



Thomas Keating Ltd

Station Mills, Daux Road
Billingshurst, West Sussex
ENGLAND. RH14 9SH

Tel: +44 (0) 1403 782045 Fax: +44 (0) 1403 758464

www.terahertz.co.uk

Project Title	340 GHz Quasi-Optical Circulator system for atmospheric loss measurements				
Doc. Title	Performance measurements in Imperial College, London				
TK Doc. Number:	QOC_TK-RP-0005	Issue	Draft a1	Project Ref. No:	TK_QO_ATM_2008 13
Date:	23/6/2015				
TK Project No:	Issued on order		Customer	CRIRP	
TK Contact	Richard Wylde		Contact:	Dr Lu	

Prepared by:
Richard Wylde

Authorised by: Richard Wylde

Signed: 
(Richard Wylde)

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Document Change Record

Issue	Date	Remarks
Draft	23/6/2015	Initial draft for customer comment.

1 INTRODUCTION

This technical note presents the results of test measurements performed on the **340 GHz Quasi-Optical Circulator system for atmospheric loss measurements**. Measurements were performed in the basement of the Royal School of Mines building, Imperial College (IC), in London

1.1 METHODS OF OPERATION

To recall, the method of operation is based upon the use of two grids to form the circulator. This is the simplest system and is frequency independent, but has a -6dB Quasi-Optical (QO) loss. The return reflector is flat. The transmitted and reflected beams are in a single linear polarization.

1.2 QUASI-OPTICAL DESIGN

The QOC will take a low power (few 10's mW – say 13dBm) 340 GHz mm-wave source (assumed supplied by VDI) and form a Gaussian beam using a corrugated feed horn. The horn injects a signal into the Quasi-Optical circulator circuit and onto a main off-axis ellipsoidal dish of about half a metre in projected diameter. The beam will then propagate about 500 metres and be reflected back by a reflector (curved mirror, roof mirror or corner cube) where the circulator will route the signal to the detector via a second corrugated horn.

1.3 LOSSES FROM BEAM EXPANSION.

Gaussian beam-mode calculations have been made of losses due to beam expansion.

For 300 GHz and using a 150mm 1/e amplitude beamwaist, then losses at a few metres are negligible. At 500 metres to the mirror, the beam expansion/curvature losses are -17dB and at 1km, about -27dB. At 50 Metres, the loss is under -2dB

2 HARDWARE

The QOC system has been made from two parts - the Transceiver and the Reflector

2.1 TRANCEIVER QOC

- Two corrugated feed horns – one attached to the source, the other to the receiver
- Focusing and flat mirrors: One of these mirrors will be large at about 0.5m in size
- Polarizing wire grids
- All mounted on a slave baseplate.

See Figure 1 below

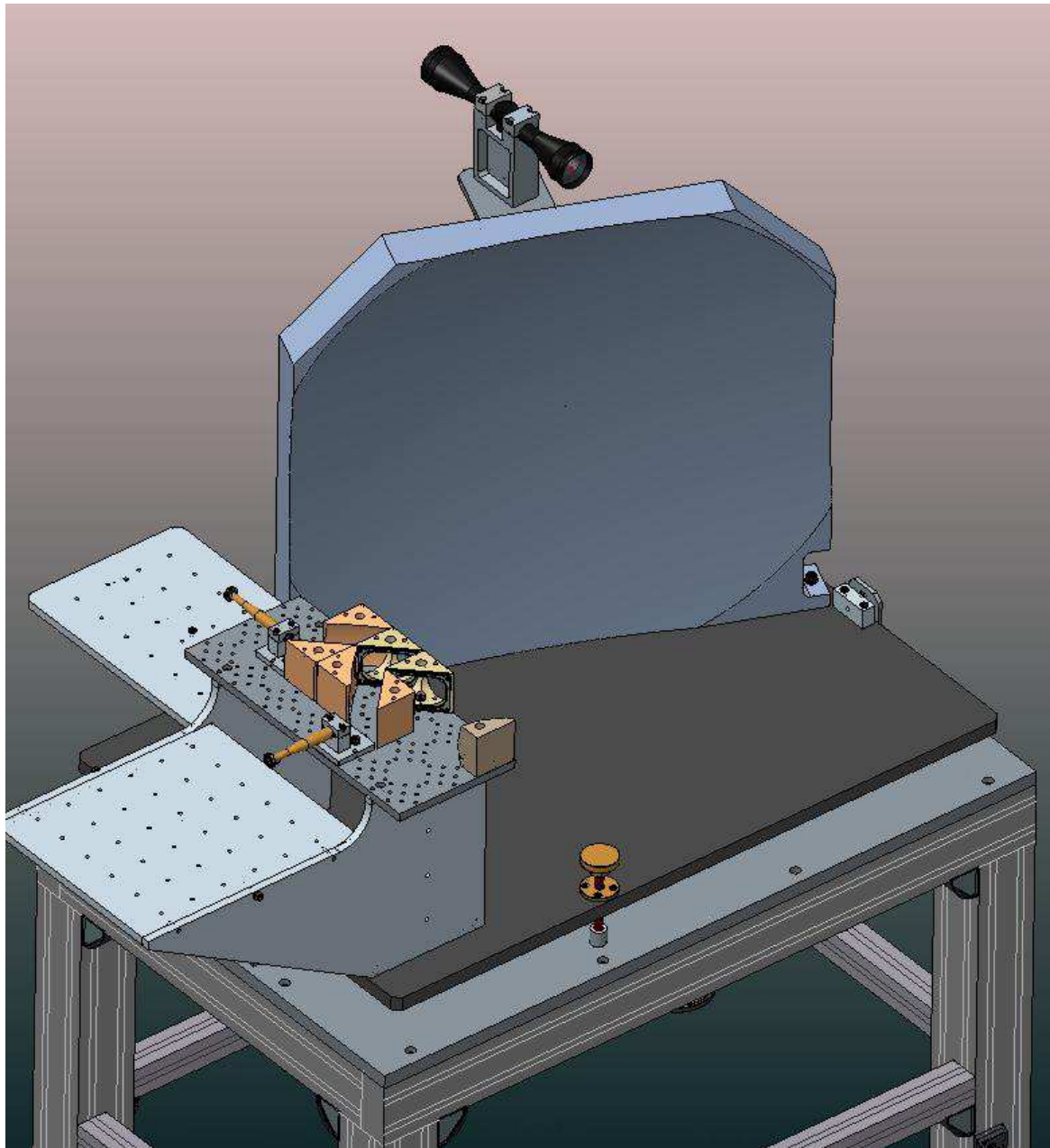


Figure 1 - the Transceiver QOC structure showing the half-metre main ellipsoidal dish

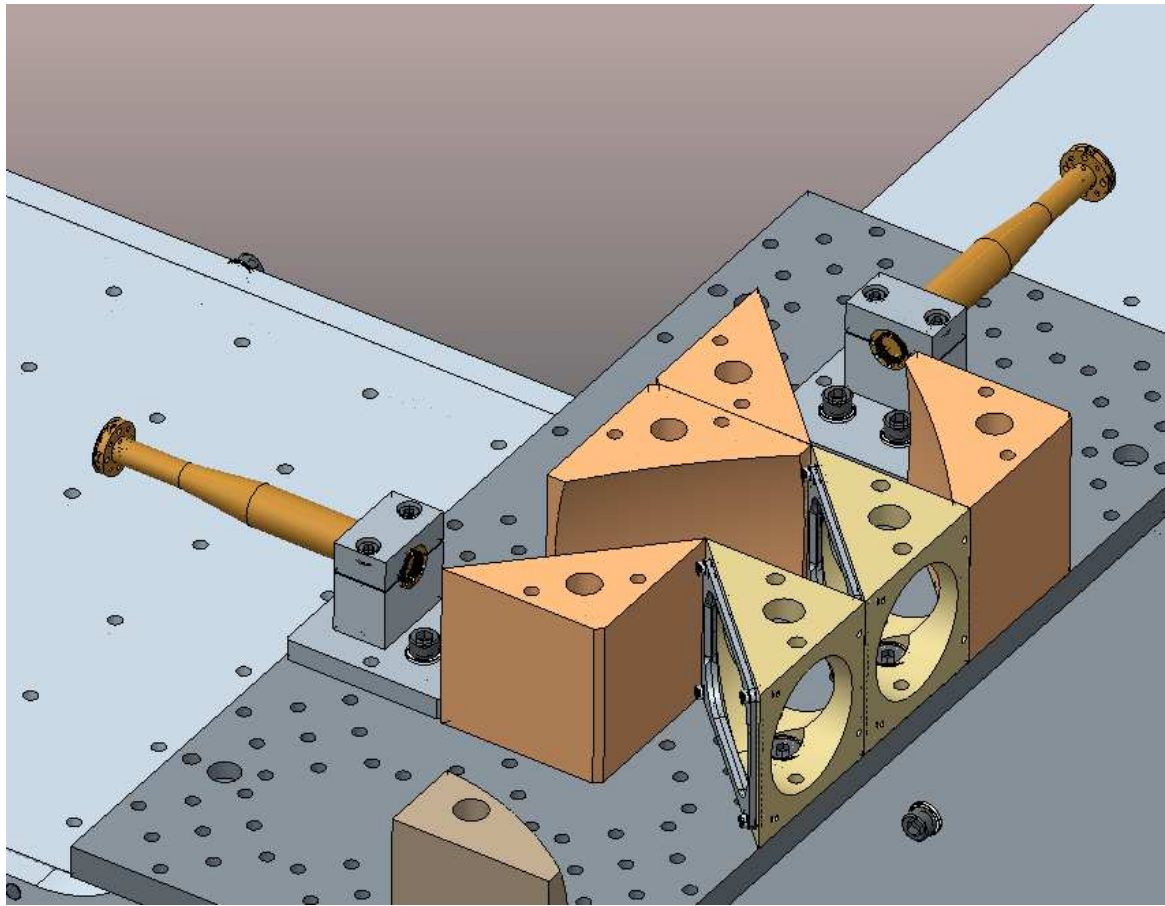


Figure 2: Detail of the QOC internal workings.

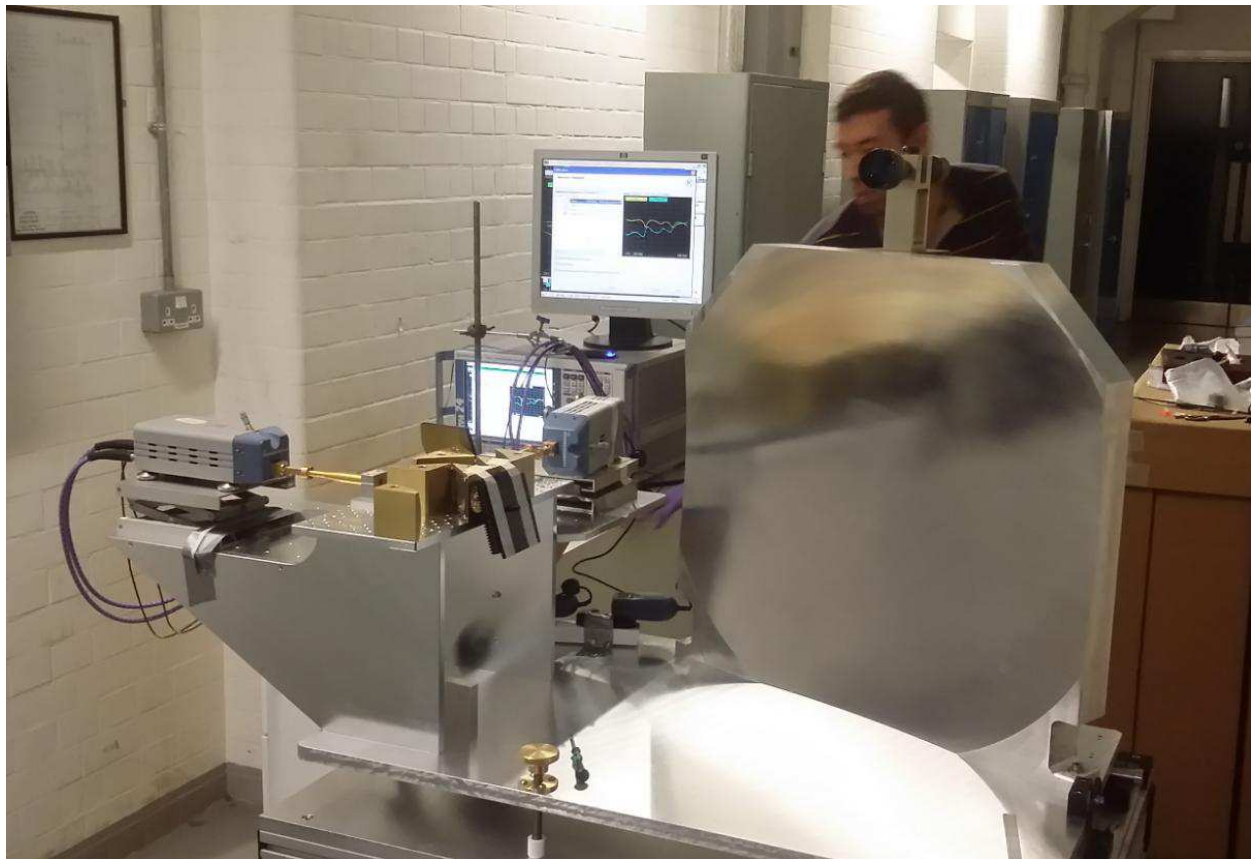


Figure 3: The Transceiver with the VNA heads mounted and the VNA instrument in the back

2.2 REFLECTOR

The Reflector, mounted onto a stable horizontal platform, with appropriate Rexroth mounting to ensure that the mirror could be gimbaled, was positioned some 25 m down the corridor.



Figure 4: The Reflector at the end of the IC basement corridor

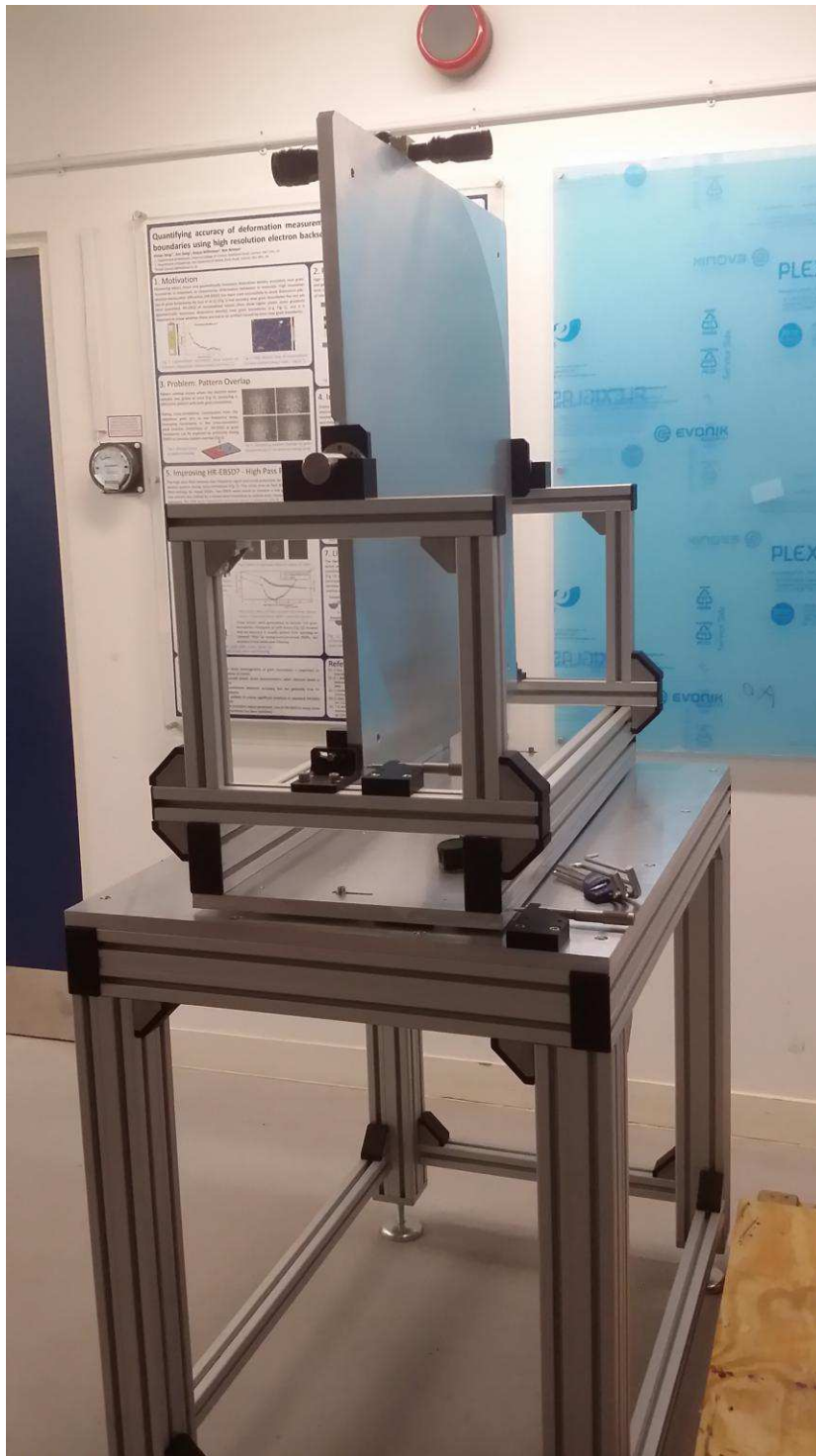


Figure 5: The Reflector showing the method of adjustment

3 PERFORMANCE & ACCEPTANCE CRITERION

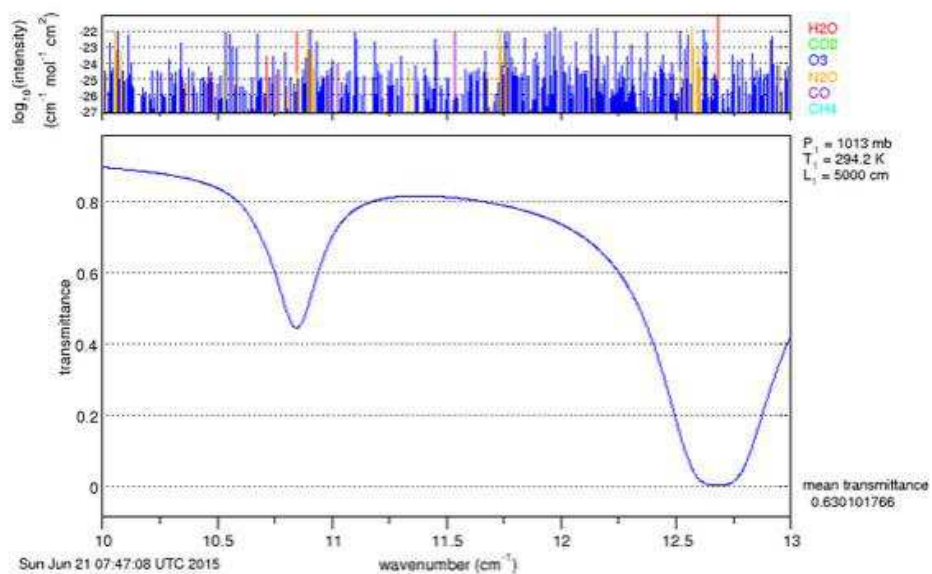
The order to TK set out the following specifications, and set out that Acceptance testing will take place in the UK.

Parameter	Requirement
Double grating device loss	-7dB (This loss ignores small losses from the feed horn and mirrors)
Beam spreading loss	-2dB (TK can only test in the UK the 50M round trip, 25M each way). -8dB (TK can only give Analysis to show for 300M round trip (150 M each way))
Transceiver isolation	Better than 40dB (TK has achieved 50dB in an instrument at 94 GHz (a Cloud Radar) recently. But this is dependent upon grid performance and we are operating at a higher frequency. For this project, TK can accept 40dB as an acceptance specification.)
Tx Input Port	UG387/U-M flange on a WR2.8 flange,Horizontal E-field
Rx Output Port	UG387/U-M flange on a WR2.8 flange,Vertical E-field

4 ATMOSPHERIC LOSSES

On the day of the measurement, the temperature in London was 20 degrees Centigrade with humidity of 73%. A HiTRAN model for US mid-latitude atmosphere gives a 50 m transmission at 11.33 CM-1 of 0.8 or a loss of 1dB. The US mid-latitude atmosphere model has a lower humidity, and losses are therefore expected to be slightly higher. See image from <http://www.spectralcalc.com/> below

Gas	Isotopologue	Scale Factor
H2O	All	1.0
CO2	All	1.0
O3	All	1.0
N2O	All	1.0
CO	All	1.0
CH4	All	1.0



5 MEASUREMENTS

Though the good offices of Dr Stephen Hanham, we had the use of an R&S Vector Network Analyser and appropriated extension Heads to perform a 340 GHz vector measurement. The VNA can be seen in the photo presented in this note.

Calibration of the VNA was difficult: Calibrations at such high frequencies require that the cables attached to the Heads remain very stable, and to perform a S21/S21 calibration requires the two Heads to point at one another. Movement to the positions required to test the circulator requires that the cables be moved and one head twisted. That limited the accuracy of the S21 measurements (but not the S11 measurements) performed.

Measurements were performed from 335 to 345 GHz, a band of 10 GHz.

The two Ultra-gaussian corrugated feedhorns were first checked for performance. Their S11 return loss can be seen below and is well below -30 dB, indicating good performance.

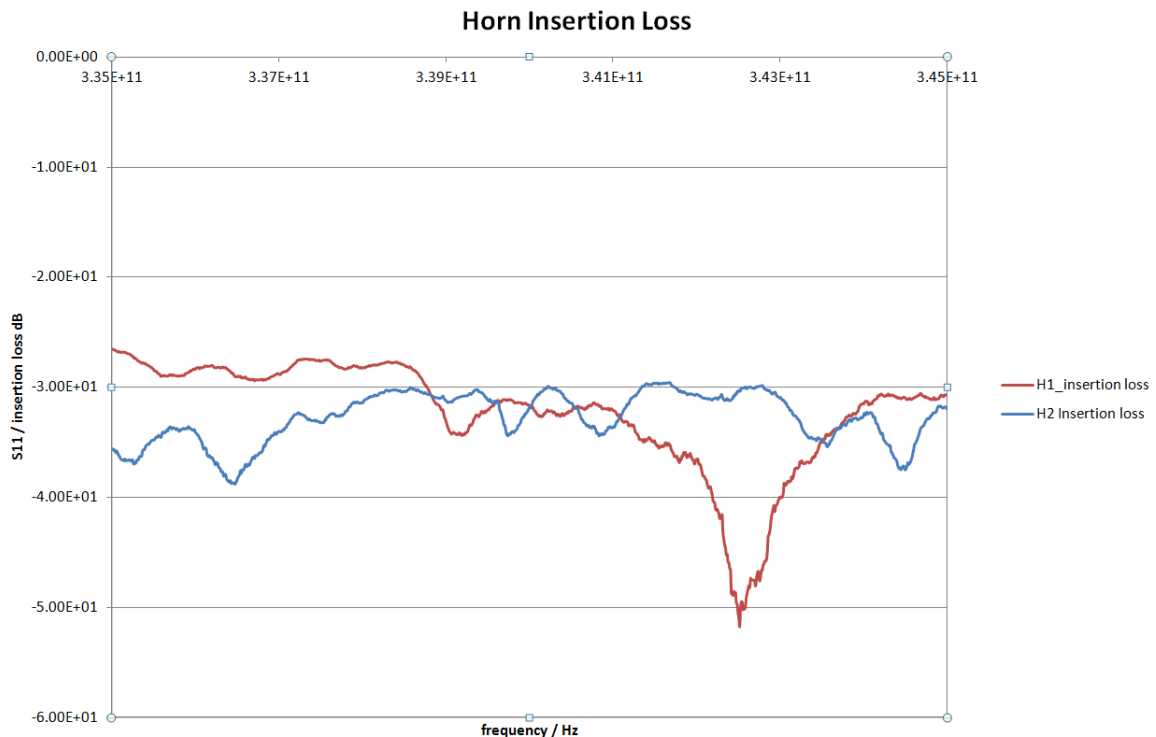


Figure 6: Horn Insertion loss

The Transceiver isolation was then measured, by attaching the Heads to their appropriate positions, and placing a piece of Radar Absorbing material (RAM) in the beam path to the reflector. We were very encouraged to note that the isolation was in the range of -57dB (a nearly 20dB margin over the requirements. This will (given the high dynamic range of the VDI Transceiver) allow very sensitive/absorbing paths to be measured.

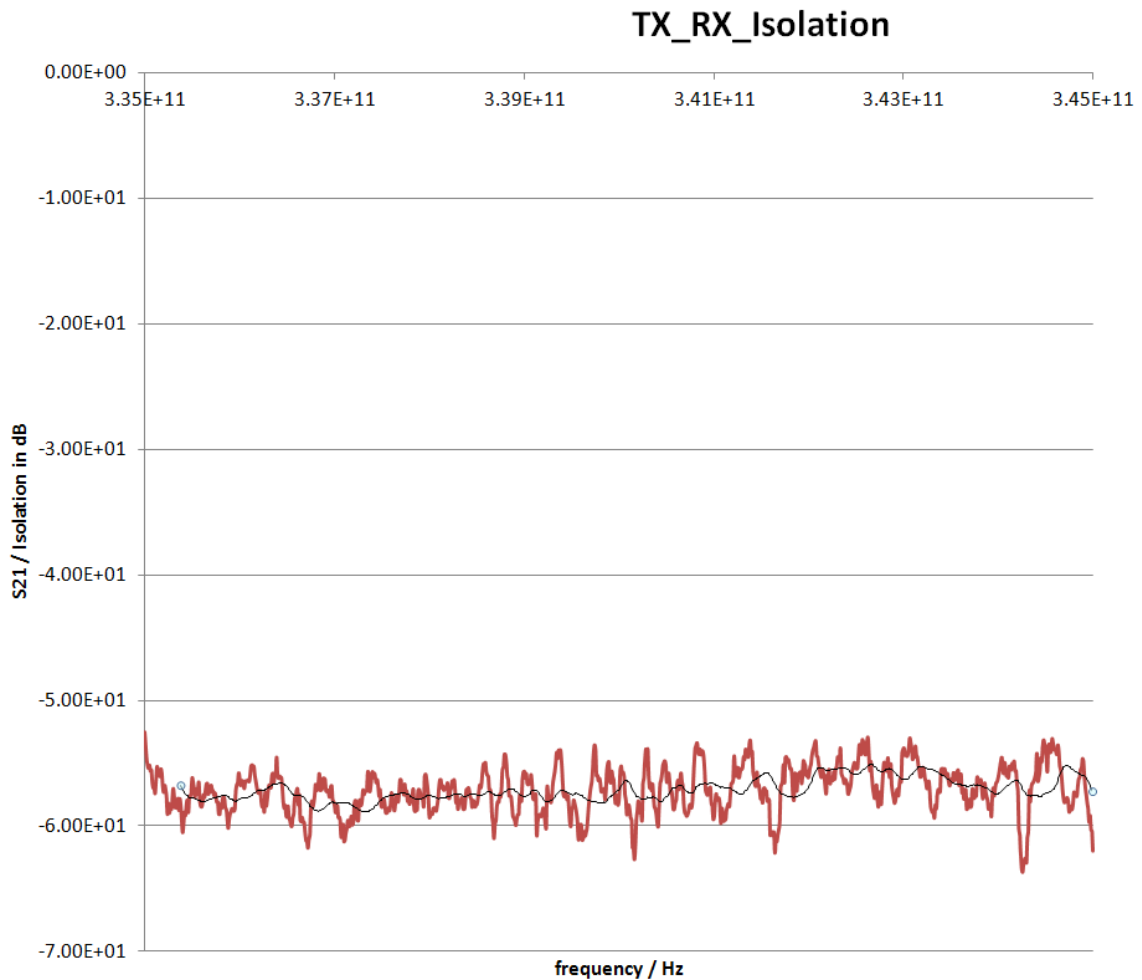


Figure 7: TX to RX isolation

Short range S21 loss was measured by placing a flat mirror placed before the hyperbolic subreflector and these showed S21 path loss close to the -7dB predicted.

Finally the 50 m round trip loss was measured. The scope sites on both the Transceiver and the reflector were co-aligned with each other, to obtain an initial S21 signal, and then the reflector adjusted using the micrometers provided to maximise the signal. The VNA results below show this to be of the order of 9.6dB, a satisfactory result, and within the specification, when taking into account the >1dB of atmospheric loss.

A check was made that the beam was centred on the middle of the Reflector by introducing RAM material from the edge in all 4 quadrants - the return signal started to drop in roughly the same intrusion distanced in all 4 quadrants.

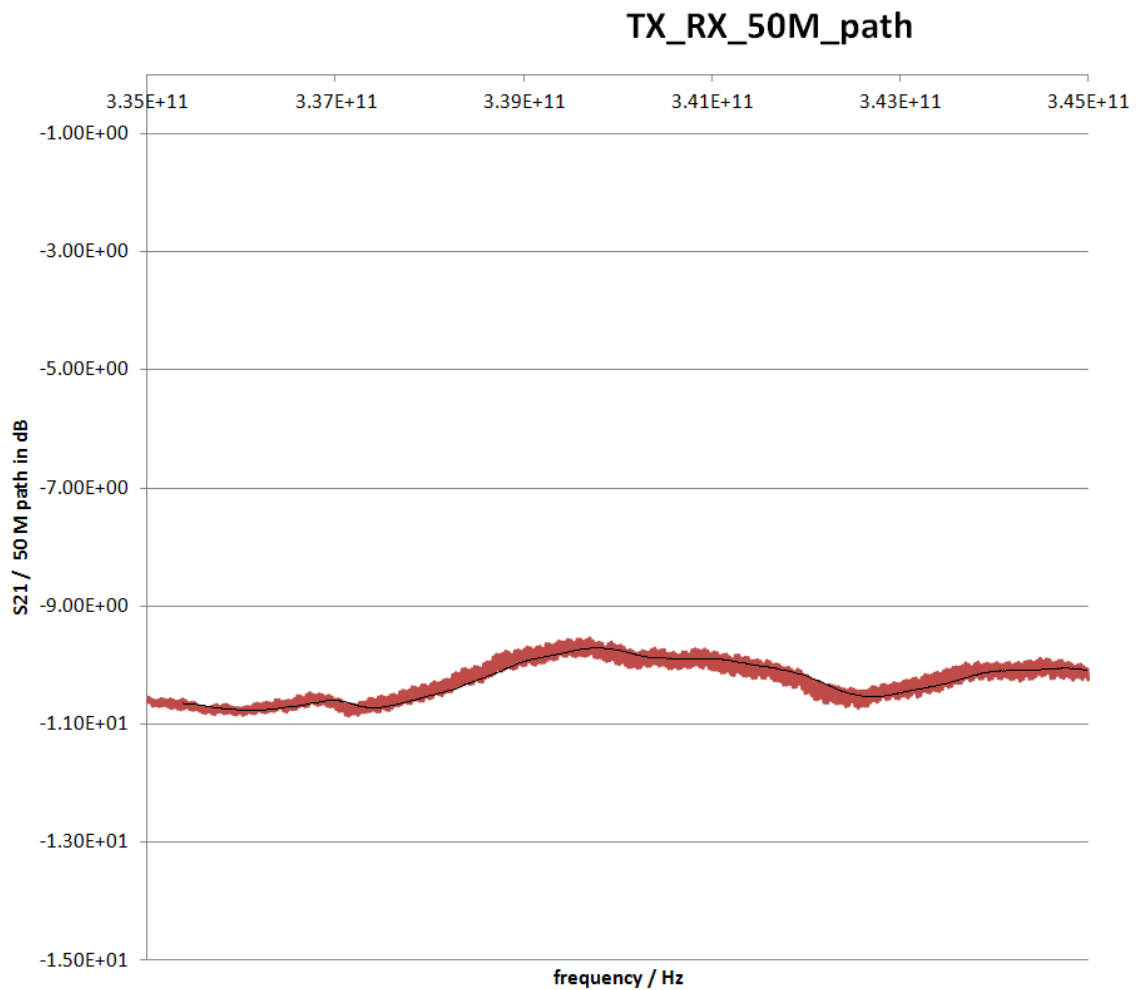


Figure 8: TX to RX loss over 50 M path length

Given the ability of the VNA to measure S_{11} and S_{22} performance we are also able to check the transmitted beam and receive beams were well co-aligned - i.e. movements of the Reflector off beam boresite lead to very similar drops in signal levels. It should be noted that a precision setting - which will be provided by the X and Y adjustment micrometer - is needed to optimise signal power and small angular movements of the Reflector do reduce the signal rapidly. So firm mounting of both the Transceiver and Reflector will be necessary.

6 CONCLUSION

We have achieved the required specifications. The Transceiver isolation is particularly pleasing.

Parameter	Requirement	Result
Double grating device loss	- 7dB (This loss ignores small losses from the feed horn and mirrors)	Measured at -7dB
Beam spreading loss	-2dB (TK can only test in the UK the 50M round trip, 25M each way). -8dB (TK can only give Analysis to show that 300M round trip (150 M each way)	At 50M round trip Measured at -2.5 dB, less >-1dB of Atmospheric absorption, giving -1.5dB of loss.
Transceiver isolation	Better than - 40dB	Measured at -55 to -60 dB
Tx Input Port	UG387/U-M flange on a WR2.8 flange,Horizontal E-field	Confirmed
Rx Output Port	UG387/U-M flange on a WR2.8 flange,Vertical E-field	Confirmed