

Pre Dinner Talk at LAPC March 2008

By Peter Clarricoats

I am good at having my arm twisted! Your worthy Chairmen decided in September last, that I should give a light-hearted review of the first 40 years of the QM Antenna Group that I started when I moved to London from Leeds in 1968.

First let me say that although I was Group Head from 1968-1995 David Olver and then Clive Parini took over for the last 13 years so I hope they will forgive my errors of late.



I know it is a boring way to start a talk with a list(2) but it will give you some idea of the scope of our activities and to some extent how these have reflected the changing requirements in the antenna world.

Queen Mary Antenna Group 1968-2008

1. Corrugated Horns and Waveguides
2. Dielectric (dielectric) feeds
3. Scanning Antennas for Ground Stations
4. GTD
5. Leaky wave antennas
6. Ground penetration radars
7. Mutual Coupling in Feed Arrays
8. Graded Index Optical Waveguides
9. Diffraction over terrain
10. Propagation through Rocket Exhaust jets
11. Shaped reflectors for shaped beams
12. Mesh reflectors
13. Anechoic Chambers
14. Compact Antenna Ranges
15. Adaptive Antennas
16. Reflector Metrology
17. Compact Corrugated Horns
18. Dielectric Horns
19. Sub MM Antennas
20. Mobile phone antennas
21. UWB Antennas
22. Metamaterial and EBG antennas
23. Interaction with Bio-Materials
24. FDTD Modelling
25. On body transmission

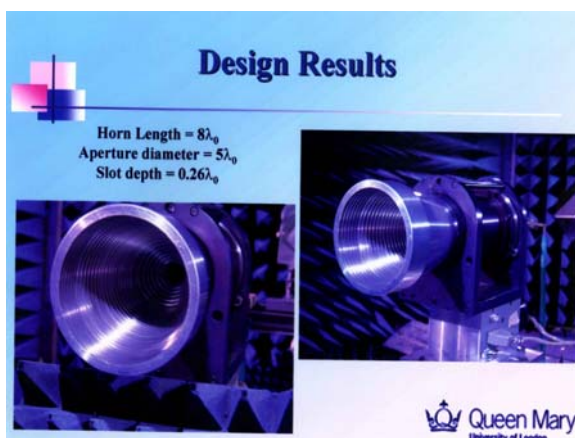
Slide 2

When I joined QMC, the MoD was a strong supporter of our research and it was then quite customary for them to pose problems to Universities and to seek help with solutions. It may seem hard to believe but the first military communication satellites had poor station keeping and followed a figure of eight around their nominal geostationary position. We were thus asked to come up with schemes to allow ground stations to track this movement and in the course of our studies investigated spherical reflectors, stepped reflectors and something I coined a

spheraboloid ! I will not bore you with the details but I did have the fortune to have some outstanding Australian RAs, of course the first of many from all over the world and in those distant days many from the UK !

In those days too I did wonder why many of the Group did not start work until mid-morning but it was later explained that their best work was done in the evening in East-End Pubs. The married ones had normally tolerant wives but on one occasion one of the RAs arrived home at 2am. He then found that the sandwich prepared by his wife for his lunch the next day had butter replaced by soap! I am glad to say they are still happily married.

My early years at QM were much taken up with Corrugated horns as the slide(3) shows and together with David Olver and Clive Parini we established a fairly comprehensive theory backed up by experiment . This led to two books and other books by members of the Group followed. The Montage (4) shows a selection of the books produced by members of the Group over the forty years with, of course, some benefiting from outstanding co-authors.



Slide 3



Slide 4

Back though to corrugated horns, our first horn was made from brass and weighed about thirty pounds. One morning I was told that it had disappeared from the lab overnight and while the locals in the workshop surmised it might be recovered from the local scrap merchant one of my enterprising research students said in all seriousness “Professor could this be industrial espionage?”

Subsequent horns were made from Aluminium and attracted a lot less attention from the Kray Brothers and others from the East-End criminal fraternity!

Now as this is an Antenna and Propagation Conference I should mention that the Rocket Propulsion Establishment invited us to study microwave propagation through rocket exhaust jets for many early missiles were controlled by a microwave signal that had to pass through the jet. This gave us the chance to visit

a rocket firing at MoD Westcott in Buckinghamshire. We watched in awe as concentrated nitric acid at 300 atmospheres pressure was pumped into the rocket along with mixed amine fuel. When combined they created the most enormously powerful jet with a noise about 200dB above the threshold of hearing at least when you stand just fifty feet away! The tethered rocket produces a huge plume skywards but just before firing it was suggested by the Chief Scientist that I might like to move my car from down wind as a good deal of concentrated nitric acid would descend as rain and I might have some difficulty with my car insurance if the car dissolved on my way back home!

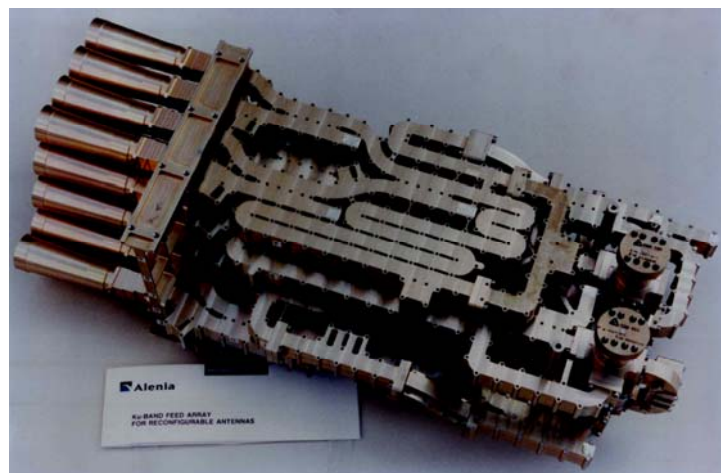
The Group was the first to be asked to examine the possibility of finding plastic mines by microwave means. We followed this up with experiments and the Finance Director at Queen Mary did look a bit surprised when the department put in an invoice for sand, spades and wheel barrows. The study later led British Gas to ask us to search for buried pipes and it was a touch worrying when they told us that all the old London gas pipes were made of wood and most of the wood had actually rotted away over the last century. Later our work was taken up by Alan Rudge then at ERA and he took a contract to search for mines left over after the Falklands War. He said it was a bit disconcerting to be led through a minefield in the Falkland Islands by an army major with only one leg! Fortunately his risks were of a different kind when they made him deputy chairman of British Telecom. Alan was a Visiting Professor at QMC and it was he who inspired us to begin our studies of shaped reflectors to produce shaped beams. I should explain that early satellites had antennas that spread their beams across a wide angle most of which was sea it was therefore very desirable to concentrate energy where there were actually land-based receivers hence the desire to shape reflectors to synthesise shaped beams. This was quite a challenge since an eminent Russian had apparently proved that synthesis of the reflector surface to create a shaped beam was impossible. Fortunately for us he was wrong and we first pursued a geometrical solution that I frankly found very difficult to understand. The research worker was from Brazil. We worked closely with ERA and in the early eighties on a visit to ERA I could not understand why this bearded colleague was stared at by everyone we encountered between Waterloo and Leatherhead. Then I realised that Jose was the splitting image of all 16th century paintings of Jesus Christ and this explained why pretty young ladies were crossing themselves when they entered our carriage assuming they were witnessing the second coming!

Later, I and my colleagues turned to diffraction synthesis of reflector surfaces that was highly successful but without spiritual encounters of the third kind!

It was around that time we decided that we should apply for what was then called a Rolling Programme Grant (now called a Platform Grant) from the SRC later called the EPSRC. We made a strong case for some automated equipment to measure antenna patterns and requested a sum of about £25000 (probably equivalent to £.25m in today's money). I was duly summoned to appear before the Award Panel. I was questioned closely by a Panel Member and asked why I

required this sophisticated equipment since when he measured antenna patterns during the WW2, a probe and a spot galvanometer proved quite adequate! As a consequence we were awarded £1200. Fortunately our luck changed later and QM now has one of the best antenna labs among universities in Europe.

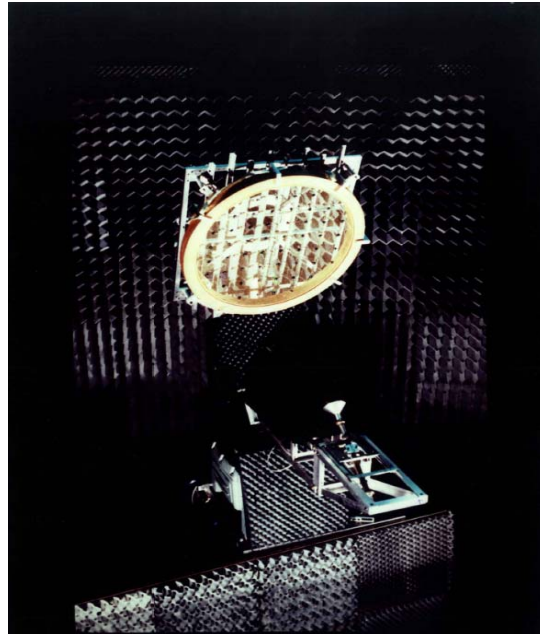
Although financial support from ESA was never large they did pose some excellent problems and gave us unqualified support for future applications to EPSRC. One of the problems that we tackled was the issue of mutual coupling in feed arrays. Superficially an array (5) pattern might be expected to be just a convolution of the pattern of the individual feed and the array factor. However this neglects mutual coupling and this can have a quite profound effect on the cross-polarisation which is so important in dual polarised satellite applications. Again we were able to solve the problem and through my contacts with ESA I was able to watch at close hand the encounter of the Giotto Spacecraft with Halley's comet in March 1986. There was no Global Warming in those days for as I drove to ESA the school children were skating home along the frozen canals and I could have been living in the 17th Century at the time of the mini-Ice Age. I think that was the last time they held the 200km skating race covering a large part of the Netherlands and ESA was proud to have a skater from among the thousands of participants who came fourth.



Slide 5

From shaped reflectors we moved on to mesh reflectors the idea being that with suitable actuators it should be possible to alter the shape of the reflector while the satellite is in-orbit. The slide (6) shows the mesh reflector as it appeared on the cover of the ESA magazine. Now initially we were unsure where we could obtain the metallic mesh and toyed with the idea of metalising nylon. I asked my Secretary to enquire about obtaining some nylon and of course she approached a company that made ladies stockings. They were somewhat puzzled when she told them it was require for a satellite antenna but she was more than surprised when they asked how many hundreds of square metres we required! Fortunately ESA found us a real source of metallic mesh. Unfortunately during assembly on to the

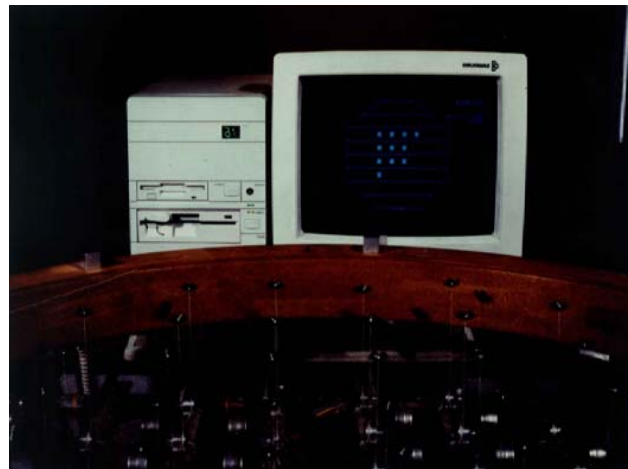
frame a portion of the mesh was torn. So I asked my wife if she would be kind enough to bring her sewing kit down to the College and undertake a repair. I venture to suggest that this must have been a unique experience within the world of antennas pity is that we did not photograph this unusual achievement!



Slide 6

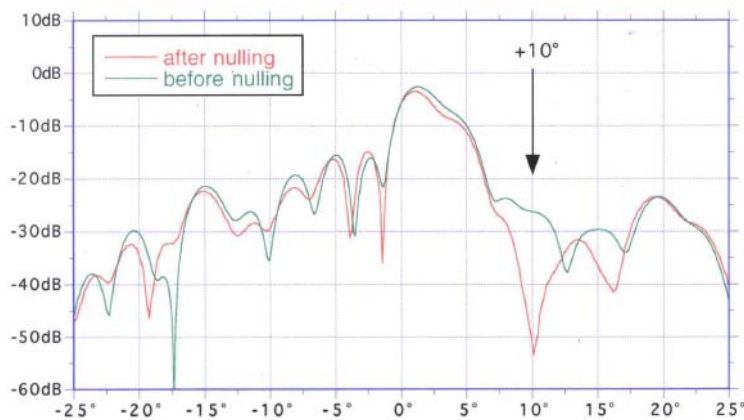
It was short step to contemplate using the mesh reflector to place a null within the coverage for Direct to Home Television from Satellites for one of the European Satellites was already experience unwanted interference from a rogue ground station They were seeking a means to place a null in the direction of the rogue while leaving the rest of the coverage in place. The next slides(8,9) show the null process as set up and the result of nulling the pattern. ESA placed an open tender for the next phase and QM was not part of the successful bid. That went to a French antenna group who unfortunately employed a Swiss Train Company to build the actuators. They each weighed 2.5 Kgm which can hardly be described as a suitable payload as fifty plus were required. Thus the best laid plans of mice and men came to nought although we did win the European Microwave Prize

Now it must be said that none of this would have been possible without the excellent antenna measuring facilities created at Queen Mary especially under Clive Parini and his technical assistants. One of the most



Slide 8

fortunate circumstances was a spin-off from the James Clerk Maxwell Radio Astronomy Telescope on Mona Kea in Hawaii. The reflector comprised panels with a surface accuracy of 32 microns. Fortunately, the Rutherford Appleton Laboratory allowed QM to use a number of spare panels so as to create a very high performance Compact Antenna Range. This has been in use for the last twenty years and slides showing the facility are in (10) and (11). In the second of these you can see the AMSU-B Spacecraft under test in a specially devised chamber with 100 micron particle specification achieved through a controlled air supply within the polystyrene shroud. This work was undertaken for British Aerospace under a Contract arranged by Clive. The AMSU-B meteorological spacecraft has been in orbit for several years and supplies excellent weather images although QM does not accept responsibility for the weather!

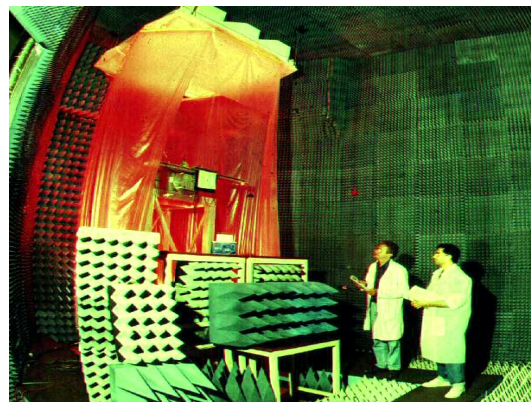


Measured Patterns Before & After Shaped Beam Nulling

Slide 9

This Range allowed operation into the sub-mm range of wavelengths where the manufacture of components that are right first time is an essential requirement as the antenna is so small.

ESA asked us to build a prototype antenna for a quai-optic receiver for 650GHz and the slide (12) shows the outcome. The signal and the IF are both fed into the antenna through a silicon lens. The 10GHz IF is then extracted through a transmission line all at micron size.

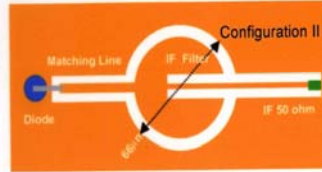
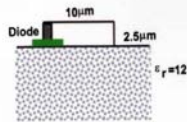


Slide 10

Moving closer to the present time, the Group has had a long-standing involvement with Industry in the realm

- This design is intended to match a low impedance diode to the annular slot and isolate the IF port from the RF and LO.

- Working frequency 650 GHz
- IF frequency 10GHz
- RF isolation at IF port >20 dB



Slide 11

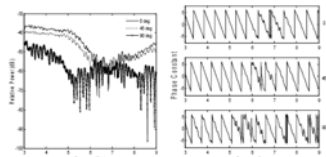
of Mobile communication. As you will know the real problem is the need to make a handset antenna efficient when electrically small in size. The Group had been involved in that in conjunction with several industrial groups and has also looked at on body communication which has military value. There is also an interest in adaptive base station antennas where the Group collaborates with the Software experts in the Department.

Another area of interest has been the potential for UWB antennas. UWB offers, in principle, the chance to send large packets of data between two closely separated PCs and the trick here is again to make an efficient broadband antenna. As you all know very short pulses occupy large bandwidths and in the range from 2-10GHz it is also necessary to null the regions occupied by WiFi at 2.4 and 5 GHz. Slides (12, 13) show some recent results due to Clive Yang and their research workers. Whether UWB will take off is a mute question but research is essential to define what is possible and what is not!

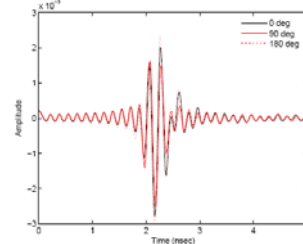
UWB in QMUL ANTENNA



Spectral Analysis

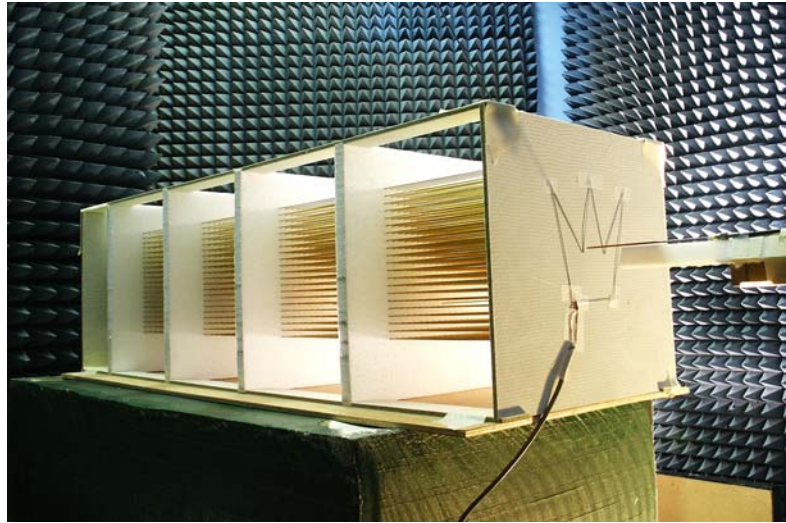


Transient Analysis



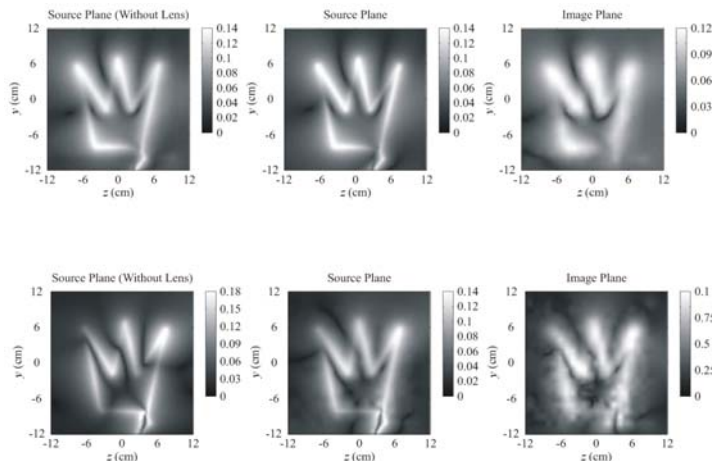
Slide 12

- **Metamaterials in QMUL Antenna Group:**
 - Electromagnetic Bandgap (EBG) structures and their applications to Antennas.
 - Wire Medium Metamaterials for subwavelength Imaging
 - Solid Free-forming Techniques for Millimeter/Submillimeter Wave Metamaterial Fabrication
 - Numerical Modelling Techniques for Microwave Metamaterials and Plasmonic Waveguide including Spatially dispersive FDTD and Conformal Dispersive FDTD etc.



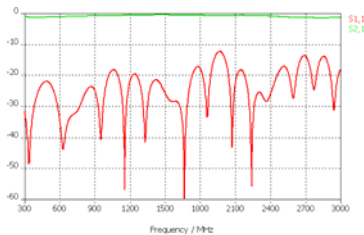
Slide 13

Perhaps this too applies to Metamaterials and EBG. As you will know a vast amount of research money has been expended in pursuit of this topic. At QM my colleagues have been very active and slide (14) shows some recent results. It also allows me to acknowledge the considerable achievements that have occurred in modelling using FDTD and other numerical techniques. My only comment is that it is so important not to lose sight of the underlying physics for within my rather long experience stretching back to the early 1950's some of the most creative developments occurred through a bit of lateral thinking and this is much more likely if the underlying physics is well appreciated.

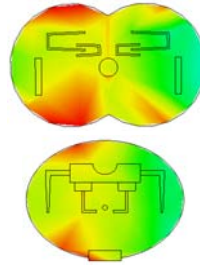


Slide 14

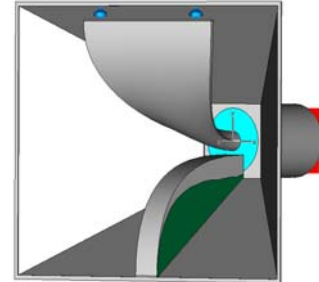
Finally and I am sure you must be well and truly hungry and thirsty by now (I certainly am!) I must mention the excellent work at QM led by Dong Chen concerning electromagnetic interaction with biological materials. This general area is of potentially great importance in the future especially with the advances in the generation of THz power at useful levels. THz probing offers the chance to see inside complex molecules beyond the range of x-rays and the near infra-red. As I look to the future I see an unbounded opportunity for microwaves, antennas and propagation and I feel sure that one of you will be asked to give a pre-dinner talk on the period 2008-2048 !



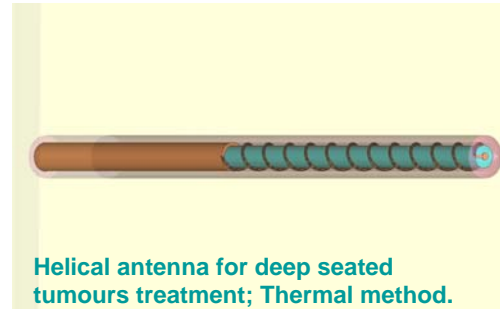
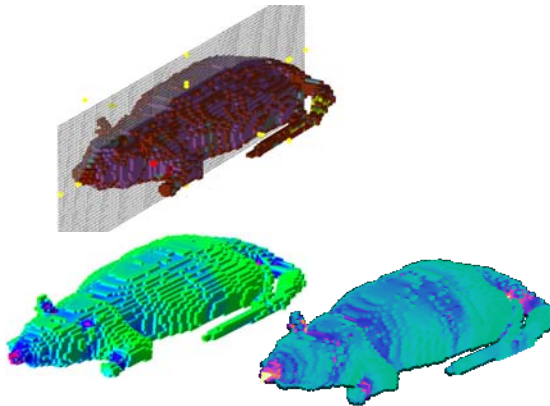
S11 and S21 (dB) as a function of frequency (Complete system)



SAR distribution of porcine brain slices



Horn antenna for tumour treatment, using UWB signals



Helical antenna for deep seated tumours treatment; Thermal method.

Slide 15

Thank you ladies and gentlemen for your kind attention and have a pleasant evening.