flat
Record any access difficulties encountered during the survey	

6.5 ANNEX E : Building Information SWA1

Building Survey

Swansea

28th February 2013

Address	
Street Address	Meridian Tower Trawler Road Maritime Quarter
Postcode	SA1 1JW
City	Swansea
Approximate date of construction	2008
Building Topology	
Number of apartments	122
Size of apartments	Spacious apartments some over two floors
Number of floors	29 floors – top two are restaurant and the floor below is a single apartment
Apartments per floor, for each floor	4 or 5

Draw sketches of the building (plan and elevation), showing The tower has 29 storeys, double the number of the previous tallest building in Swansea, the BT Tower. Most of the tower houses residential apartments. The ground floor features a concierge desk which is manned 24 hours a day, whilst the top three floors consist of the Grape and Olive restaurant run by the Cardiff brewery SA Brains 4 or 5 flats per floor Floors 1 - 27 Meters in split level meter room in basement No gas supply to building 107meters high
Building photograph (external view, whole building)


TAXI

View from 23rd floor Appt

Building Wiring

Describe the general wiring scheme:	
• Cable entry • Cable trunking • Distribution of phases • Lengths of cables from meter through to flat • Cable junctions	Riser cables on steel tray Then clumped up building Risers very close to each other Probably dedicated concentric riser Blocks of 20 meters lead to cutout board –

	Distributed over 3 phases Meters connected to three separate substations for building.
Draw a wiring schematic, e.g.	

Meter Rooms(s)

One area split over two levels and 3 rooms

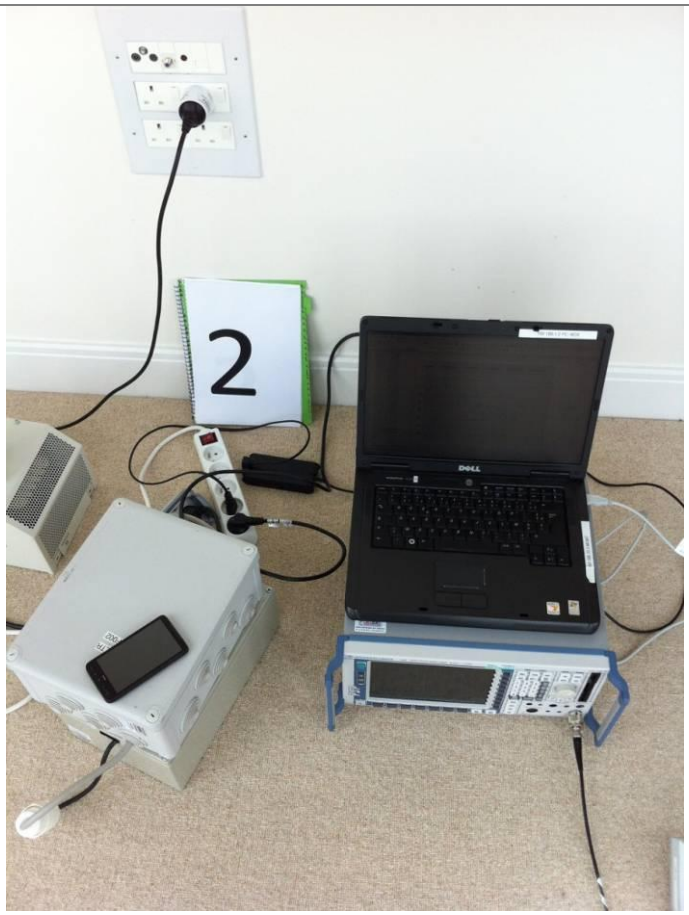
All in basement

43 – 122 on lowest level a -42 and restaurant on upper level

Blocked off area marked lift machine in upper level of meter room

How many meters have been relocated to individual flats?	None All meters original two rate E10

Flats



Test equipment in flat

Photograph examples of circuit breakers / fuses

Noise Sources	
Record potential noise sources such as: • Inverters connected to solar panels or other micro-generation equipment • Inverters controlling pumps • Cable TV equipment • Lift motors and controllers	2 lifts for apartments not near meter room 1 service lift near meter room
Low Impedance Sources	
Record potential low impedances such as: • Power factor correction equipment (e.g. for lift controllers) • Cable TV equipment	None seen
Gas	

No Gas Supply	no
Test Locations	
Record ranges of flat numbers tested	To Flat on 23 floor and one other apartment on 20 floor.
Record any access difficulties encountered during the survey	

6.6 ANNEX F : Building Information POR1

Building Survey

Porthcawl

1 March 2013

Address	
Street Address	Retirement House Lake View Close
Postcode	CF36 5NA
City	Porthcawl
Approximate date of construction	1976 Recently refurbished PV installed
Building Topology	
Number of apartments	3 blocks
Size of apartments	One bedroom retirement studio flats
Number of floors	2 Floors Long buildings
Apartments per floor, for each floor	20 Flats approximately per floor

sketches of the building

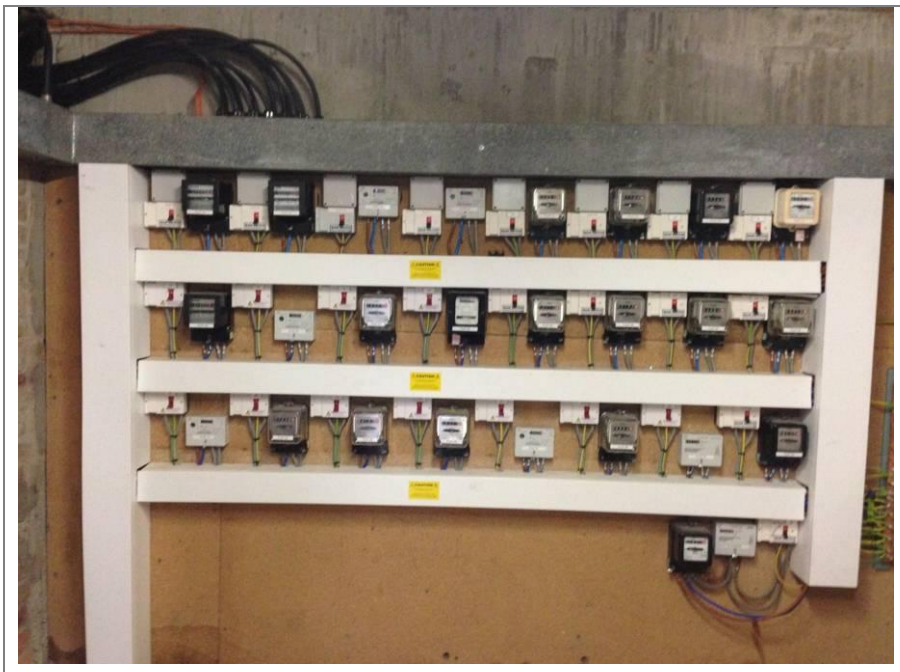
End of building showing PV

PV feed in Meter room

- Location of the electricity meters

Meters in basement room

In tightly packed board



No gas metering

See above

Building

Approx

60m long.

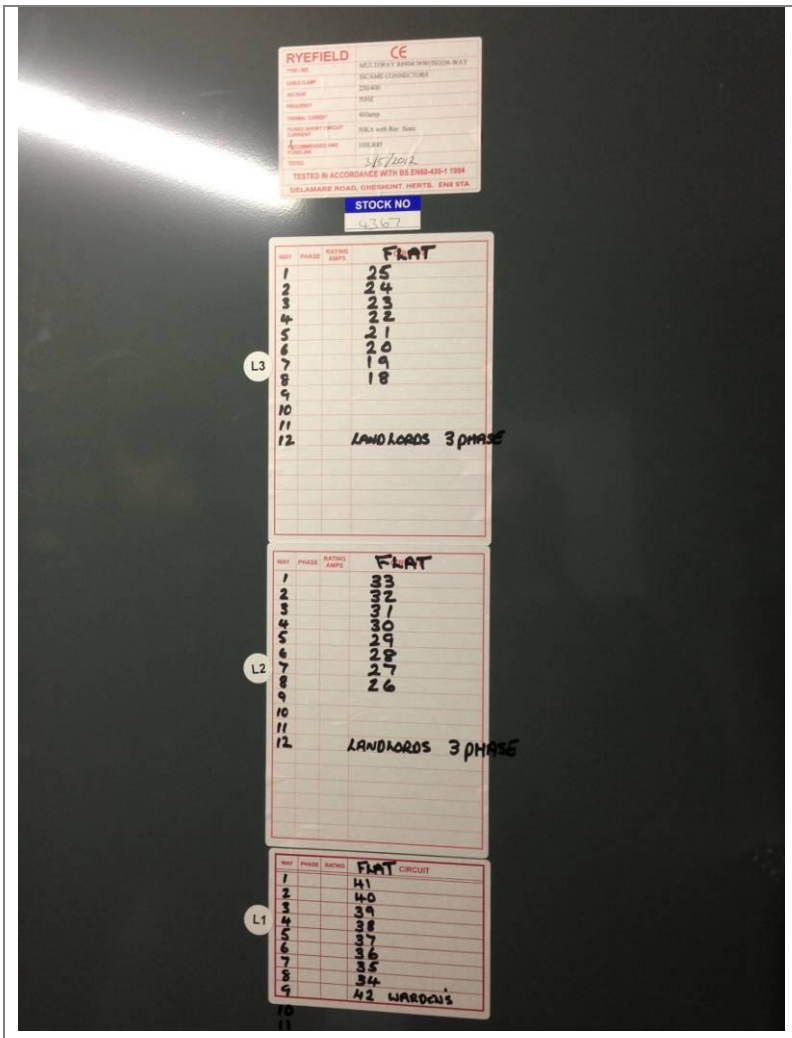
20 m wide

Each floor 3.5 mm tall

Building photograph (external view, whole building)

End view of Building showing PV

Building Wiring	
Describe the general wiring scheme: • Cable entry • Cable trunking • Distribution of phases • Lengths of cables from meter through to flat • Cable junctions	
Draw a wiring schematic, e.g.	
Meter Rooms(s)	
Describe the meter rooms, and provide photographs Meter room in basement below Warden's flat in middle of building Meters at one end of room tightly packed. **Distribution of meters and phases**	

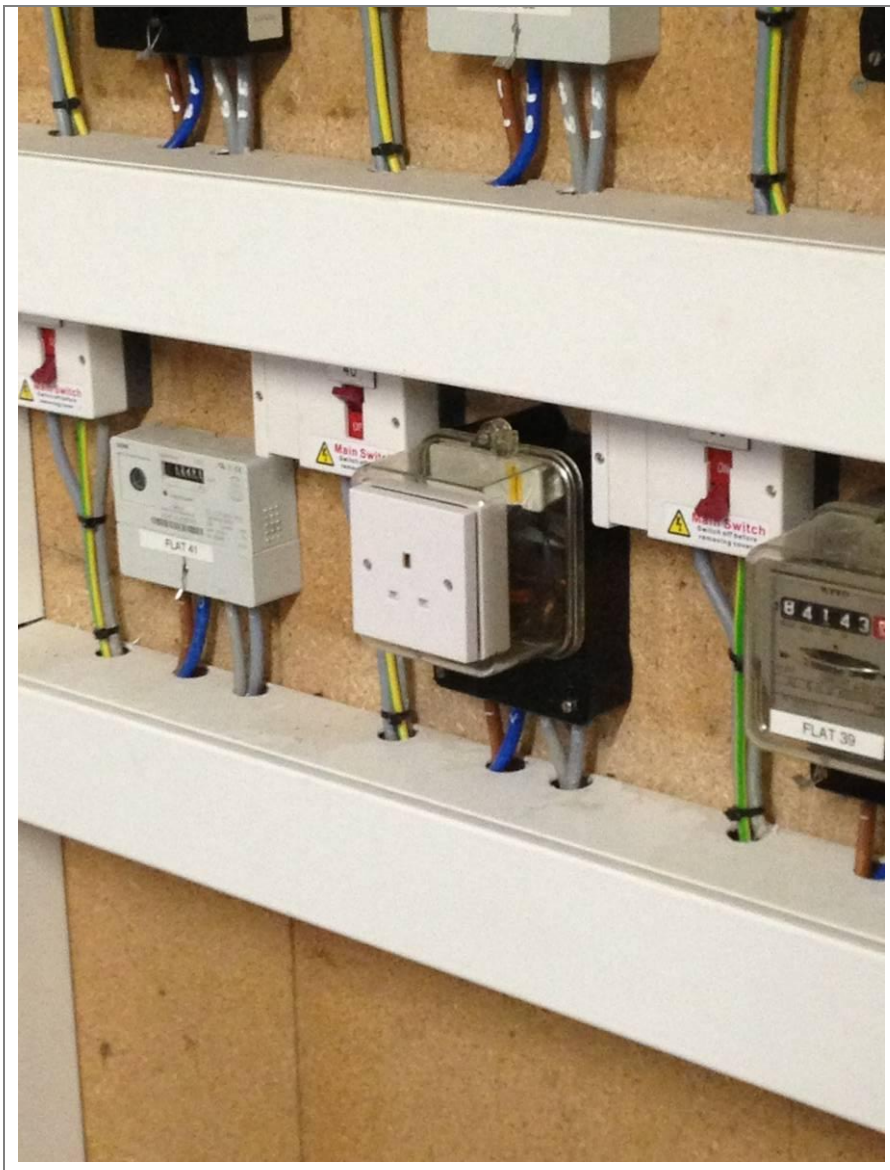


single feeder from sub station

to single block of control

3 Phase to landlords supply

Single rate Single element meters to flats



Meter for flat 40 replaced with Dummy meter

RTS equipment for Building heating.

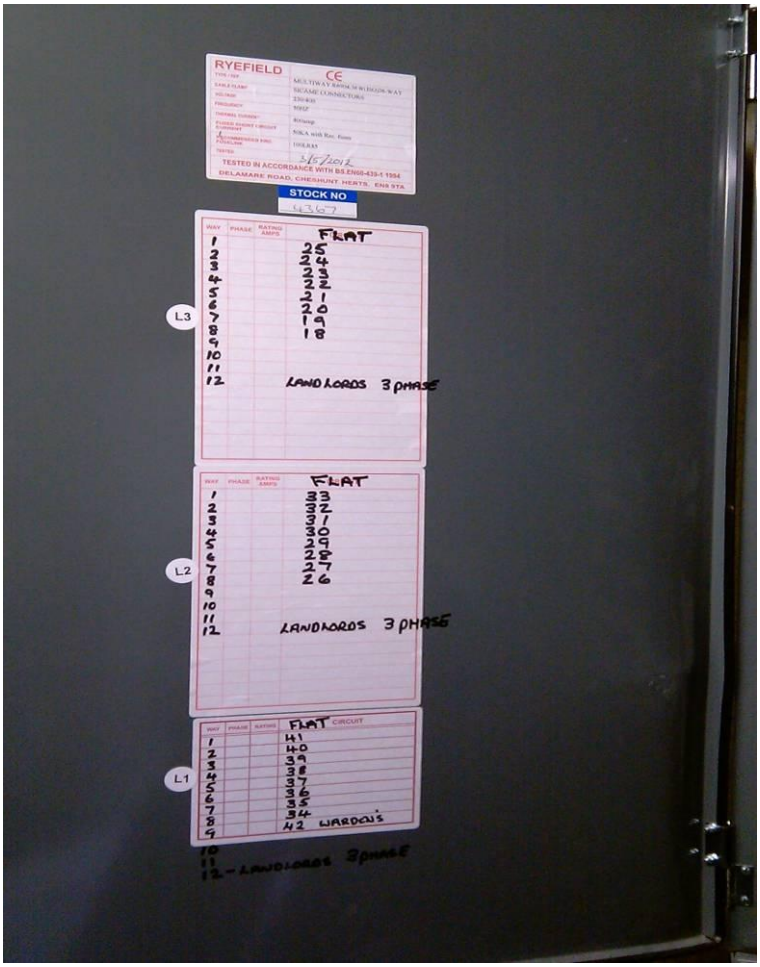
How many meters have been relocated to individual flats?	None all original meters

Flats

Photograph examples of testing in customer flats

Test equipment in flat

Noise Sources	
Record potential noise sources such as: • Inverters connected to solar panels or other micro-generation equipment • Inverters controlling pumps • Cable TV equipment • Lift motors and controllers	PV installed Service lift
Low Impedance Sources	
Record potential low impedances such as: • Power factor correction equipment (e.g. for lift controllers) • Cable TV equipment	None seen
Gas	
Is the building heated by gas?	No Gas supply
Is the building heating centralised, or local to each flat?	central
Describe the position of the gas meters in relation to the flats, and in relation to the electricity meters	
Test Locations	
Record ranges of flat numbers which would be good candidate test locations	Testing at between meter room and furthest flat (Flat 40) And between flat and flat on different phase 40 and 24

	and flat and flat on same phase 40 and 42 42 is Wardens Flat.
	

6.7 ANNEX G : Building Information MAN1

Building Survey

Date – 6th and 7th 2013 - Manchester

Address	
Street Address	Freshfields Mossfields Drive Manchester
Postcode	M9 7HQ
City	Manchester
Approximate date of construction	1970s
Building Topology	
Number of apartments	90
Size of apartments	Varied. Some appear to be small 1 bedroom, some average 2 bedrooms and those on the top floor appear to be slightly larger 2 bedroom apartments Details – www.abode-residential.com/wp/developments/freshfields
Number of floors	16 (1 being the ground floor with no flats)
Apartments per floor, for each floor	6 Appts per floor

sketches of the building

- Location of the electricity meters

1 Meter Room on the ground floor in the centre of building

No gas meters

Building

Approx

Height c 70m

Width c30m

Depth c15-20m

Floor Plan


bicycle store
meter room
water tanks
electrical sub station
office
entrance
lobby
foyer
entrance
lift
stairs
waiting area
bin store / recycling
lobby
01
hall
bedroom 2
bathroom
utility
bedroom 1
gymnasium
living / dining / kitchen
North

Building photograph (external view, whole building)

Building Wiring

Describe the general wiring scheme:	Main phase to site 400amp feed split into 3 BEMCO boxes – all using the same sub-station All the 3 feeds from the BEMCO boxes are fed via two distinct sets of trunking that feed separately up the centre of the building (one at either side of the 2 lift shafts) and consumer flats are fed from these.

- Cable entry
- Cable trunking
- Distribution of phases
- Lengths of cables from meter through to flat
- Cable junctions

Draw a wiring schematic, e.g.

Trunking (pic 1)

Trunking (pic 2)

Bemco boxes (3 of)

Meter Rooms(s)

Describe the meter rooms, and provide photographs

1 meter room in the building located on the ground floor

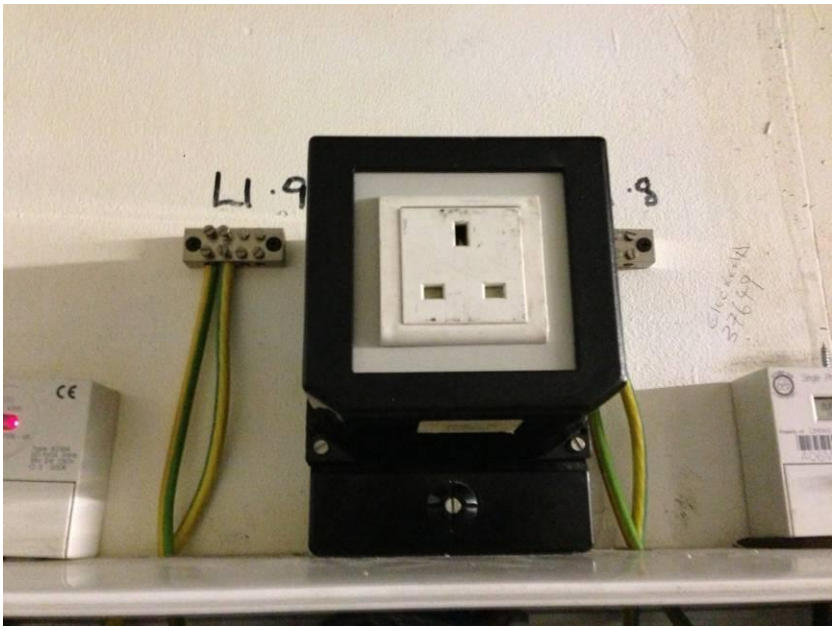
Meter Room (pic 1)

Meter Room (pic2)

Meter Room (pic 3) – gap note the gap for a smart meter to be fitted

'Smart Meters' (pic 4) – Smart meter on the left Landis + Gyr E470 and the meter on the right is an Elster meter with a comms hub fitted to the top.

Dummy Meter In place (pic5)



How many meters have been relocated to	None

individual flats?	

Flats

Photograph examples of circuit breakers / fuses

Noise Sources	
Record potential noise sources such as: • Inverters connected to solar panels or other micro-generation equipment • Inverters controlling pumps • Cable TV equipment • Lift motors and controllers	No generation or special equipment

	Two lifts in building In centre near meter room
Low Impedance Sources	
Record potential low impedances such as: • Power factor correction equipment (e.g. for lift controllers) • Cable TV equipment	None seen
Gas	
Is the building heated by gas?	No Gas supply
Is the building heating centralised, or local to each flat?	Local
Describe the position of the gas meters in relation to the flats, and in relation to the electricity meters N/A	
Test Locations	
Record ranges of flat numbers which would be good candidate test locations	Testing at Meter Room and customer flats
Day1 – Flats 85 and 47 - on separate phases in the building. One customer not in so two customers available on the day. 1st and 2nd test (flat to meter room and meter room to flat) – the flat was on the 16th floor, number 85 (picture of test 2 in the meter room)	

3rd Test (cross talk) flat on the 15th floor and 8th floor – flats 85 and 47. Different phases, but only recorded noise.

4th test meter room to flat on the 8th floor – flat 47

5th test impedance against flat 47 floor 8

Day2 – Flats 54, 64 and 88 – 54 and 88 on the same phases and 64 on a different phase.

1st test impendence test against flats 54,64 and 88 – floors 9,11 and 16 respectively

2nd and 3rd test flat 88 (floor 15) to meter room and vice -versa

4th test - Cross talk between 54 and 88 (both flats on the same phases)

5th Test – meter room to flat 64

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