ANTENNA DEVELOPMENT AT NIDR IN THE 1970s AND 1980s – SOME PERSONAL RECOLLECTIONS

DPSS TECHNICAL FORUM

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by

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WHY ANTENNAS?

- In the 1960s, as a young physicist, I was fascinated by the diffraction patterns of light past edges and through rectangular and circular apertures.

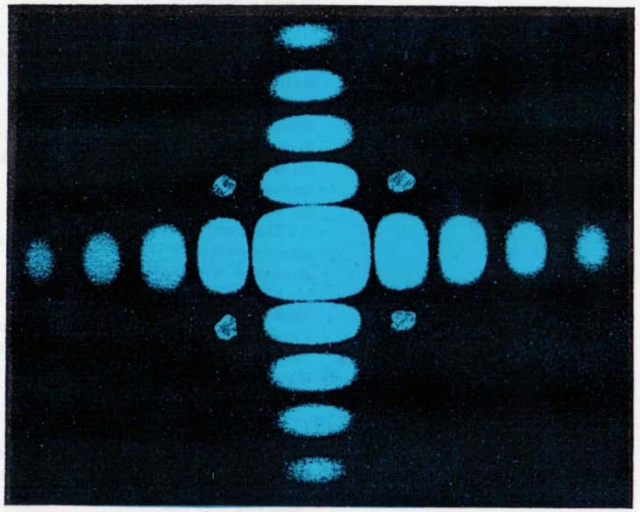


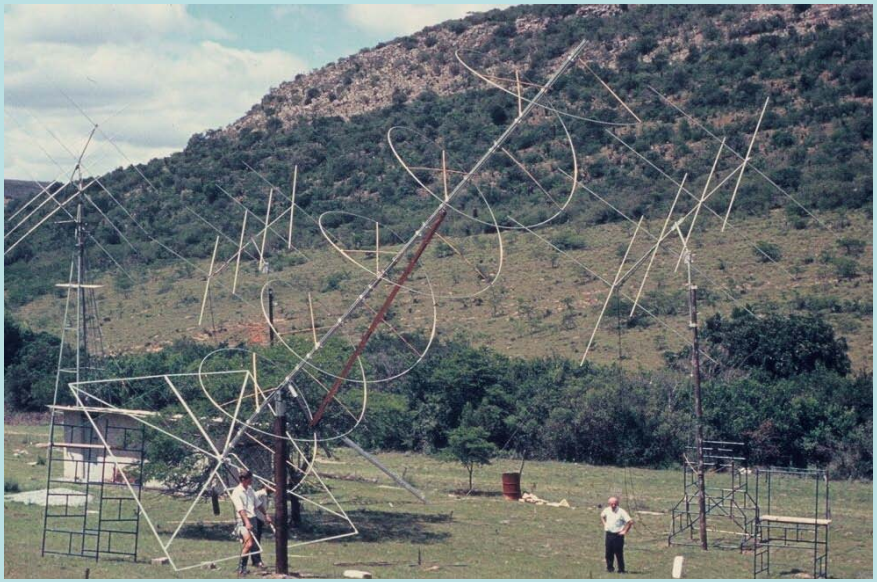
Fig. 8.10. FRAUNHOFER diffraction pattern of a rectangular aperture 8 mm × 7 mm. magnification 50×, mercury yellow light $\lambda = 5790$ Å. To show the existence of the weak secondary maxima the central portion was overexposed.
(After H. LIPSON, C. A. TAYLOR, and B. J. THOMPSON.)

- You will recognise this as the pattern of a rectangular horn antenna.

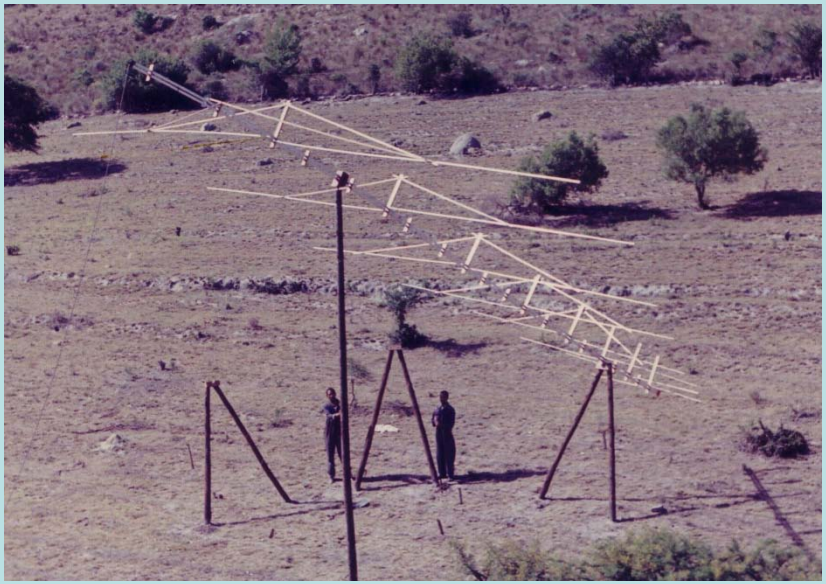
HELICALS AND LPDAS

- As part of the radio astronomy programme at Rhodes University for observing decametric radiation from Jupiter, I designed and built helical antennas and LPDAs in 1968. These formed part of a polarimeter.

Photos: Dirk Baker



30 to 45 MHz steerable helix
There were also 15 to 25 MHz
helical antennas (RHCP and LHCP).



15 to 45 MHz ground-arrayed LPDA

WHY THE SEVENTIES AND EIGHTIES?

- The 1970s and 1980s saw rapid expansion of all electronic engineering disciplines in South Africa.
- Universities were establishing fully fledged departments of electronics and computer engineering.
- More and more students were attracted to these ‘light-current’ disciplines.
- The CSIR was well placed to lead the drive for South Africa to become self sufficient in radar and electronic warfare.
- An ideal climate was created at NIDR for applied research and development in many engineering disciplines (electronics, signal processing, aeronautical, mechanical, systems engineering, etc).
- This talk will try to illustrate by means of photographs some of the developments in antennas at that time and how some of those basic technologies were transferred to industry in South Africa. Here these ideas were adapted and developed into products.
- World class industries were established in South Africa by drawing on the local expertise developed at the CSIR and NIDR.

SOME RELEVANT DATES

About 1968: The Rocket Research Institute of the CSIR sent engineers and scientists overseas to study radar and missiles.

1970: The first anechoic chamber in South Africa was built at NIDR with HP 8410 vector network analyser operating to 12.4 GHz.

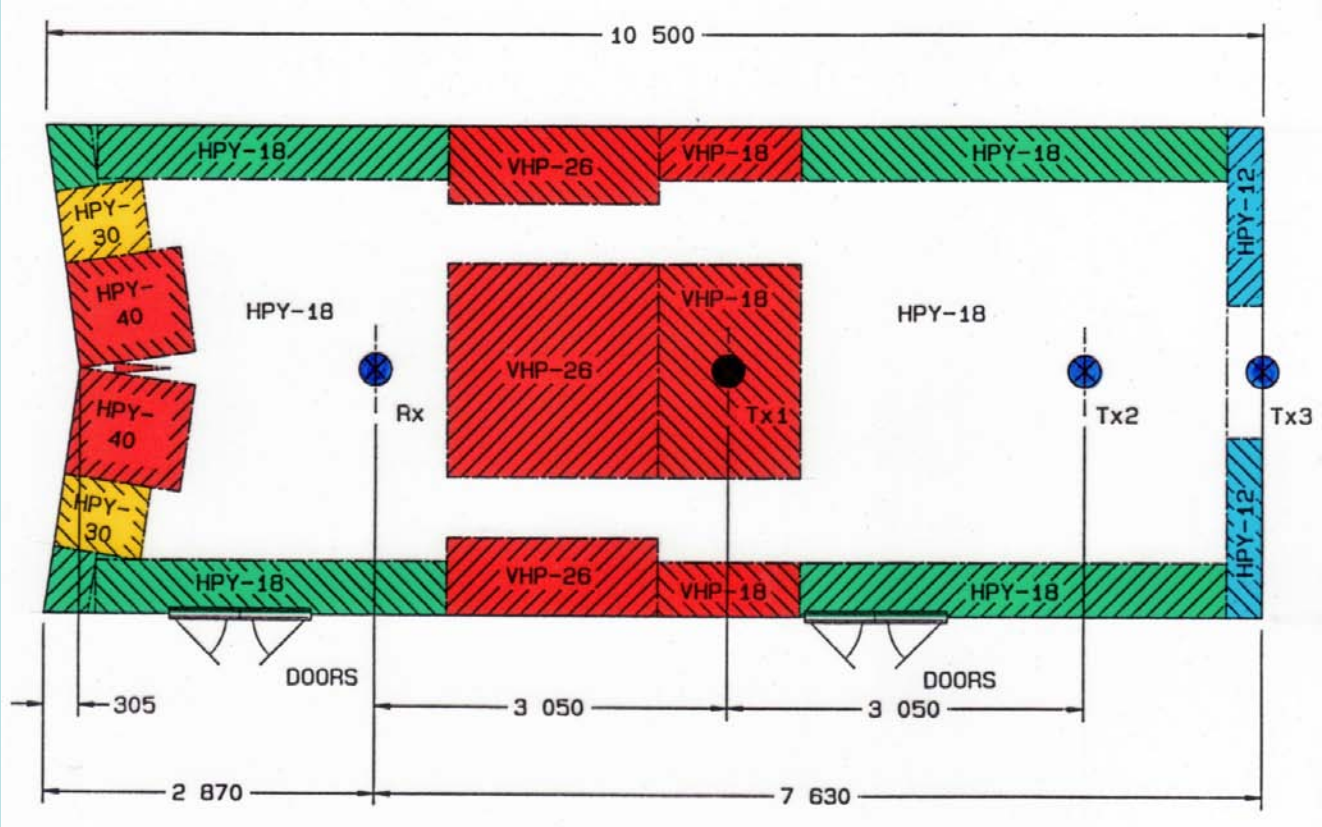
1970–1974: Dirk Baker left Rhodes University to do a PhD in Antennas, EM Theory and Radio Astronomy under Prof John D Kraus at the Ohio State University (OSU).

1972–1973: NIDR sent John Cloete and Ad Sparrius for MEng studies in USA. John Cloete spent 6 months at Scientific Atlanta which led to long-term cooperation. Bob van der Neut spent a sabbatical in Europe working on antennas.

(These were unrelated events – I was unaware of NIDR)

THE ORIGINAL ANECHOIC CHAMBER AT NIDR

(with upgrades *circa* 1980)



- From 1970-1980 this was the only anechoic chamber in SA.
- 1980-1991 a further 10 anechoic chambers were built.
- The original absorbers are now way beyond their useful life.

1972: Jan Malherbe at U of Stellenbosch acquires an HP8410 vector network analyser and starts research programme into filters and components.

1975: Critical mass of engineers assembled at NIDR. Collaborative projects with universities begin.

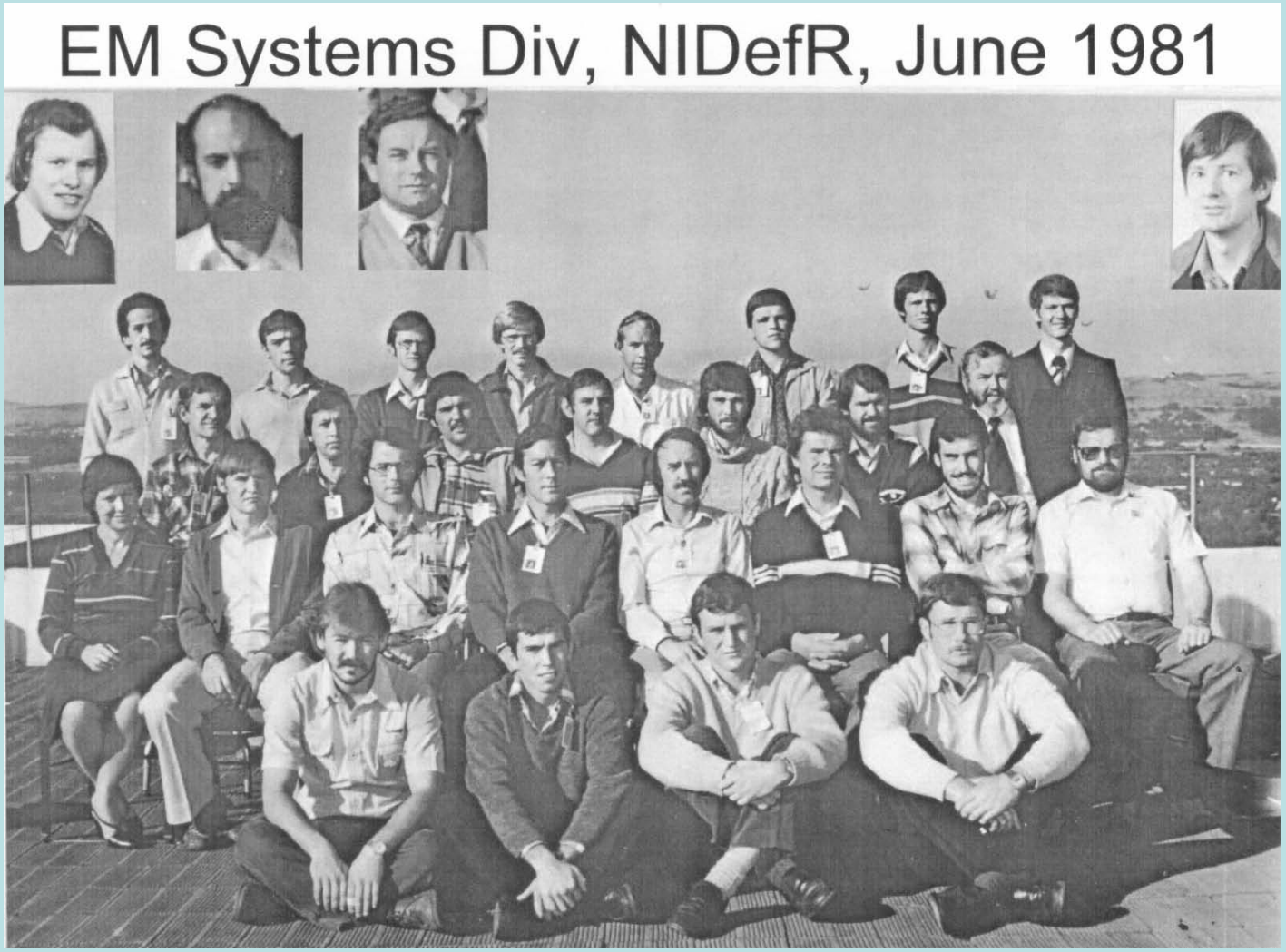
1975 on: The push to higher frequencies, excellent measurement facilities and exciting projects attracted young and innovative engineers.

1976: Started annual Electronic Warfare (EW) Systems course with SAAF. In various forms this course has run almost continuously since then.

1978–1979: Derek McNamara goes to OSU to study GTD and on his return leads computational electromagnetics efforts at NIDR.

SOME OF THE ACTORS

Photo: DPSS



EXPANSION OF FREQUENCY RANGE

1970: Up to 12.4 GHz

1975: Up to 18 GHz (This led to major frequency upgrades to EW equipment)

1980: Up to 40 GHz (mmWave radars such as Nimbus and Fynkyk)

1983: Up to 100 GHz (150 mm diameter lens antennas for radar)

The automated vector network analysers revolutionised measurements in the 1970s, a far cry from the manual measurements of only a few years earlier.

SYSTEM LEVEL DEVELOPMENTS

The 1970s was a time of exciting projects not only at component level but also at system level. Extensive programmes began at NIDR addressing:

- Radars – tracking, pulse compression and mmWave
- EW – Radar Warning Receivers, ELINT
- Missile guidance – TV, Radar, IR.

Much of this work was classified and still remains unpublished. A small sample of antenna related developments appears in the Proceedings of the SAIEE Symposiums on Antennas and Propagation held in 1983, 1986 and 1988.

UPGRADING DAPHNE SUBMARINE EW TO 18 GHz

(1976/1977) Photos: DPSS

Set of six 7.5 to 18 GHz horns with beam shaping, pulse transformers and limiter-detectors. Cloete and Baker used double-ridged waveguide as high-pass filter.

2 to 18 GHz slant 45º polarised omni-directional antenna with integral limiter-detector. First use of polariser with design by Baker based on classical optics.

HORN INSTALLED AT 45º POLARISATION

Photo: DPSS

Lots of experimental work was done by Bob van der Neut to optimise patterns over frequency band.

2 TO 18 GHz OMNI IN HIGH PRESSURE RADOME

Photo: DPSS

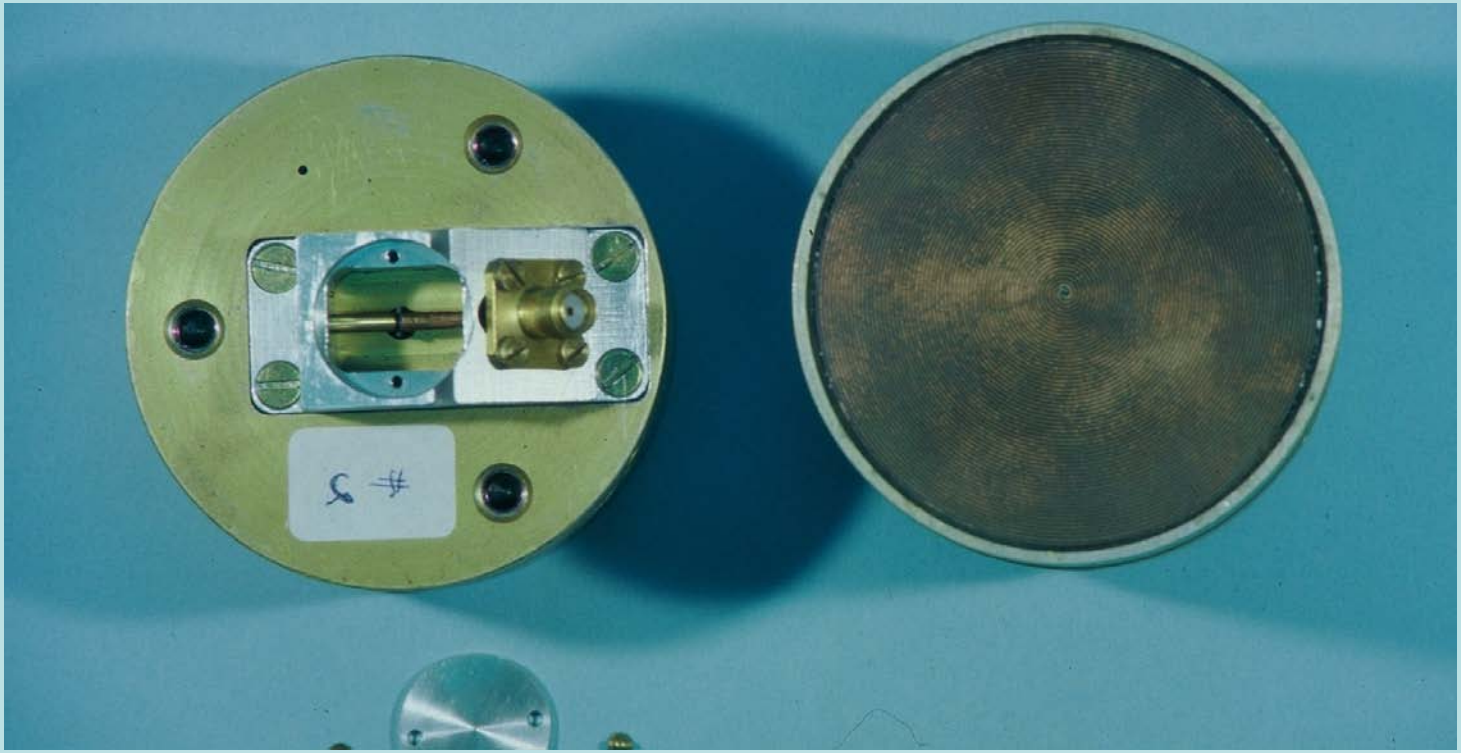
30 YEARS LATER ANOTHER SUBMARINE SYSTEM

(Photo: Saab EDS)

A 300 kHz to 18 GHz SIGINT System

THE EW SYSTEM ENGINEER'S DREAM – THE 2 TO 18 GHz SPIRAL ANTENNA

Photo: DPSS



An early prototype (1977) with a Marchand balun. John Cloete introduced me to the Marchand balun and the Hecken impedance matching taper. Two concepts I have used for almost 35 years.

TRANSFER OF SPIRAL TECHNOLOGY TO GRINEL

(About 1984, some 400 spirals were built)

Continuous improvement of Marchand balun led to improved pattern performance and major export orders (4 000 +).

(Photo: Saab EDS)

SPIRALS ARE EVERYWHERE IN EW SYSTEMS

(This was a key breakthrough for local industry.)

(Photo: Saab EDS)

HELICOPTER INTERFEROMETER AND DISTRIBUTED AMPLITUDE COMPARISON DF

(Photos: Saab EDS)

Rear view of phase-matched antenna panel for interferometer

Amplitude panel for one quadrant

DF SYSTEMS INSTALLED ON AIRBORNE PLATFORM

Photo: Sysdel

DF INTERFEROMETER AND QUADRANT SYSTEMS ON HELICOPTER

Photo: Sysdel

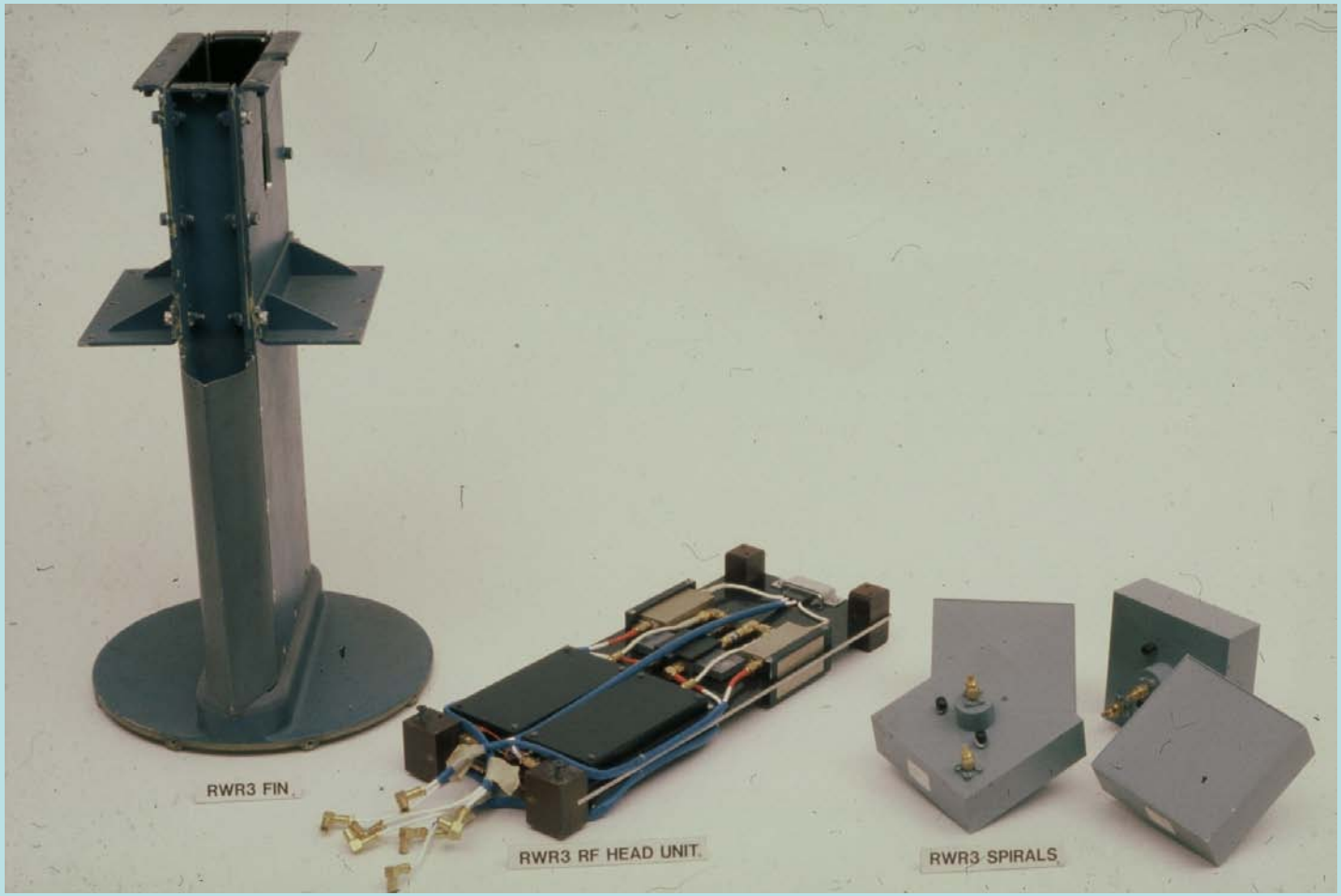
RWR 2 - A 0.7 TO 4 GHz OMNI-DIRECTIONAL RWR

Photo: DPSS

Originally RWR was vertically polarised, subsequently a slant 45 polariser was added.

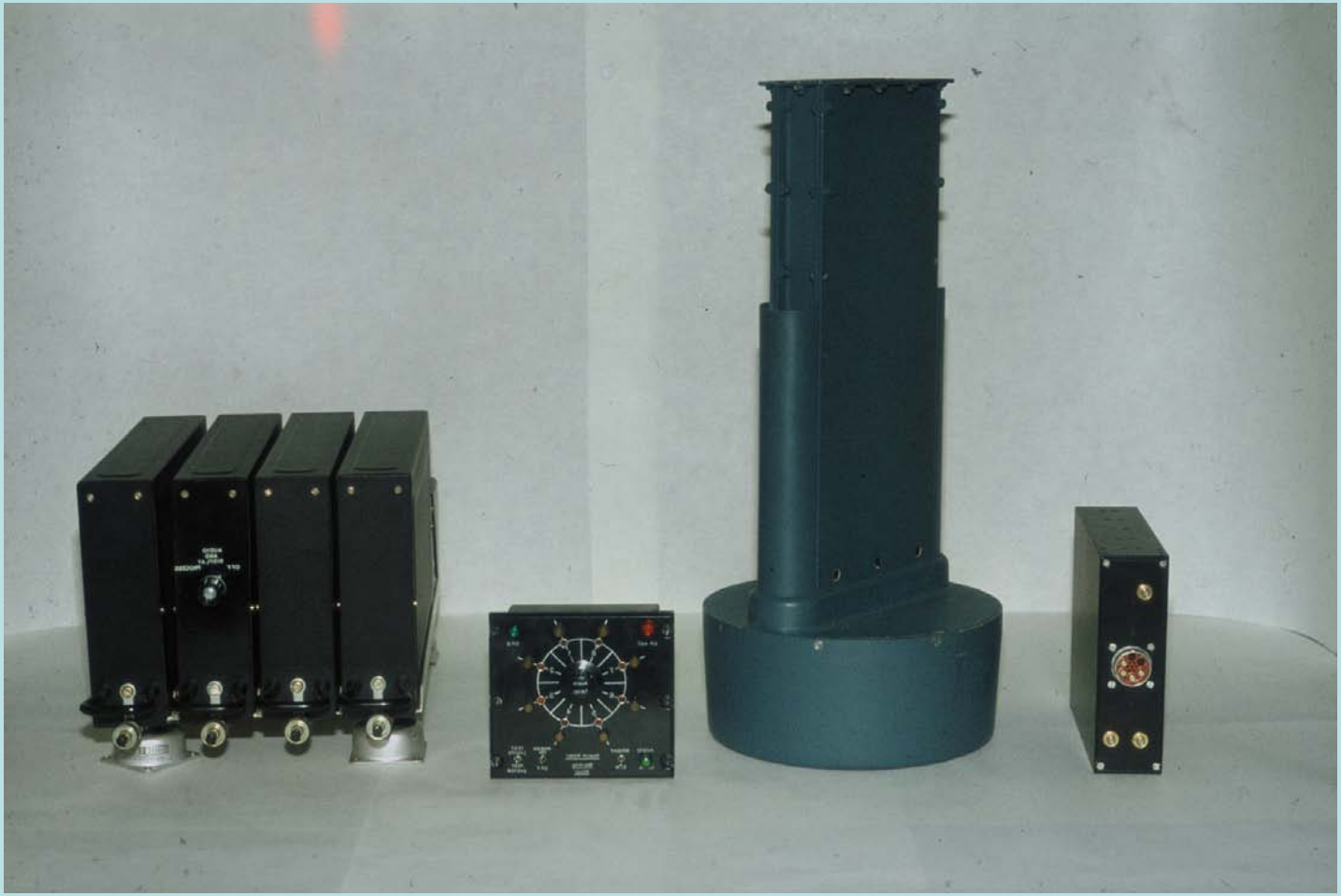
RWR3 - A FOUR SPIRAL RWR WITH DF CAPABILITY

Photo: DPSS



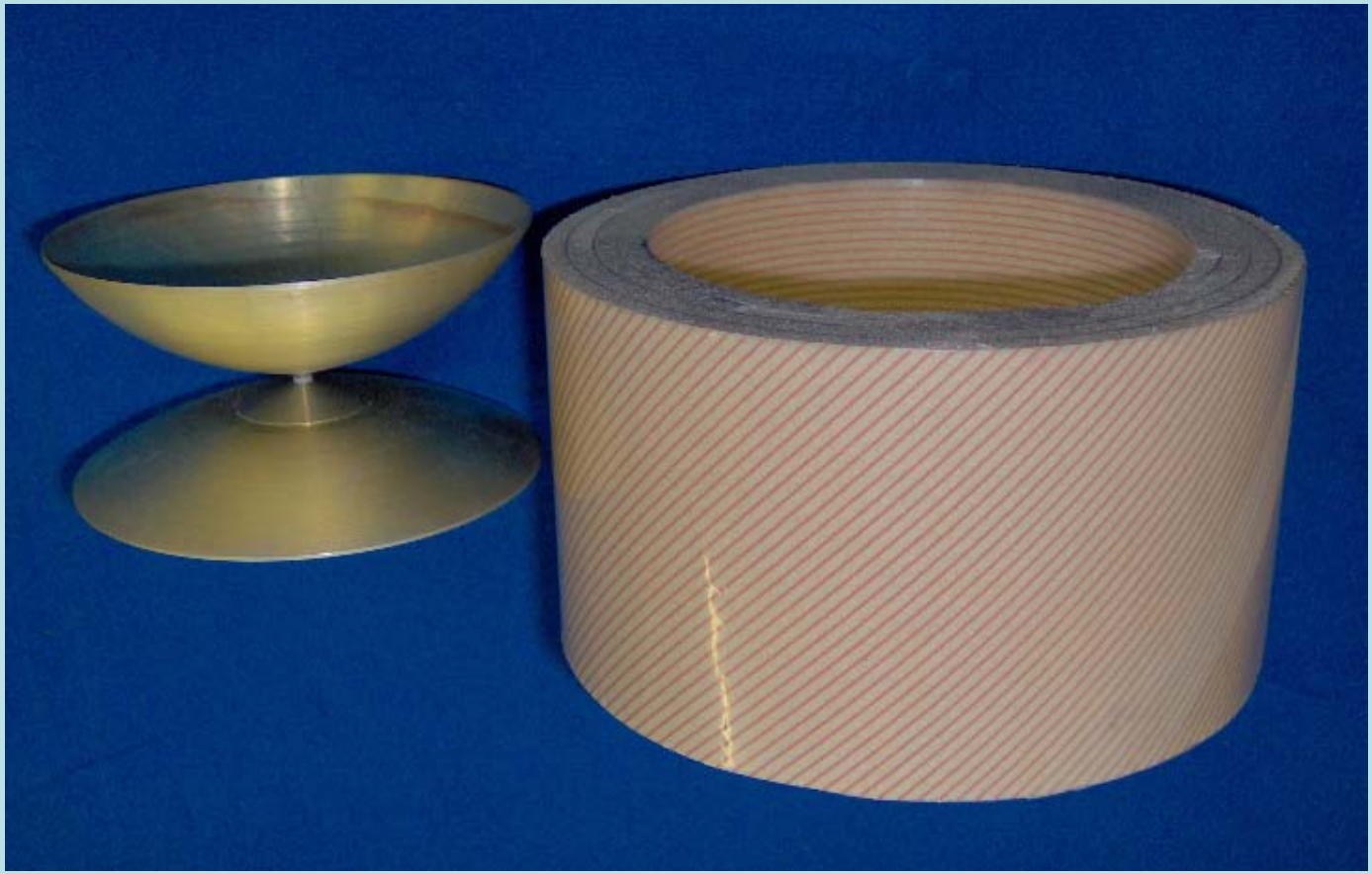
RWR3, COMPLETE SYSTEM FOR INSTALLATION

Photo: DPSS



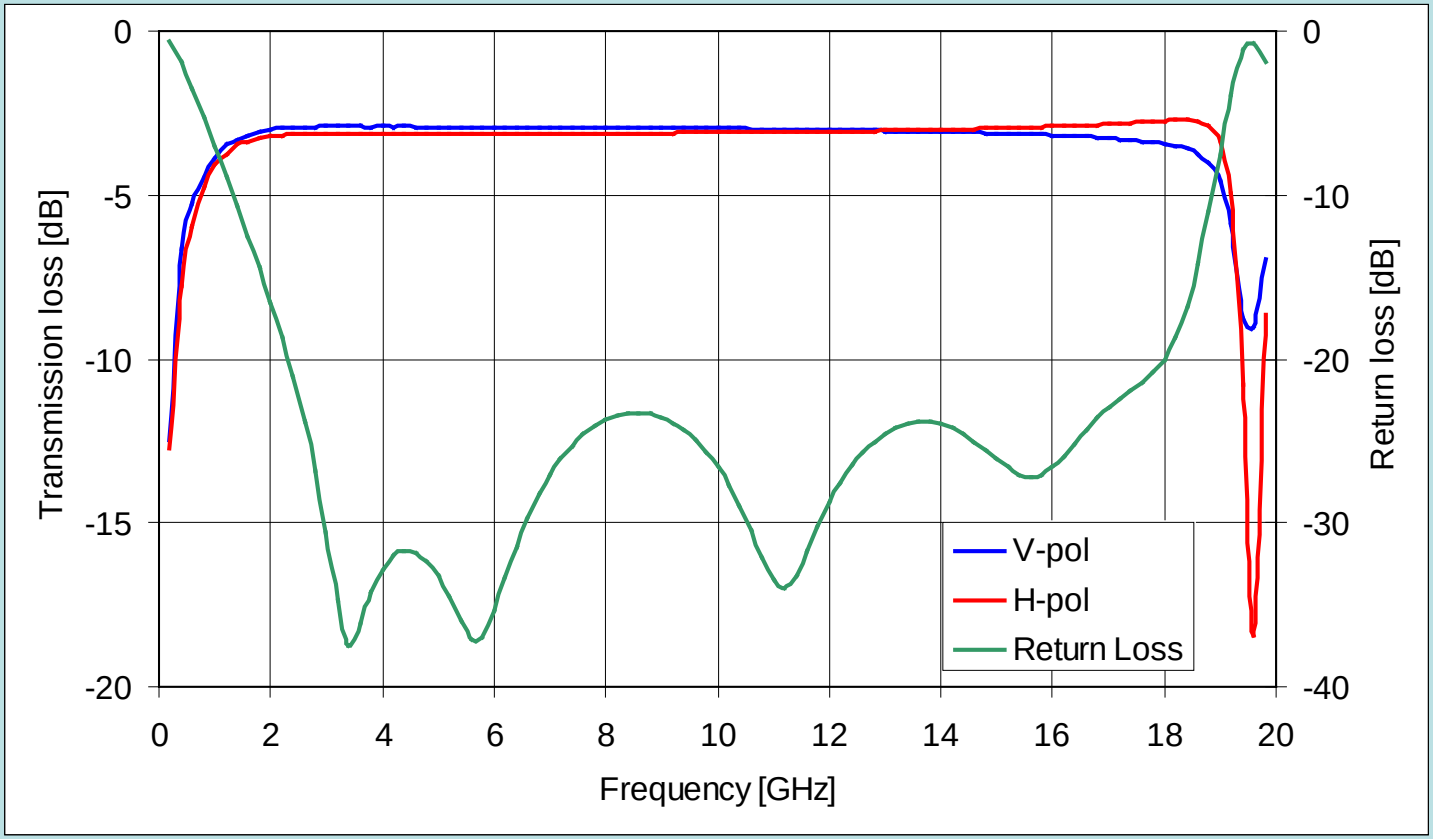
A MAGNIFICENT DEVICE – THE POLARISER

(Photo: Saab EDS)



POLARISER RESPONSE AFTER HILL AND CORNBLEET

(Programmed by McNamara and Joubert)



1 TO 7.5 AND 6 TO 18 GHz ‘SUPER-OMNI’ ANTENNA FOR NAVAL APPLICATIONS

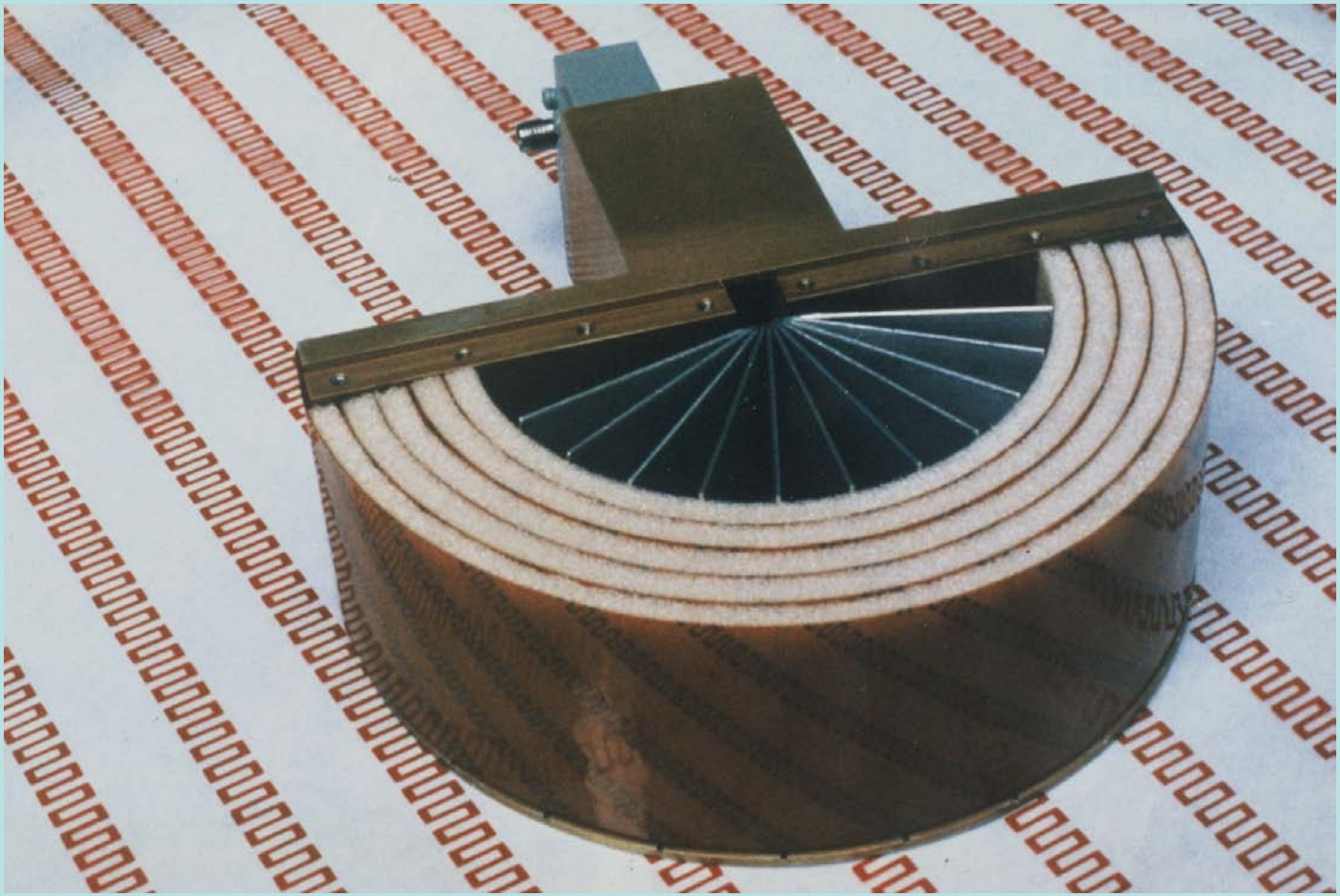
(Replaced four other antennas, sits top of mast.)

(Photo: Saab EDS)

THE MEANDERLINE CIRCULAR POLARISER

(McNamara, one of the most cited papers)

Photo: Saab EDS



COMPUTATIONAL ELECTROMAGNETICS

Up to about 1978 most of the antenna design and development depended on the skill and intuition of some extraordinary engineers.

Many computer programs were written to solve closed-form expressions to assist in design and analysis. These were not user-friendly or documented.

From 1978: There was a concerted effort in general purpose EM codes under Derek McNamara:

- GTD codes for antennas on aircraft and structures
- Physical optics/GTD codes for reflector analysis
- Relatively simple numerical analysis (at least it seems so now) and integration of aperture fields (horn antennas)
- Moment method analysis of thin wire antennas using NEC 2 (also at NITR) and Richmond's codes
- General purpose finite element codes

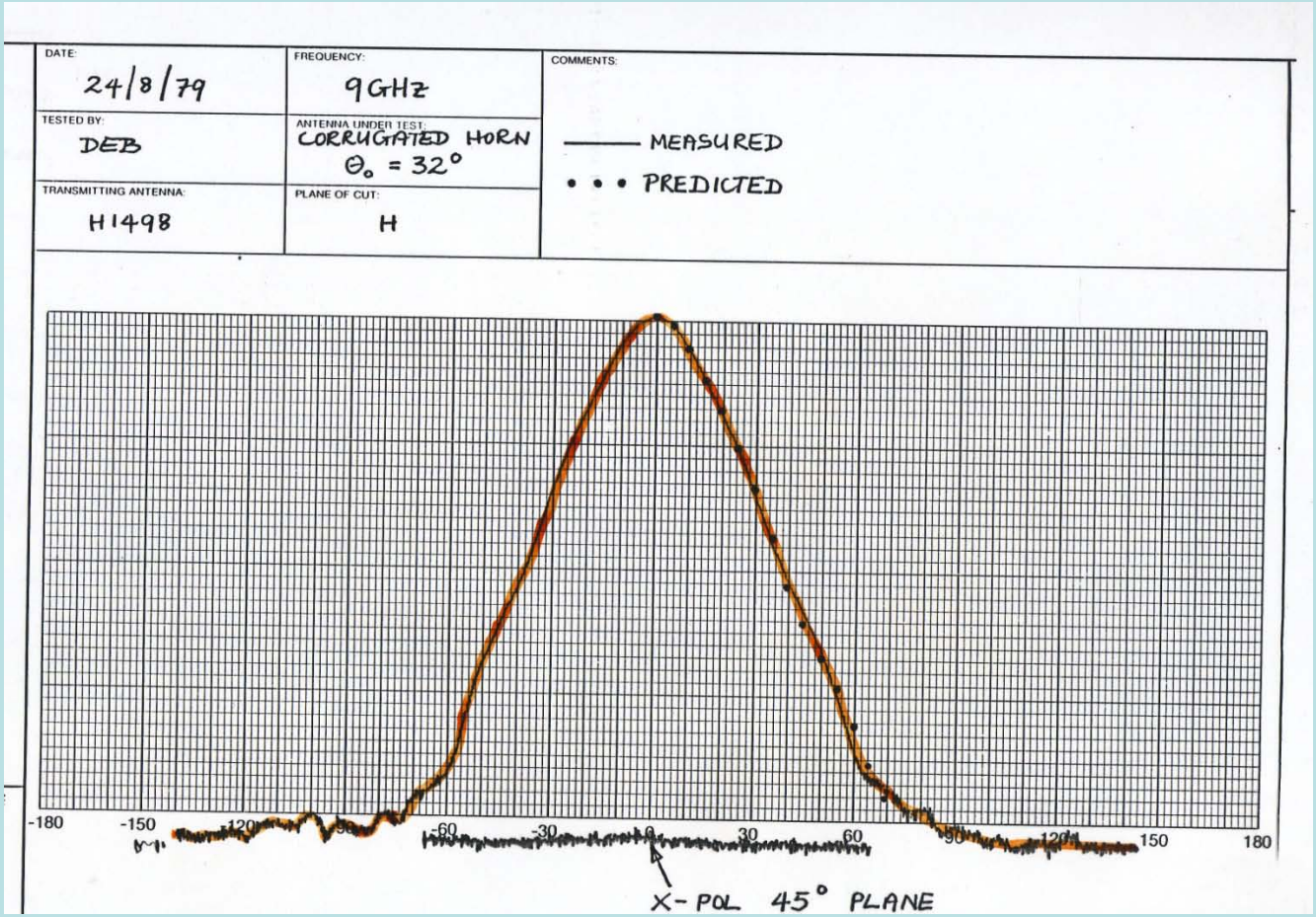
(Johan Joubert, David Davidson, Louis Botha all contributed to these efforts)

THE X-BAND CORRUGATED CONICAL HORN

Photo: DPSS

ONE OF THE FIRST COMPARISONS BETWEEN MEASURED AND PRDEDICTED PERFORMANCE

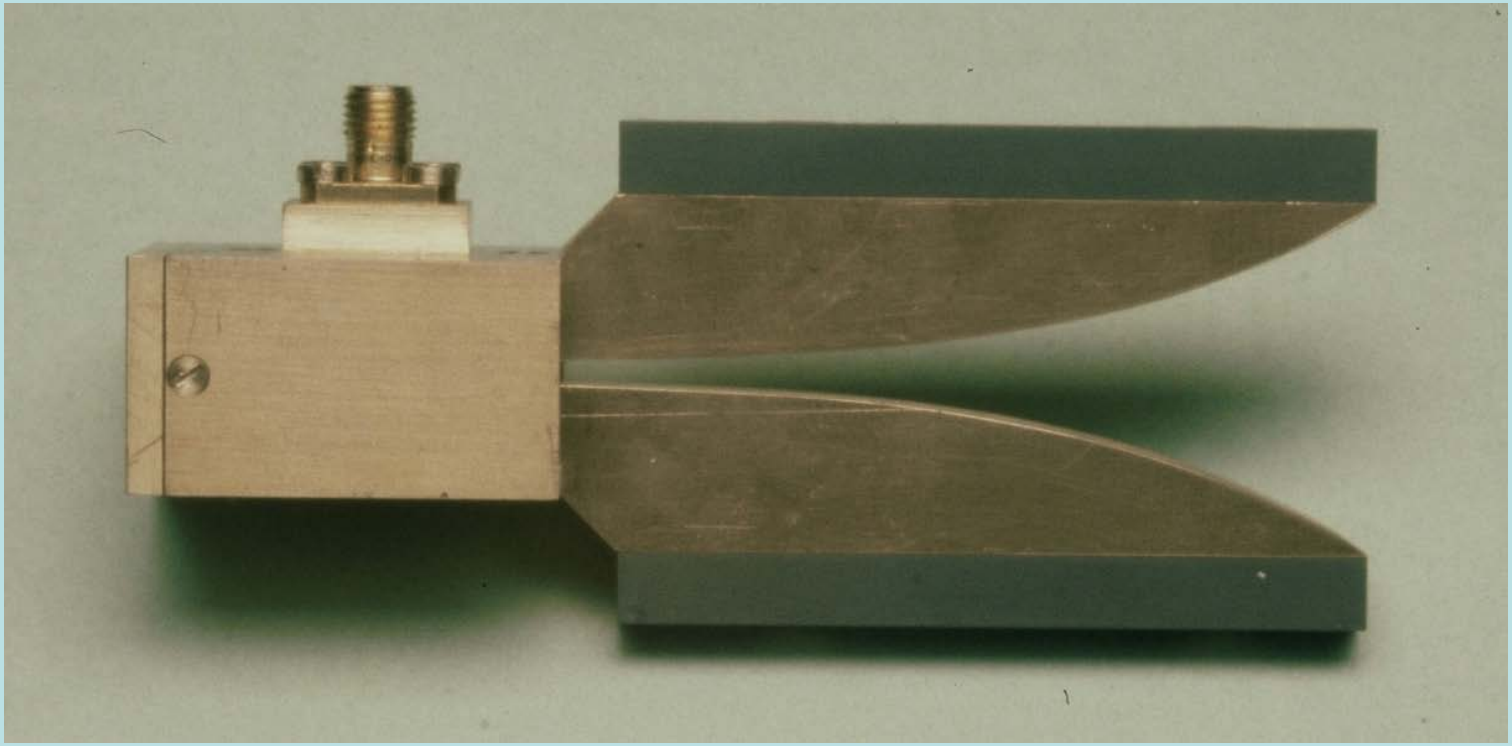
(Baker and McNamara)



OCTAVE BAND DOUBLE RIDGED HORN

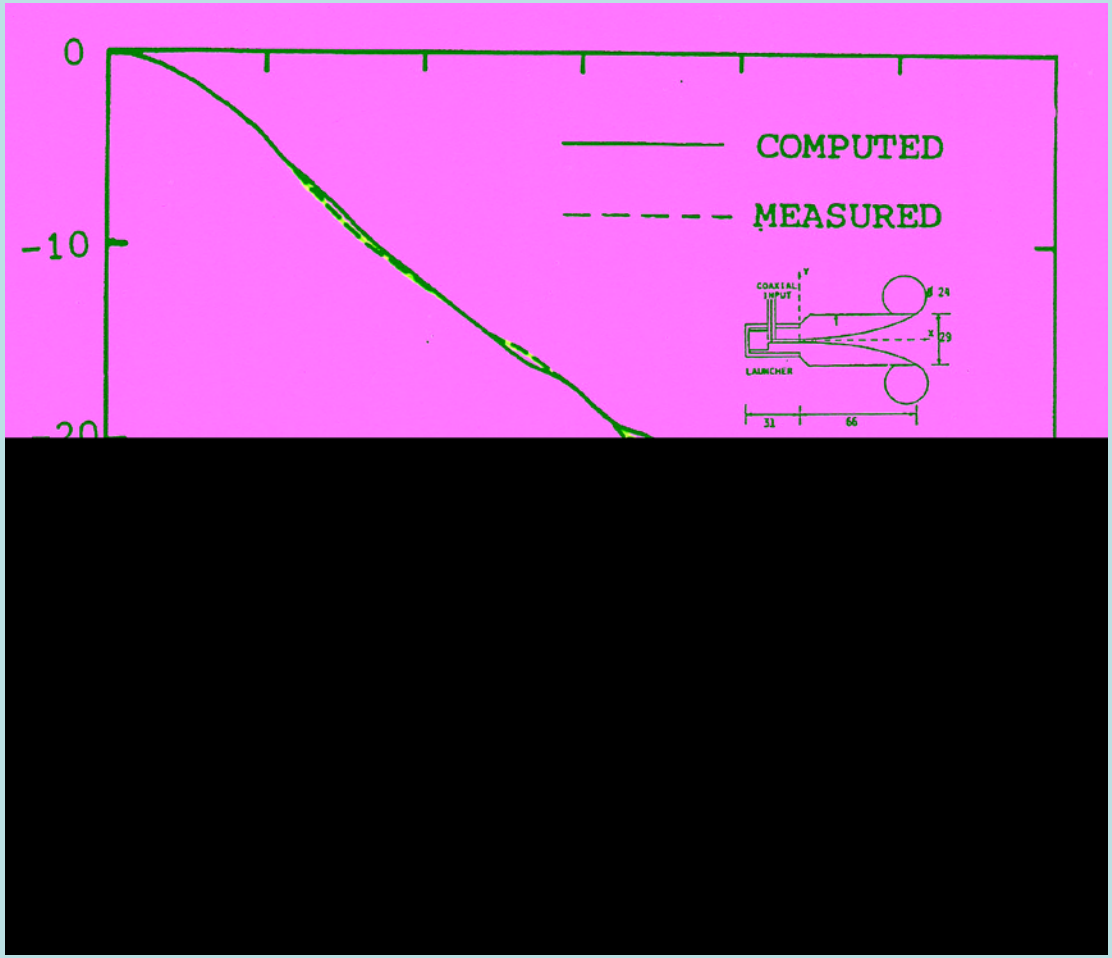
(later added cylinders to improve E-plane patterns)

Photo: DPSS



COMPARISON BETWEEN MEASURED AND PREDICTED E-PLANE PATTERNS USIND 2-D MOM

(Botha)



BODY OF REVOLUTION MOMENT METHOD CODE

(Baker and Botha)

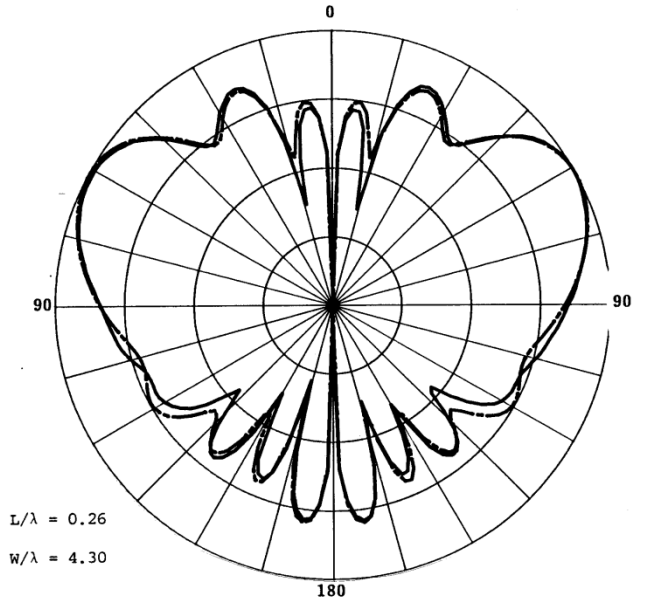
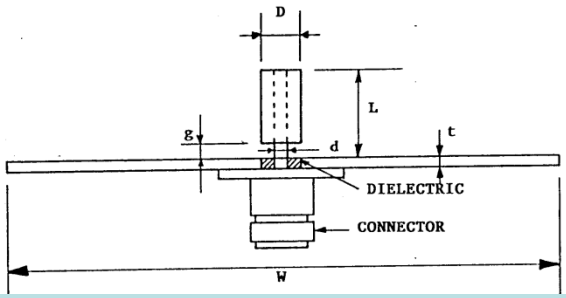
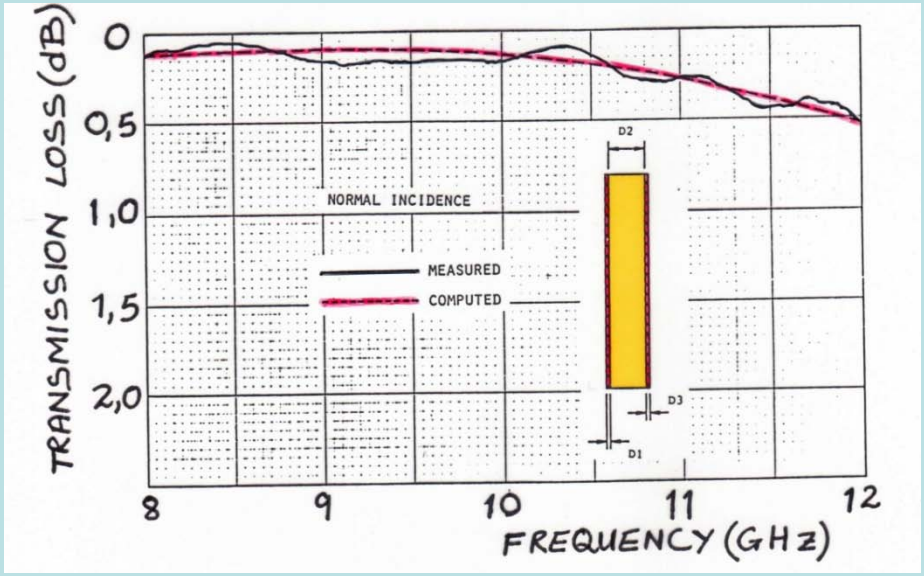


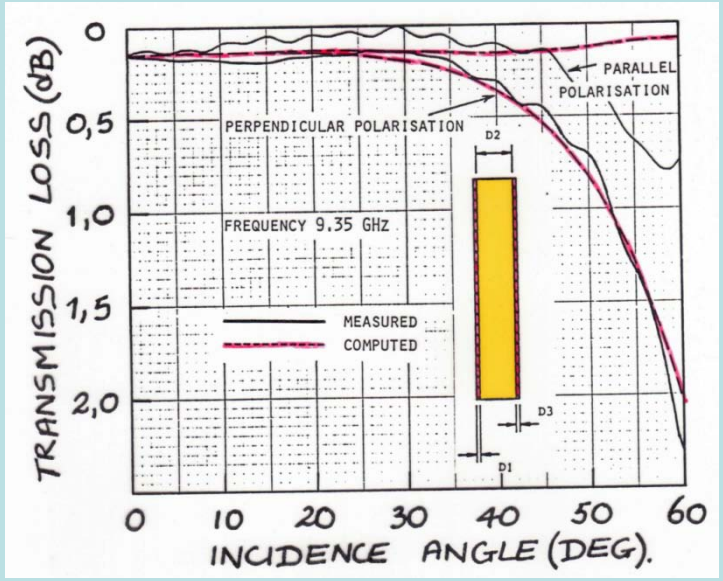
FIGURE 17 : Measured (——) and predicted (----) patterns at 10 GHz for antenna no. 1 on 129 mm groundplane.

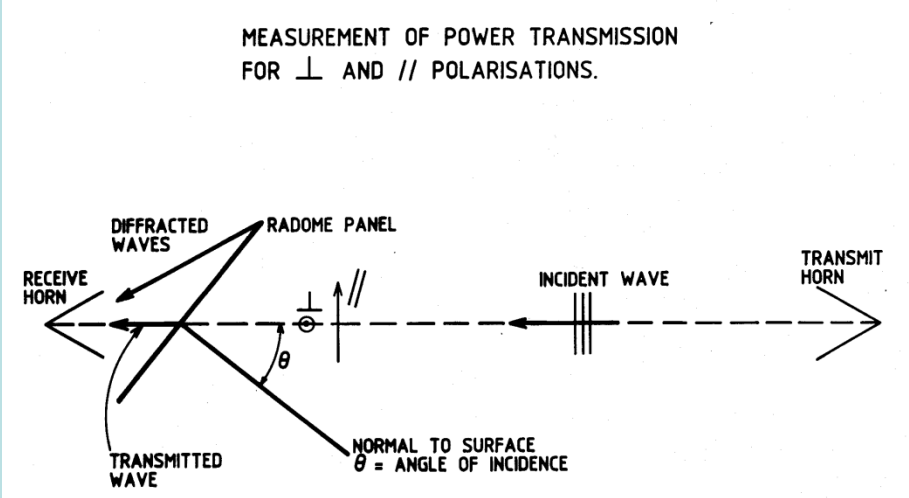


RADOME ANALYSIS

(Joubert, McNamara, Baker)







7.75 m DIAMETER RADOME FOR HEIGHT FINDER

(Baker, Speth, Wocke, McNamara)

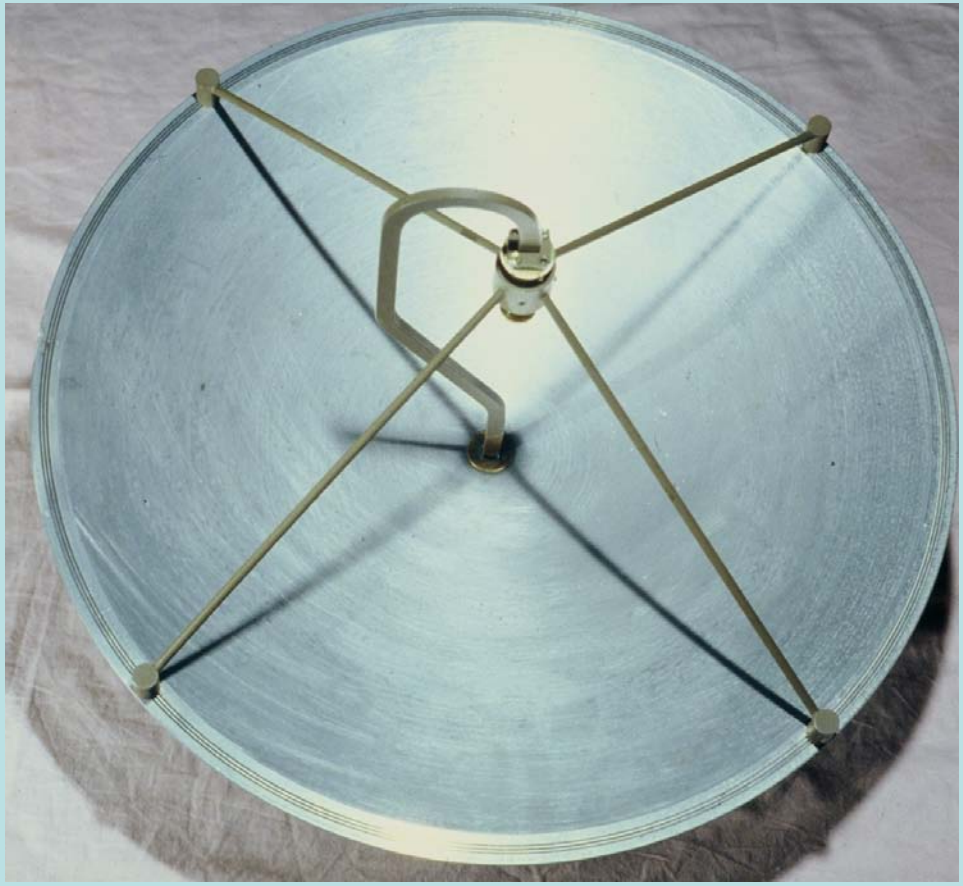
Photos: DPSS

This was one of many joint projects with the Aeronautics Division.

THE NIMBUS 35 GHz REFLECTOR ANTENNA

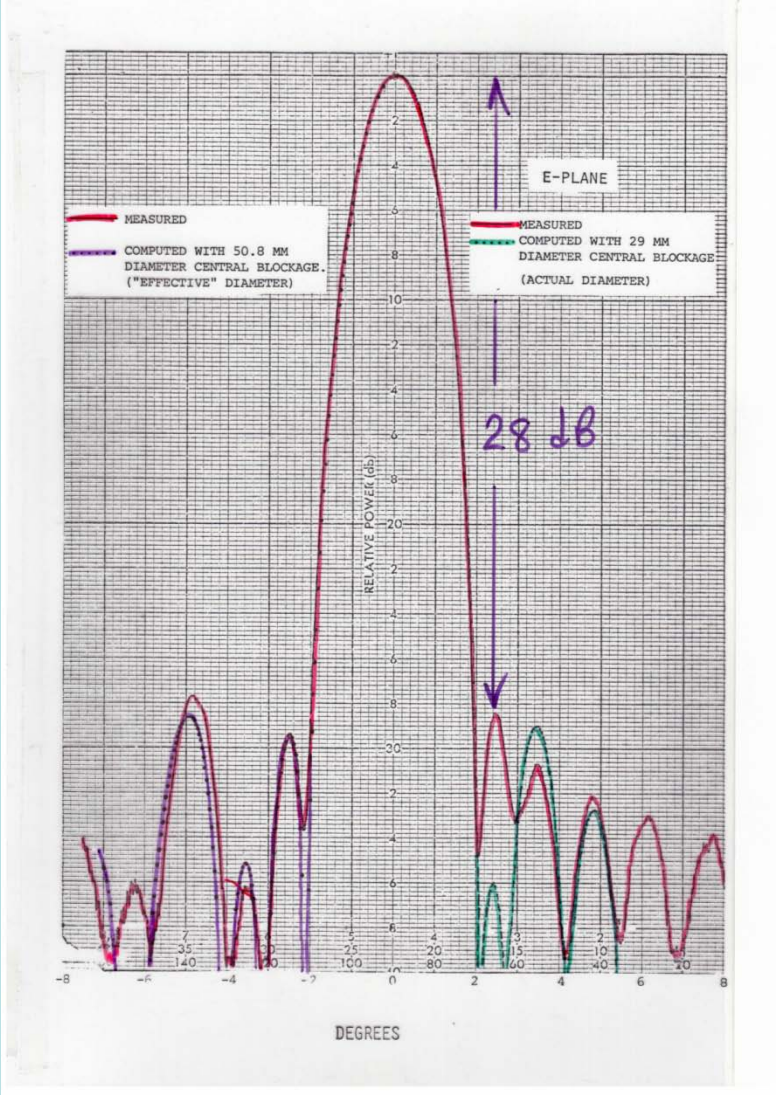
(prime focus, 450 mm diameter)

Photo: DPSS

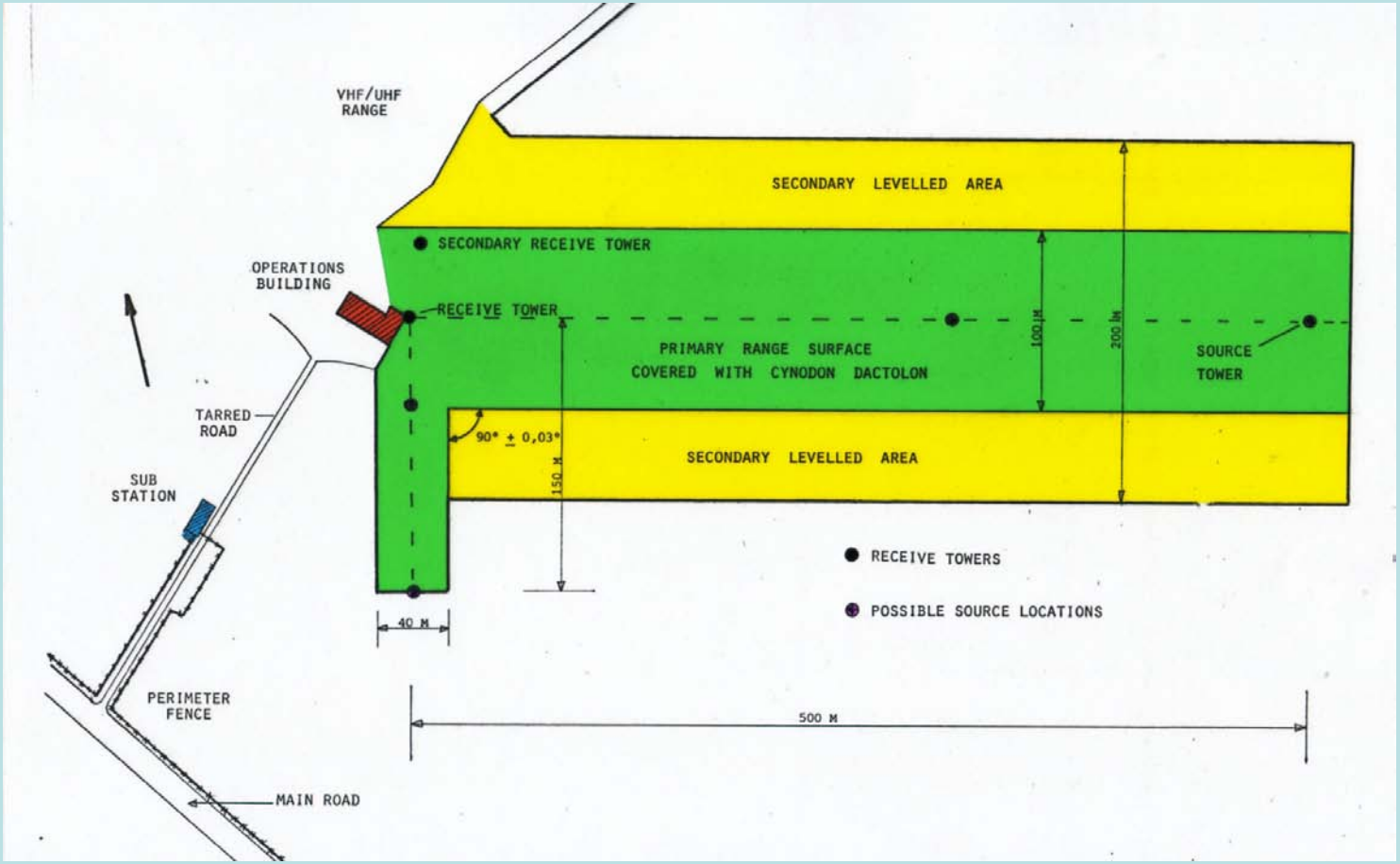


ONE OF THE EARLIEST GTD RESULTS FOR NIMBUS

(McNamara and Baker)



OUTDOOR TEST RANGE FOR LARGER ANTENNAS – THE NATIONAL ANTENNA TEST RANGE AT PAARDEFONTEIN (Baker)



ATCR33 RADAR ANTENNA ON TEST POSITIONER

(S-band, 5.5 m x 2.7 m)

Photo: DPSS

THE NATR IS STILL HEAVILY USED TO THIS DAY

(Less radar work, much more HF/VHF/UHF communications DF)

(Photos: Saab EDS)

MIGRATION FROM NIAST (NIDR)

• Late 1970s to mid 1980s: Experienced engineers moved to industry: Abel van der Merwe (ESD, Sysdel), John Howard (ESD, then UK), Garth Milne (Kentron), Denis Milton (Kentron), Johan Pretorius and Dirk Baker (EMLab).

• At the same time, experienced engineers began moving to the Universities of Pretoria and Stellenbosch (Ad Sparrius, John Cloete, Derek McNamara, Johan Joubert, David Davidson and others). This resulted in academic programmes where the practical and theoretical aspects of antennas and electromagnetics were emphasised. We still see the benefits of this today.

• Teaching and research activities were further enhanced by more overseas PhDs (Callie Pistorius, Barend Taute, Howard Reader).

• Throughout this time a core of experienced engineers remained at the CSIR to carry on the work started in the seventies and eighties (Bob van der Neut, Francois Anderson, Louis Botha, Barend Taute, amongst others).

•Many of you in the audience know and have been influenced by these people.

SOME CONCLUDING OBSERVATIONS

The seventies and eighties were exciting times. NIDR was a wonderful place to work. Here Dr. Thom Hugo the Chief Director created an environment where young engineers could take technical risks and be creative and innovative.

Practical antenna design and development dominated and many antennas were successfully developed without the benefit of modern computational tools.

The advances in numerical techniques and their widespread application have now made it possible to design far more complex antennas and antenna systems than were possible in the seventies.

We have seen the growth of antenna technology from the design and manufacture of isolated antenna elements to complex antenna systems where interactions between the antenna and its environment dominate performance.

Much has been achieved and antenna technology in South Africa is on a par with the best in the world. However, we should remember those earlier events which picked up speed some 40 years ago and set the scene for where we are today.

Those were extraordinary and wonderful times to be a young engineer – I am privileged to have been part of it.

ACKNOWLEDGEMENTS

- Some years ago Bob van der Neut and Louis Botha provided me with copies of the historical photographs for a presentation to the SAIEEE.
- Saab EDS provided photographs of some of their antenna products.
- Sysdel provided photographs of some of their installed systems.
- John Cloete encouraged me to put this together.