Transit Case to Transverse Waves, a Low Cost Anechoic Chamber

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Abstract

This paper shows how a compact anechoic chamber with Electro Magnetic Compatibility (EMC) shielding, constructed by Surrey Satellite Technology Limited (SSTL), for the testing of its satellite antennas has alleviated the need to rely upon external and expensive anechoic test house facilities. This novel low cost system has allowed SSTL to accurately and repeatedly test a range of different production antennas including L-Band and S-Band patch antennas, X-Band horn antennas for current satellite missions and the development of X-Band patch antennas for future missions in an environment that is immune from reflections caused by surrounding objects in a typical laboratory. The flexibility of the system has also allowed it to be used to test whole global positioning system (GPS) and communications receiver modules in a 'quiet' environment.

Introduction

SSTL is the worlds leading small satellite provider. It specialises in the design, manufacture and operation of small satellites, and provides high quality performance at low cost. SSTL has currently launched 32 satellites gaining over 200 years of in orbit operations experience.

SSTL manufactures several antennas for use on its satellites. In order to qualify these antennas they had to be measured in an antenna test range facility. As SSTL had no facilities of its own costly anechoic chambers had to be rented. As SSTL began producing larger quantities of antennas the need for its own facilities grew, not only to make financial savings but also to save engineers time.

Construction and Test

SSTL has constructed a low cost compact anechoic chamber with EMC shielding from a transportation case typically used for transporting large equipment used in the music industry. The primary aim of the chamber was to support the production testing of X-band horn antennas used on a high data rate antenna pointing mechanism.

The wooden case (width: 740mm, length: 1240mm, depth: 715mm), nick named the "X-Box", was first lined with aluminium foil. This was attached using adhesive and rolled onto the lining of the box. This layer provided the backing required for the correct attenuation characteristics of the Eccosorb AN75 material, as well as providing a shielding function. Eccosorb AN75 is the commercial name of a particular radar absorbent material, (RAM), with the following properties: thickness 2.9cm, frequency range of 600MHz to 40GHz.

After construction was completed a "quick and dirty" preliminary noise performance test was performed. This included comparing the noise in the lab with that in the box with and without the lid of the box open, see figure 1. The graph in figure 2 shows the results of this test. The traces displayed are as follows: test antenna outside the box (black trace), antenna placed in the centre of the box with the lid open (brown/red trace) and the antenna in the box with the lid closed (blue trace). This measurement was performed using a VHF whip antenna and a spectrum analyser with peak hold. The difference in level across frequency was quite apparent (black and blue traces) and indicates that the screening effectiveness was mostly greater than 40dB.

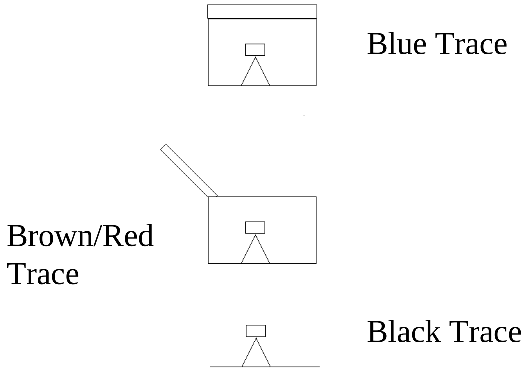

Figure 1 – Set up for noise level test

The second test performed on the box was to measure the insertion loss of the system across frequency between two antennas. This was done by placing a target antenna inside the chamber and a source antenna on the outside, see figure 3, a second measurement was then made where both antennas were outside the chamber, the difference between the two measurements

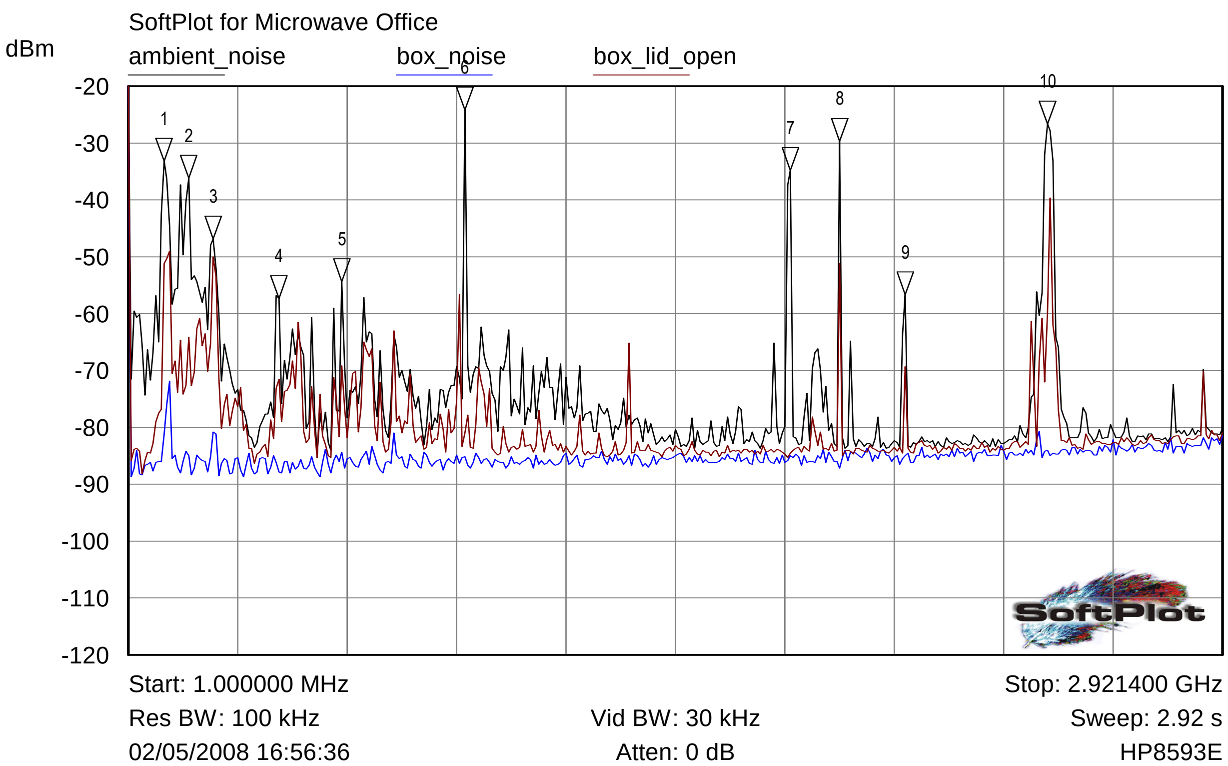

Figure 2 – Graph showing the noise levels over a few minutes in a typical laboratory.

was the insertion loss. The result of this measurement is shown in figure 4.

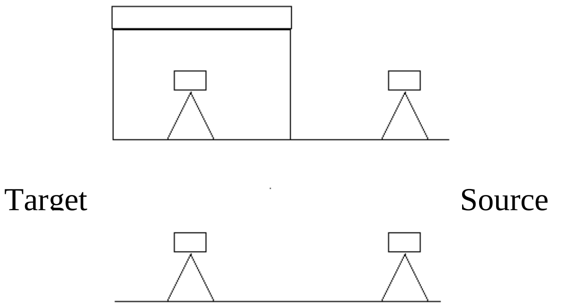

Figure 3 – Set up for insertion loss test

The results in figure 4 show that the insertion loss, which infers the shielding effectiveness, varies from 10 to 70dB over the 10MHz to 8GHz range, The attenuation of 40dB at S-Band frequencies makes the chamber useful for Bit Error Rate (BER) performance testing of the S-Band Telemetry Telecommand and Control (TT&C) RF equipment, where local interference could cause the BER to deviate substantially in bursts. The chamber has also been used for pre-compliance radiated emission measurements on the SSTL GPS module.

Antenna Measurements

The primary aim of the test box was to functionally verify the radiation pattern performance of the SSTL production X-band antennas. This data then had to be compared to previously measured data, which had been obtained from an external test house. The initial measurements were

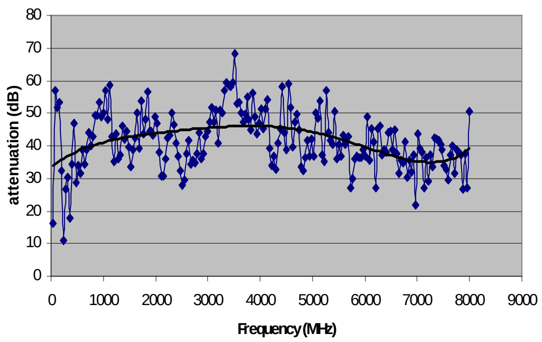

Figure 4 – Insertion loss between two antennas 450mm apart.

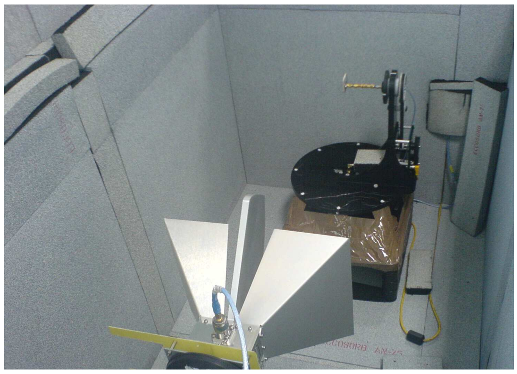

Figure 5 – Anechoic chamber with DAMS antenna measurement system

obtained using a dipole antenna which was rotated by hand; this system was later replaced by the Diamond Engineering Automated Measurement System (DAMS) antenna measurement system. The DAMS system comprises of hardware and software that provides a complete spherical co-ordinate measurement system. Figure 5 shows this system placed within the chamber, with a reference horn antenna.

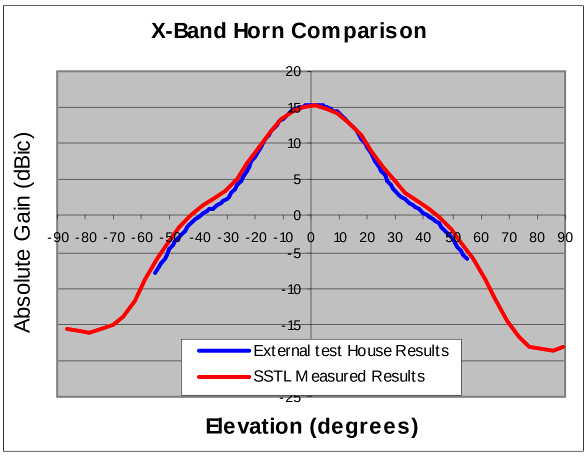

Figure 6 – Comparison between gain measurements from an external test house and gain measurements from the SSTL anechoic chamber for the X-band horn antenna.

Figure 6 shows the co-polar gain and it has a close correlation over ± 25 degrees. This measurement was performed using the DAMS full spherical mounting system and a circularly polarised antenna. The result is cross and co-polar gain measurements at specific phi and theta angles. The cross-polar data (not shown) also had good correlation though there is more variance due to the sensitivity of the measurement. Although it is satisfying that the absolute levels have a good correlation the results show that the "X-box" anechoic chamber allows repetitive comparative measurements to be made which verify the final product.

The preliminary tests showed that the chamber could possibly be used to measure S-band antennas. The S-band antenna measurements were taken using the same method as used for the X-band horn, figure 7 shows the results. This graph shows that there is a close correlation over ±50 degrees for the co-polar gain and has acceptable correlation from ±90 degrees.

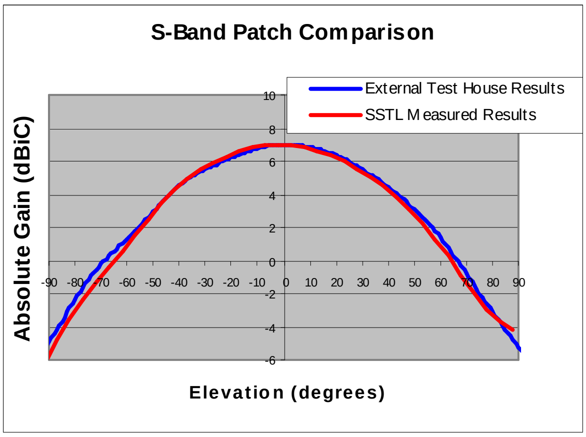

Figure 7 – Comparison between gain measurements from an external test house and gain measurements from the SSTL anechoic chamber for the S-Band patch.

Current Uses

The main purpose for building the anechoic chamber was to measure the gain characteristics of the X-band horn antennas. These horn antennas are currently used on the antenna pointing mechanism (APM) as shown in figure 8. The APM's off-pointing properties have greatly increased the download throughput capability reducing the download time, facilitating higher resolution images[1]. The successful production of the X-band horn antenna has been instrumental in providing image data for disaster monitoring, figure 9.

Figure 8 – Antenna pointing mechanism with X-band horn antenna

Based on the good correlation achieved from the initial testing SSTL currently uses the anechoic chamber for precisely measuring S-band patches, it has allowed them to be produced with no deviation in their performance throughout production. It has also allowed the development cycle of a new X-band patch antenna, which would previously been unthinkable due to the general noise level in a typical laboratory. The characterisation of a GPS L-band patch has also been possible as

Figure 9 – Mississippi delta after hurricane Katrina

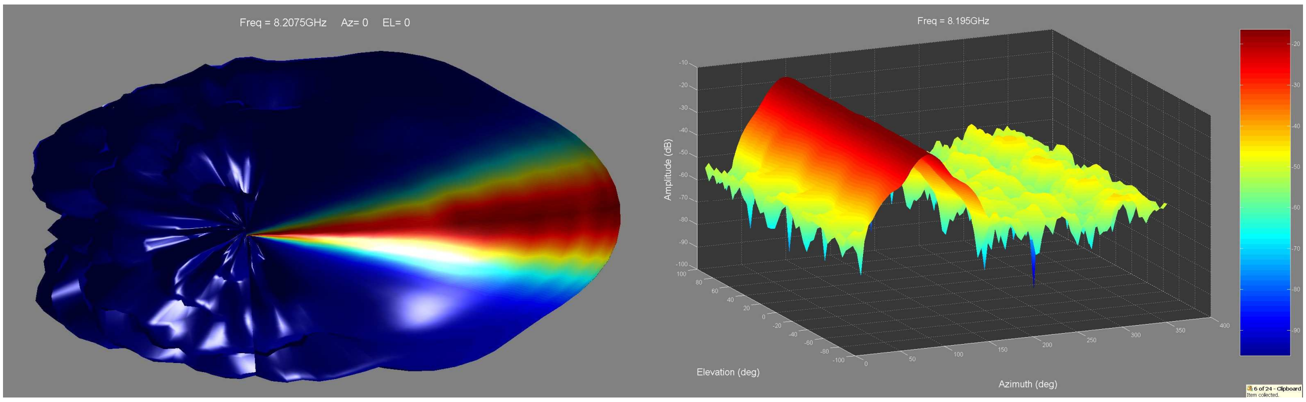

Figure 10 – 3D gain and carpet plots for the X-band horn antenna.

well as an investigation into the effects of placing radome’s over both the X-band horn antenna and the S-band patch antenna.

The quiet environment has also meant that GPS L-band patch pre-compliance radiated emission measurements could be taken. Gain plots were measured, though this was only possible when using a horn which had a good gain at low frequencies.

The DAMS software can not only produce 2D gain plots for antennas but also offers 3D representations as shown in Figure 10.

Future Uses

To enhance the use of the SSTL anechoic chamber a near field transformation[2] setup is being planned, this should increase the usability of the chamber as currently its size is one of its limiting factors.

Conclusion

The SSTL anechoic chamber has allowed SSTL to not only characterise and tune its antennas in-house but has also allowed for the development of new antennas. The flexibility of the system has enabled the testing of antennas for which the chamber was not designed (GPS L-band patch).

Not only has it allowed SSTL to test and tune its antennas, it has reduced the cost involved. Before the construction of the “X-Box” SSTL was hiring commercial facilities which cost approximately £1,500 a day, the complete cost for the “X-box” chamber was approximately £15,000. This value includes the DAMS hardware, software and a commercial reference antenna. A very simple measurement system, using the “X-Box” and dipoles, cost around £1,250. The DAMS system allows automated measurements with advanced post processing functionality.

References

[1] Keith Clark, Kevin Maynard *‘"I Can See You!” - How Satellite Imagery Dictates the Need for Speed’* ARMMS 2008

[2] Dan Slater *‘Near-field antenna measurements’* ISBN 0-89006-361-3