Tender for AO/1-1289/80/NL/PP(SC) definition of IMR antenna test techniques

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Tender for

AO/1-1289/80/NL/PP(SC)

DEFINITION OF IMR ANTENNA TEST TECHNIQUES

ET-4-81

Eindhoven, February 1981.

TABLE OF CONTENTS

1. Title of Project

DEFINITION OF IMR ANTENNA TEST TECHNIQUES

2. Principal Investigator

Dr.ir. V.J. Vokurka
Eindhoven University of Technology
Department of Electrical Engineering
P.O. Box 513, 5600 MB EINDHOVEN
The Netherlands, Tel.: 040/473329, Telex: 51163

3. Period of Research

This work will be completed within eight months with an additional one month for the finalization of reports. Proposed starting date: 1 April 1981.

4. Institutional Endorsement

Dr.ir. V.J. Vokurka,
Principal Investigator

Prof.ir. F.J. Kijlstra,
Dean Dept. of Electrical Engineering

drs. P.J. Krens,
Secretary of the University

drs. H.J. ter Heege,
Chairman of Executive Board

5. Technical Objectives

It is the purpose of this work to carry out an investigation into the suitability of Compact Ranges with double-crossed parabolic cylindrical reflectors (Fig. 1) for high-performance measurements on the IMR antenna system. The lower and upper frequency limits are 7 and 90 GHz, respectivily.

A Compact Range, used in combination with a planar scanner, is assumed to be the most attractive arrangement for this particular application. After determining the field characteristics across the test area by planar scanning, far-field radiation patterns are directly measured under similar conditions as at infinite distance. Consequently, the phase and amplitude response of the test antenna can both be simply determined with standard equipment.

The following advantages are expected:

- Full band coverage (7-90 GHz) within a single indoor facility,
- far-field patterns are measured under well-known conditions; error analysis is relatively simple and reliable,
- if necessary, true far-field pattern as occurs at infinite distance can be reconstructed numerically,
- a planar scanner can also be used for the purpose of aligning the test antenna and the feed system,
- such a facility is assumed to be suitable for development as well as verification and re-verification tests,
- repeatability of measurements under the same conditions is possible (environmental & electromagnetic).

For experimental investigation a Compact Range will be available in April 1981. The maximum dimension of this range is approx. 1.5 metre without serrations. The shape of the serrations is optimized to avoid unwanted diffraction effects. Both reflectors are precision-made parabolic cylinders which have proved to be suitable for operation up to 70 GHz. Further increase of the upper frequency limit to 90 GHz will probably cause no difficulty, however, the equipment for this frequency (mixers, source) is not available in the laboratory at present.

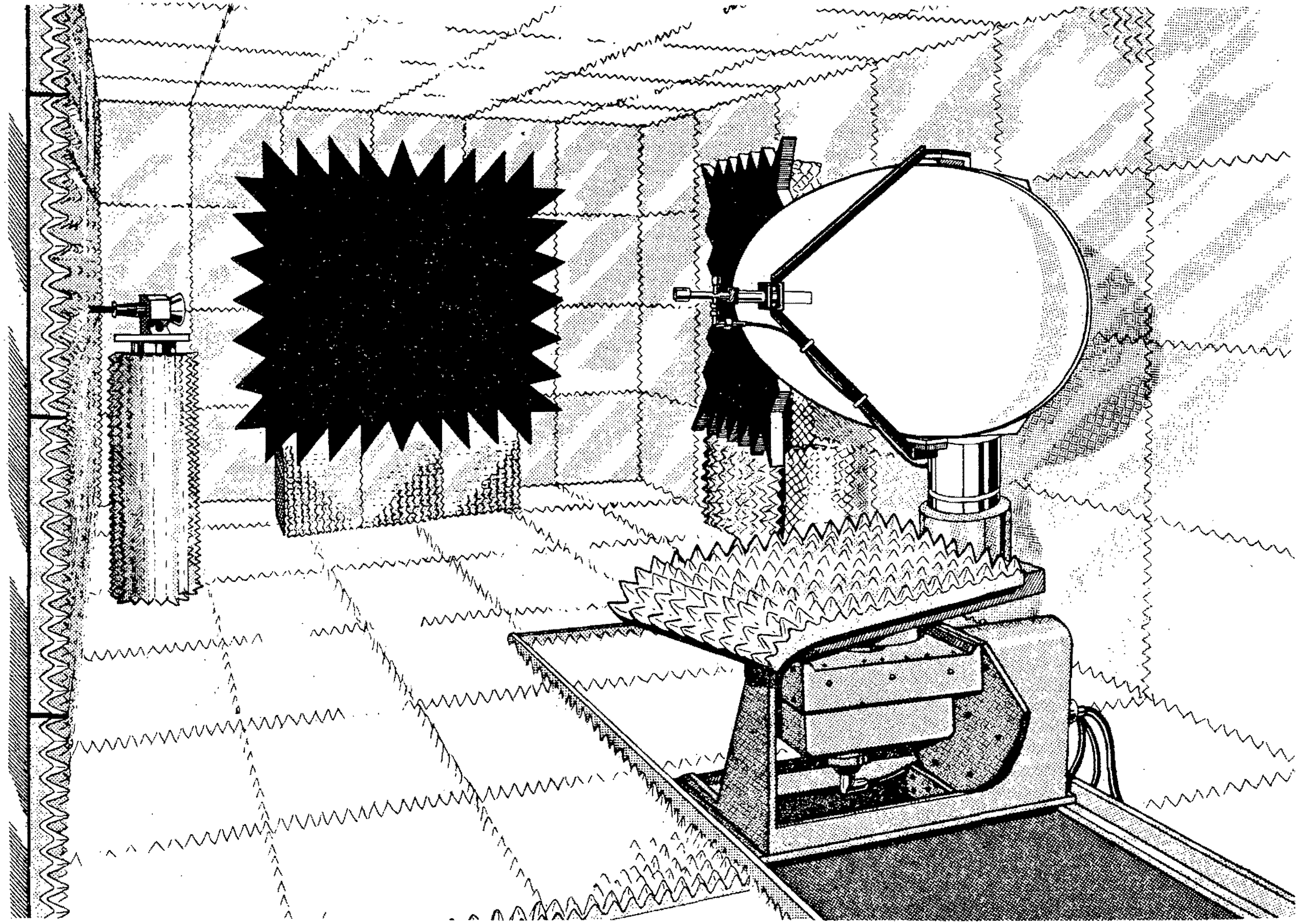

Fig.1: Compact Antenna Range with two cylindrical parabolic reflectors.

"

From the data collected in previous investigations we found a plane-wave zone of about 60-80 cm in diameter (max. amplitude taper 0.5 dB, max. phase variations ± 4°). The full-size Compact Range for IMR application will thus have an aperture of about 2.5-3 metres, depending on requirements as to maximum allowed deviation in phase and amplitude over the test zone. This indicates that this type of range is considerably more compact than any other existing design.

Obviously, this study must be supported by a large number of experiments. Since the range available is about half the size needed for the IMR antenna measurements, it would seem to be most advantageous to use a 60cm parabolic reflector as a reference antenna during the experimental investigation. In combination with wave characteristics across the test area (measured by planar scanner) an accurate prediction can be made as to the range performance. Finally, the experimental data recorded indoors will be compared with measurements taken on a far-field range.

6. Historical Background

Measurements on microwave antennas are based on electromagnetic environment simulation so that the errors between the measured and true radiation behaviour of a test antenna are minimal. The importance of high-quality measuring ranges is evident; even slight errors between the measured and real radiation patterns could raise doubts as to the design technique or the theoretical approach used in predicting the radiation properties of the test antenna.

Most antenna measurements have to be carried out in the far-field, i.e. the test antenna should be illuminated by a plane wave. The oldest and most frequently used technique is based on sufficient separation between the transmitter and the receiver so that part of a spherical wave approaching the test antenna has almost a plane-wave character. However, the common far-field criterion $R > 2D^2/\lambda$ gives a phase deviation of 22.5° at the edge of the test antenna, which results in errors in the recorded pattern. For electrically large antennas the range length could be several kilometres. Ground reflections, high towers, high powers needed and the dependance on weather conditions are the disadvantages.

For indoor measurements the far-field technique is used in anechoic chambers. Electrically small antennas (feeds, small reflectors) can be measured directly at these ranges. These measurements are, however, often less accurate than is assumed [1].

There is, however, another method which allows indoor measurements under far-field conditions. In this case we have to collimate the rays originating from a line- or spherical source. Let us, for example, assume that we are able to collimate the beam within a cone $2\theta_o = 20^\circ$, having a uniform amplitude distribution across the latter, According to GO we find a "plane-wave zone" with a diameter of 2 metres, provided the collimation takes place at a distance of 5 metres from the source. The amplitude taper due to the space loss is about 0.07 dB. Since GO is used in this consideration, such design is basically independent of frequency. Collimating, as required above, can be achieved by using a lens or a reflector. It should be noted that the effect of diffraction at the edges of the collimator are not considered here.

Although some attempts have been made using a lens for Compact Range design, reflectors are preferred for practical applications.

Theoretical and experimental investigations into Compact Ranges have been carried out by several authors. Johnson [2] has described two such ranges. The point-source range consists of a reflector of revolution and a spherical source. The feed illuminates the upper half of the reflector (a conventional dish may be used). The line-source range consists of a parabolic cylindrical reflector and a line feed (hoghorn type). Such a range possesses some mechanical advantages, but is unsuitable for wideband operation. Moreover, the polarisation of this C.R. is fixed. The application of the C.R. to measurements of tracking antennas has been described by Hansen [3]. Results of experimental investigations of a Scientific Atlanta Compact Range are given by Johnson and Hess [4].

However, it is known that this solution has certain disadvantages. High system cost and limited physical dimensions of the test area ($d = 120$cm) are seen to be the main obstacles to wide use of these devices. Further increase of the test-area dimension would require a very large reflector, while higher upper frequency limit can only be achieved by improving the reflector surface accuracy. On the other hand, low reflectivity and very low variations in phase make high performance measurements possible.

A new class of Compact Ranges has been described by Vokurka [5], [6], [8]. This system consists of two parabolic cylinders positioned perpendicular to each other (Fig. 2). When illuminated by a spherical source the resulting wave front in the aperture of the main reflector will have a plane-wave character. Such a system is very suitable for the offset arrangement which is required in our case. First, the primary source may be pointed in any direction fixed by angles θ and ϕ. Further, the subreflector and the feed can both be rotated about the focal line F_2, which is identical with the image focal line F_1'. Due to the increased focal length, the uniformity of the amplitude distribution across the final aperture is increased considerably compared to conventional design (Fig. 3). According to the reflector geometry, the cross-polarization is to be expected at very low levels (<-35dB); naturally the latter depends also on the feed characteristics. It may, therefore, be possible to use this C.R. for cross-polar measurements.

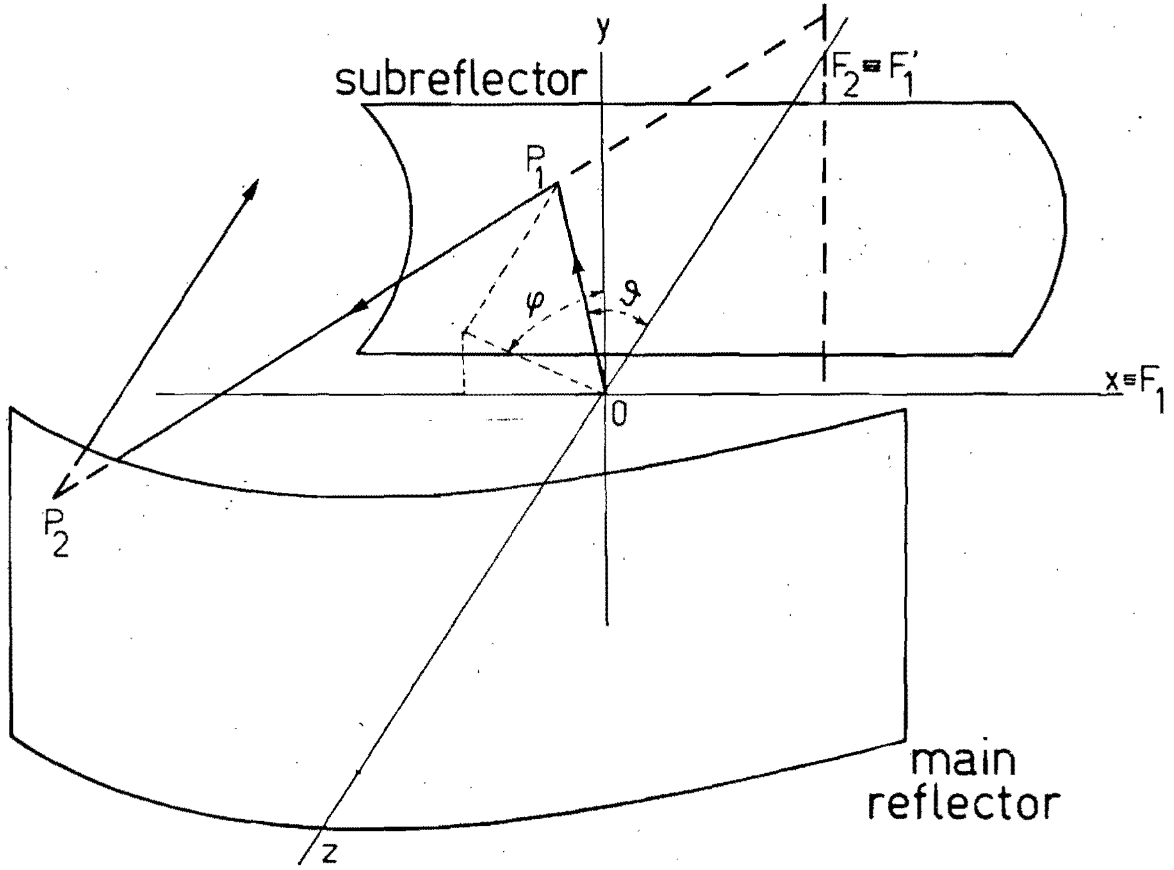

Fig.2: Double-crossed parabolic cylinders, basic geometry.

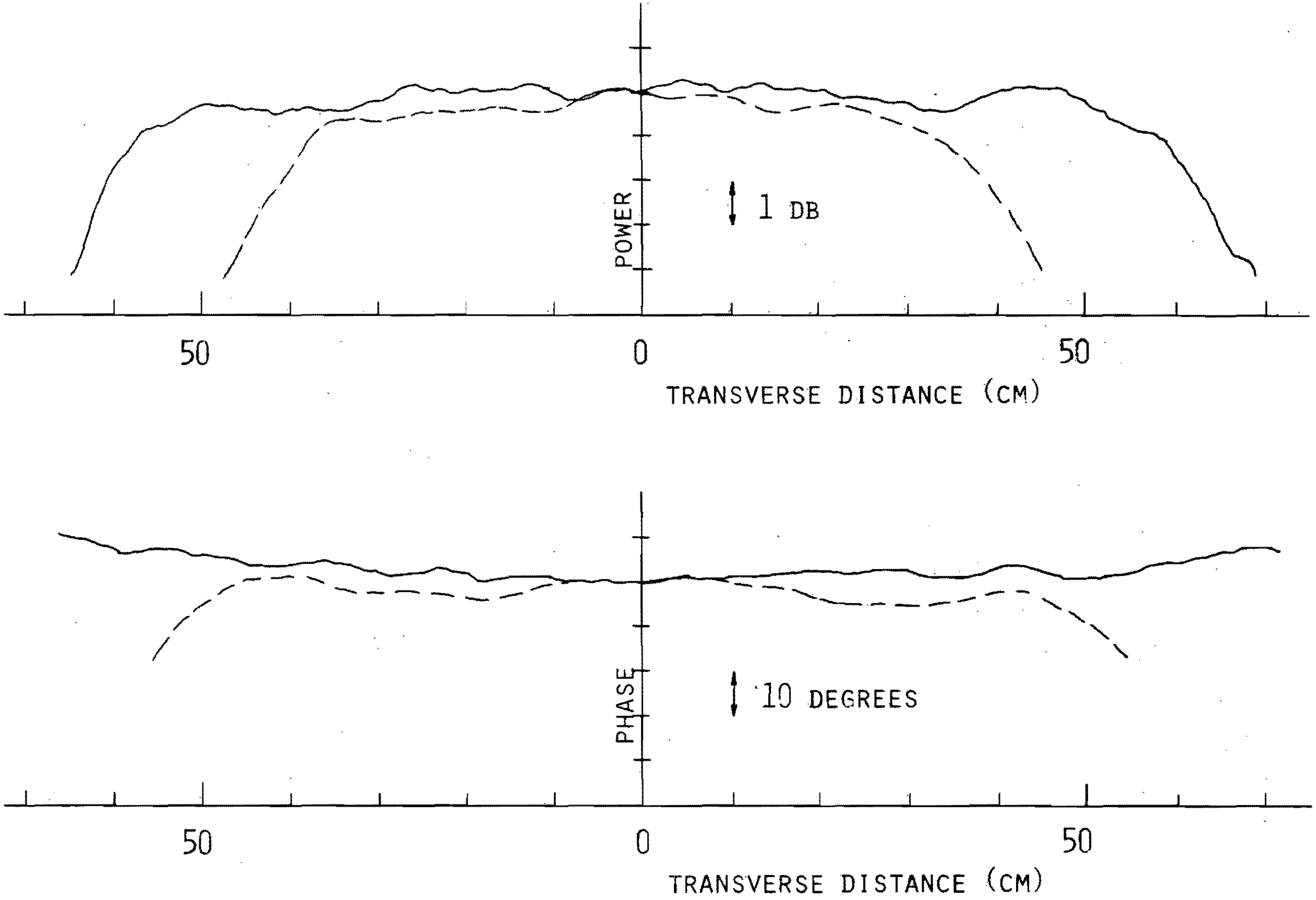

Fig.3: Amplitude and phase distribution across the test zone of an experimental Compact Range.

——————— edge taper -1.5 dB, - - - - - - - - - edge taper -9.5 dB. f=23.0 GHz.

Not optimized for diffraction effects.

Due to the fact that this design is based on geometrical optics, operation in a very wide band may be expected. The upper frequency limit depends on the reflector surface accuracy. Recently, experimental measurements have been carried out at 70 GHz. The reflector surface accuracy realized in this case was 0,03 mm. Therefore, it is expected that such a range will operate up to 90 GHz without performance degradation.

Although the measured pattern agrees very well with that which would occur at infinite distance, further improvement is possible since the phase and amplitude of the antenna response, as well as of the wave front illuminating the test antenna, are known.

An asymmetrical "plane wave zone" can be created owing to the reflector geometry. The range can be thus tailored to some particular application. Reflectivity below -60 dB has been measured with the first experimental model.

Summarizing, Compact Ranges are eminently suitable in indoor antenna measurements for various applications. The measurements are carried out directly under similar conditions as in the far-field. High performance measurements are possible mainly due to low phase variations (typically $\pm 4^{\circ}$) over the test area and very low reflectivity level. Applying the concept of two crossed parabolic cylinders, considerable improvements may be achieved for cross-polarisation and compactness of the range. For the same size of plane-wave zone, the compact range reflector will be approximately half (in linear dimension) of the corresponding design with a single offset reflector. The manufacture of cylindrical reflectors is also simpler than that of double-curved surfaces.

Another technique for determining the far-field radiation characteristics indoors is that of near-field scanning. The far-field characteristics are then determined numerically. These techniques have been developed over the past 15 years and in some particular cases they offer important advantages when compared with the classical far-field approach [9]. Planar, cylindrical and spherical scanning are three possible arrangements. A comparison of the techniques is given, for instance in [1]. A choice of one of these methods will mainly depend on the geometry of the test antenna. For the IMR antenna, application of planar scanning seems to be the best choice. However, both the mechanical stability and alignment could cause serious problems, in

	FAR FIELD OUTDOOR	NEAR FIELD COMPACT RANGE	NEAR FIELD		
CHARACTERISTICS			PLANAR	CYLINDRICAL	SPHERICAL
Real Estate/Structures	Range length $2D^2/\lambda < R < 10D^2/\lambda$ Towers 3 axis precision positioner	Anechoic room RF Absorber (100 %) 3 axis precision positioner	-------------- Anechoic room ------------------------		
			RF Absorber (15 %)	RF Absorber (20 %)	RF-Absorber (20-100 %)
Instrumentation/software	Weatherized test terminal Broadband radome Data collection system	C.R. Reflector(s) Error analysis(optional) Data collection system	2-dim scanner	1-dim scanner 2 axis positioner	3 axis precision positioner
			-------------- Control software --------------------- -------------- Error analysis ----------------------- -------------- Data collection system --------------- -------------- Analysis software --------------------		
Operational Constraints	Wind & Weather Safety Security Logistics	None	-------------- Large scan times ---------------------		
Performance Constraints	Ground reflections Rain attenuation	Reflector tolerances Quality of feed pattern	-------------- Scanner and/or positioner tolerances -- (static & dynamic) --- Inefficient for early development tests ----------		
Overall Relative Cost Estimate	5 (Highest)	1 (Lowest)	2	3	4

Table 1: Comparison of near-field and far-field techniques.

particular at 90 GHz. These aspects are also of importance to two other methods, i.e. cylindrical and spherical scanning. Moreover, due to the main disadvantage of these methods, namely the long time needed for scanning and computing the radiation pattern, their suitability for development testing (which is usually time-consuming) is questionable.

In Table 1. the methods mentioned above are compared. We observe that no single measurement technique will be ideal for general use. For instance, for measurements on large-phased arrays [9] planar scanning has proved its suitability and it saves a considerable amount of time. In other applications, the same technique might be unsuitable just because of its time-consuming character, for instance on account of the large number of repeated measurements during development test on large satellite antennas. In the case of the IMR antenna, direct indoor measurements under the far-field conditions are probably most attractive. Compact Range arrangement consisting of reflectors with a very high degree of surface accuracy and improved cross-polarisation will be needed in view of the wide frequency range and the antenna characteristics.

7. Work Statement

The two methods of determining the far-field radiation pattern (Compact Range and planar scanning) assumed to be most suitable for measurements on the IMR antenna will be considered in this study. Both methods will not be considered separately but as parts of one facility. It is believed that such a combination will be an optimum solution to measurements on large spacecraft antennas (in terms of wavelength) in a wide frequency range. The test antenna is illuminated by a pseudo-plane wave of known characteristics. Furthermore, the response of the test antenna is usually measured also for both phase and amplitude. It is obvious that the maximum amount of information is to be obtained in this way; this can lead to very accurate measurements which still have the advantages of far-field measurements (no delay in data recording, collecting only the information which is required, etc).

Error analysis will probably be simpler and more accurate than in the case of the near-field/far-field transformation. This is because the error analysis is applied directly to the far-field pattern recorded under well known conditions.

Compact Ranges are relatively new devices, commercially available for some six years. Double-crossed parabolic cylinders have not been used for this purpose before, however, it has been proved that most disadvantages inherent in the classical approach are not present in this new geometry.

Planar scanning is the first method which proved its suitability in the near-field/far-field transformation. Although the way in which it will be used here differs from the usual transformation procedure, its simplicity (data collection, numerical methods and mechanical aspects) and character (planar scan) make it eminently suitable for use in combination with a Compact Range.

7.1. General design aspects

Determination of the optimum positioning for both reflectors and the feed. Every effort should be made to minimize unwanted radiation due to diffraction effects at the edges of both reflectors. Geometrical optics and geometric theory of diffraction (GTD) are the most suitable methods for this part of a study. Optimum shape and dimensions of the anechoic chamber should follow from this investigation. The field distribution across the test area can be estimated by GO.

Theoretical and experimental investigation on feeds suitable for dual-reflector Compact Range. A corrugated horn seems to be the best choice due to its excellent radiation characteristics (low cross-polar, low spill-over). However, long focal length of this system allows the application of other feeds too, for instance the pyramidal horn could be a possible candidate. In general, an optimum feed should have a high degree of uniformity in amplitude within a cone of some 20°, while the radiation beyond this angle should be as low as possible. These characteristics should be satisfied in a wide frequency band. For feeds which are to be used at the upper frequency (90 GHz) mechanical design aspects (accuracy) will be considered.

7.2. Error Analysis

7.2.1. Pattern corrections

As already mentioned, the phase and amplitude across the C.R. aperture possess a high degree of uniformity, so that the direct measurements will give satisfactory results in most cases. However, it is possible to estimate the errors in measured patterns and to derive the "true" far-field data relatively simply. This is because the phase and amplitude of the test antenna response and also of the pseudo plane wave across the latter are known. For example, assume that the far-field pattern of a linear antenna is to be determined. This pattern, as occurs at infinite distance, may be expressed as follows, except for a multiplicative constant

$$g(\theta) = \int_{-a/2}^{a/2} F_1(\xi) e^{jk\xi\sin\theta} d\xi, \qquad (1)$$

where $F_1(\xi)$ is the aperture distribution and the factor $e^{jk\xi\sin\theta}$ corresponds to plane-wave illumination. In a more general case the test antenna is illuminated by a non-planar wave and the antenna response is given by

$$g'(\theta) = \int_{-a/2}^{a/2} F_1(\xi) F_2(\xi,\theta) e^{jk\xi\sin\theta} d\xi, \qquad (2)$$

where $F_2(\xi,\theta)$ characterizes the difference between the phase and amplitude of a plane wave. If F_2 depends on ξ only, the test antenna response becomes

$$g'(u) = \frac{a}{2} \int_{-1}^{1} f_1(x) f_2(x) e^{jux} dx, \qquad (3)$$

with $x = 2\xi/a$ and $u = \frac{\pi a}{\lambda} \sin\theta$.

It is obvious that the true far-field pattern could be derived in two steps. First, the inverse Fourier transform applied to (3) gives $f_1(x)$, and substitution of this last into (1) yields the required far-field pattern. We may, however, omit the reconstruction of the aperture field using the following method. The (unknown) radiation pattern g(u) may be written as

$$g(u) = \frac{a}{2} \int_{-1}^{1} [f_1(x) f_2(x)] \frac{1}{f_2(x)} e^{jux} dx. \qquad (4)$$

This is a Fourier transform of a product of two factors which may be expressed as a convolution of their spectra. Working out (4) we find that the correction to g'(u) pattern (as recorded at the Compact Range) can quite easily be computed numerically. The amplitude and phase of both g'(u) and $f_2(x)$ can be measured by standard techniques with very high accuracy. Summarizing, this technique allows the determination of the far-field radiation patterns with a very high degree of accuracy, probably even better than on the high-performance far-field range. This could be of great importance for measurements of pattern zeros or sidelobes at very low levels, etc.

7.2.2. Reflectivity

Another important aspect is determination of the reflectivity level inside the test area. Two methods can be used, i.e. the VSWR or the pattern comparison method. In the first case, data are available from planar scan across the test zone. The evaluation is thus simple and does not require additional measurements. On the other hand, characteristics achieved by probing must be handled with care in order to avoid additional errors. Due to the fact that the test facility is designed for measurements on medium and large-aperture antennas ($30\lambda<D<400\lambda$), the pattern-comparison method will probably be more accurate, mainly because of the test range geometry. Within the test zone, levels of unwanted radiation are very low, while locations of corresponding sources are known (reflector edges and feed). Unlike the case in the anechoic room or the far-field range, reflections from walls and ground are less important. This is an important advantage of the Compact Range. Measurements with high accuracy, also at wide angles can be realized.

7.2.3. Reflector surface errors and disalignment

Surface distortion effects can play an important part, in particular at higher frequences. Two following aspects are to be considered in detail. First, inaccuracies in the reflector surface which are due to fabrication. Second, errors which occur due to disalignment, can be caused for instance by an instable environment (temperature variations). Both effects will be studied in detail, in case of possible errors in alignment, a mathematical model will be derived.

7.2.4. Cross polarisation

Relatively high cross polarisation degradation, typically about -25 dB, in present compact ranges has been the main obstacle for accurate prediction of cross-polar performance of the test antenna. Considerably better performance is expected with a system using the double-crossed cylindrical geometry [13]. The main error contributions are:

- cross polarisation due to the wave transformation,
- contribution caused by diffractions,
- depolarisation due to the feed characteristics.

This part of the study will be complemented by experimental investigation.

7.3. Experimental Investigations

As already mentioned, the experimental investigation will play an important part in this study. This investigation will be carried out with a 60cm-precision paraboloid at 24 GHz. The following measurements will be carried out:

Indoor measurements (C.R.)

- H-plane, E-plane and 45° plane co-polar patterns will each be recorded 6 times at 6 different axial distances in the test area,
- H-plane, E-plane and 45° plane cross-polar patterns,
- gain measurements by comparison with a standard gain horn.

Outdoor measurements

These measurements will be carried out on the outdoor range (R ∿ 180m) and will serve primarily for the purpose of comparison with indoor measurements. Particularly important are the cross-polar measurements; data recorded outdoors are assumed to be highly accurate and thus give an accurate reference for the performance evaluation of the Compact Range.

All pattern measurements (except for the cross polarisation) will be recorded over 360° in the azimuth plane.

The data collected indoors and outdoors will be evaluated. Characteristics of the Compact Range determined by planar scanning and the influence on accuracy will be taken into account in this evaluation.

7.4. Experimental Investigation (Optional)

The work package as described under 7.3 could be extended to cover two other frequencies, 12 and 70 GHz. Although there is no doubt that such a programme will be very valuable in view of the evaluation procedure, it should be noted that it will be rather time-consuming. It is therefore a subject for further negotiations. This optional package is not included in the Price Breakdown Form.

7.5. Evaluation Study

In this section the following aspects will be considered:
- attainable accuracies (error analysis, mechanical aspects),
- operational aspects (limitations, time for measurements and definition of the test procedure),
- suitability for space-hardware-handling requirements,
- suitability for IMR antenna measurements,
- growth potential (electrical and mechanical design aspects),
- cost estimate.

Part of this study, that is concerning the mechanical design aspects, will be carried out in cooperation with the Department of Mechanical Engineering of the Eindhoven University of Technology.

8. Bibliography

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9. Time Schedule

According to the description of activities (see section 7), the time schedule is divided into four phases

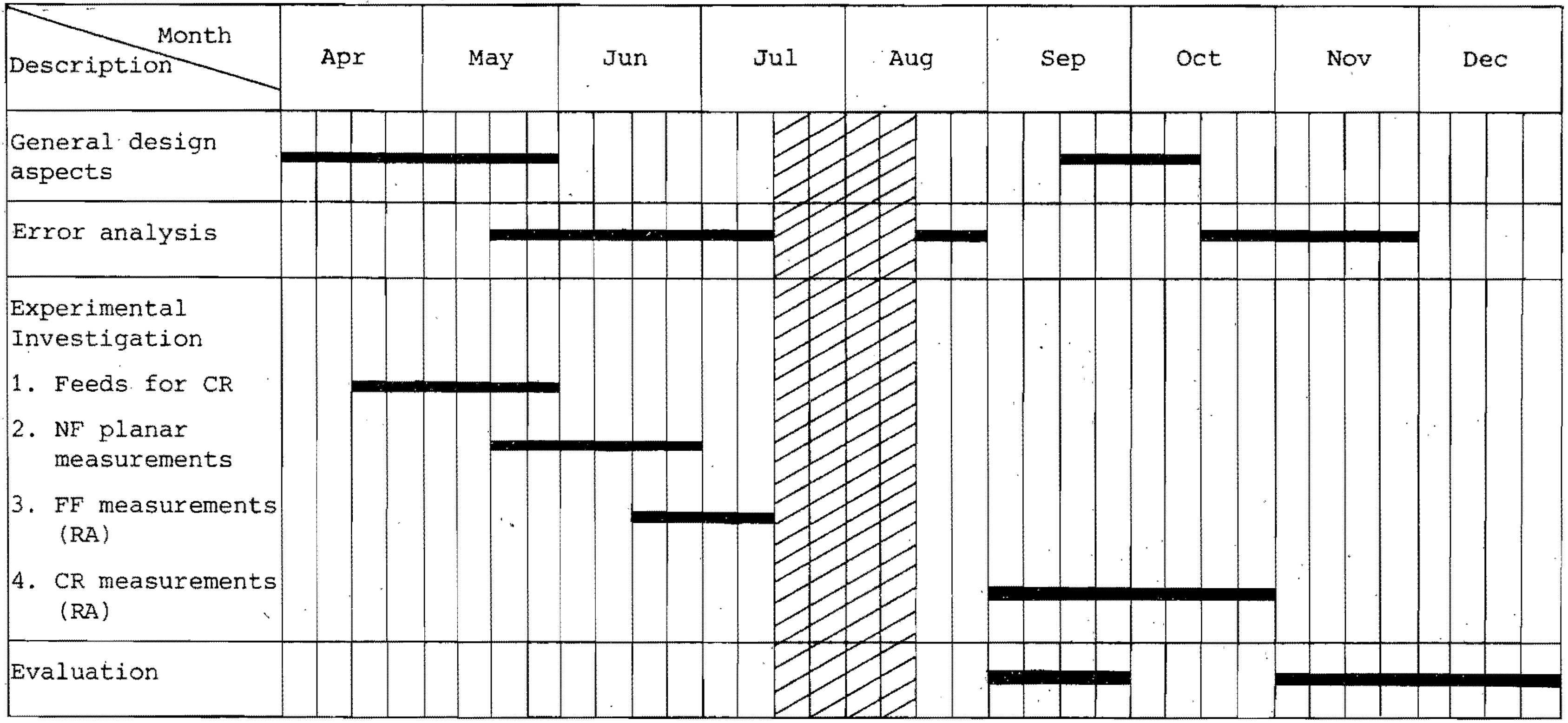
- General design aspects,
- error analysis,
- experimental investigation,
- evaluation of results.

In addition, the following meetings are proposed

- Kick-off meeting: 1 April 1981,
- first progress meeting: 3 June 1981,
- second progress meeting: 30 September 1981,
- final presentation: 18 December 1981.

During the contract period the following reports will be delivered to ESTEC

- First progress report to be delivered at the first progress meeting on 3 June 1981,
- second progress report to be delivered at the meeting on 30 September 1981,
- final draft report will be delivered one week period to the final presentation,
- final report (revised) will be delivered by the end of January 1982, four weeks after receipt of comments from ESTEC.



RA = reference antenna

<u>Meetings</u>: Kick-off meeting - 1 April 1981
Progress meeting 1 - 3 June 1981
Progress meeting 2 - 30 September 1981
Final presentation - 18 December 1981

<u>Reports</u>: Progress report 1 - 3 June 1981
Progress report 2 - 30 September 1981
Final report (draft) - 11 December 1981
Final report (revised) - 29 January 1982

Table 2: Time schedule.

10. Research Activities of the Antenna Laboratory ET

The four major areas of research within the Electromagnetism and Circuit Theory group ET are : circuit theory, optics, semiconductors and microwave antennas. The permanent staff of 22 includes 3 full-time professors.

The Antenna Laboratory, founded 15 years ago, has in this period carried out a large amount of theoretical and experimental work, in most cases, on electromagnetic field theory applied to feed and reflector antenna systems. For instance, various feed systems for radio-astronomical applications have been designed and are now in use at Dwingeloo and Westerbork. Furthermore , investigations on the theory of both corrugated circular and elliptical horns have been carried out in Eindhoven. Recently, an elliptical corrugated horn has been selected for use in the German TV-SAT project. At present the theory of corrugated elliptical horns with arbitrary flare angle is being developed. In the field of microwave reflector antennas the most important projects were: the Compact Antenna Range, multi-reflector antennas for microwave-link applications and dual-reflector antennas (optimized Gregorian design).

In addition, some 50 papers including those presented at international conferences have been published from 1968-1980.

Contract-research has been carried out for: ESA/ESTEC, Radioastronomical Observatory in Dwingeloo and for Messerschmitt-Bölkow-Blohm, Munich.

11. Facilities and Equipment

The Electromagnetism and Circuit Theory group (ET) has the following equipment available in the Antenna Laboratory. An anechoic chamber for measurements on feeds and small antennas, outdoor range $R \sim 200$m with a possibility of extension up to 1.5km. Receiving equipment consists of two Scientific-Atlanta receivers with positioners, etc. The new anechoic chamber for C.R. experiments is now completed. An X-Y scanner for near-field measurements is available. Computer facilities: Burroughs 7700 and PDP 11/40. Feeds and small antennas are usually made within the Department of Electrical Engineering. Large reflectors can be constructed by the Main Technical Service Department.

12. Key Personnel (curriculum vitae)

V.J. Vokurka

Born: 14 June 1946, Cista, Czechoslovakia.

1973: Ir. degree in Electrical Engineering from Eindhoven University of Technology.

1973-1976: Research associate at the Netherlands Organisation for Advancement of Pure Research (ZWO).

1977: Dr. in Technical Sciences from Eindhoven University of Technology.

1976-present: member of staff of the Eindhoven University of Technology, Electromagnetism and Circuit Theory group. Working mainly on feed- and reflector antenna design. Approximately 25 publications and presentations at international conferences. 12 patents and patent applications in six countries. Consultant to: MBB, Radio-astronomical Observatory Dwingeloo, US Army and US Navy.

M.H.P. van Iersel

Born: 23 June 1955, Tilburg, Netherlands.

1979: Ir. degree from Eindhoven University of Technology.

1980-present: Employed at the National Defence Organisation (TNO/RVO). Engaged in numerical analysis of phased arrays. Also concerned with development of near-field techniques (software) for application on phased arrays.

13. Budget Estimate (D.Fl.)

10 February 1981.

1. SALARIES AND WAGES

A. Engineering

Principal Investigator Dr.ir. V.J. Vokurka 1/2 time for 8 months (Category 2) 1/2 x 8/12 x ƒ 136.000,--	45.330,--
Research Associate Ir. M.H.P. van Iersel 2/3 time for 8 months (Category 5) 2/3 x 8/12 x ƒ 58.000,--	25.780,--
Total R & D engineering (A)	71.110,--

B. Supporting activities

Workshop assistance 250 hours, ƒ 35,--/hour	8.750,--
Experimental investigation 400 hours, ƒ 35,--/hour	14.000,--
Secretarial assistance 100 hours, ƒ 35,--/hour	3.500,--
Total supporting activities (B)	26.250,--
Total (A+B)	97.360,--
Labour overhead (100%)	97.360,--

2. GENERAL & ADMINISTRATIVE OVERHEAD

Current rate is 12.5% of salaries (A+B) 12.5% of 97.360,--	12.170,--

3. EXPENDABLE SUPPLIES

Waveguides & flanges	800,--
Material for feeds	650,--

4. EQUIPMENT RENTAL

2 hours Burroughs 7700 *f* 3.000,--/hour	6.000,--
200 machine hours CTD *f* 38,--/hour	7.600,--
400 hours Antenna Laboratory Equipment (indoor & outdoor sites) *f* 57,--/hour	22.800,--

5. TRAVEL

Meetings at ESTEC (4 times for 2 engineers)	880,--
TOTAL COST (1+2+3+4+5) D.Fl.	245.620,--

6. COST SHARING

Total proposed cost to ESTEC :	D.Fl. 148.260,--
Total amount of cost sharing :	97.360,-- *
Total cost of research program:	245.620,--

*Subject to approval by the Eindhoven University of Technology.

The payment scheme is proposed as follows:

- An advance payment of 25%,
- one interim payment of 25%, due at the delivery of progress report I,
- a final payment, due at the delivery of the final report.

PRICE BREAKDOWN FORM

DATE OF ISSUE: 10 February 1981
SUBJECT: AO/1-1289/80/NL/PP(SC)
ORIGINATOR: Eindhoven Univ.
REF. NO.:
TYPE OF PRICE:
NATIONAL CURRENCY: D.Fl.
ECONOMIC CONDITIONS:
ESA-AU EXCHANGE RATE: 2.78177

LABOUR COST Category	Manpower Effort in Manhours	Basic Hourly Labour Rate	Labour Overhead %	Labour Overhead Rate	Gross Hourly Labour Rate	AMOUNT NATIONAL CURRENCY (NC)	AMOUNT ACCOUNTING UNIT (AU)
R&D engineering	1240	57.35	100	57.35	114.70	142,220.00	
Support. activities	750	35.00	100	35.00	70.00	52,500.00	
1. TOTAL MANHOURS	1990				TOTAL LABOUR COST	194,720.00	70,000.00

MATERIAL COST	Amount	Overhead %	Overhead Amount	NC	AU
Mat. for feeds,waveguides	1450.00	0		1,450.00	
Hirel parts					
2.			TOTAL MATERIAL COST	1,450.00	522.00

INTERNAL SPECIAL FACILITIES	Type of unit	Number of units	Unit rate	NC	AU
Computer	hours	2	3,000.00	6,000.00	
Antenna test sites (ind.&out)	hours	400	57.00	22,800.00	
Machine hours CTD	hours	200	38.00	7,600.00	
3.			TOTAL COST OF INTERNAL SPECIAL FACILITIES	36,400.00	13,085.00

OVERHEAD	%	Amount of 1 ~~and/or 2 and/or 3~~	NC	AU
General & Administrative Overhead of basic salar.	12.5	12,170.00	12,170.00	
General Research & Development Contribution				
4.		OVERHEAD ON 1 ~~AND/OR 2 AND/OR 3~~	12,170.00	4,375.00

OTHER DIRECT COST	Amount	Overhead %	Overhead Amount	NC	AU
External Major Products					
External Special Equipment					
External Services					
Transport					
Travel and Subsistence	880.00	0	0		
5. SUBTOTAL	880.00	6.			
7.			TOTAL OTHER DIRECT COST	880.00	316.00

SUBCONTRACTS Subcontractor	Amount (in tenderer's N.C.)	Overhead %	Overhead Amount (in tenderer's N.C.)	NC	AU
8. SUB-TOTAL		9.			
10.			TOTAL SUBCONTRACTS	0	0

LICENCE FEES AND ROYALTIES Description	Licensor	Basis of calculation	%	NC	AU
11.				0	0

	Amount	%	NC	AU
12. PROFIT ON 1 - 2 - 3 - 4 - 6 - 9			0	0
13. PRICE (1 + 2 + 3 + 4 + 7 + 10 + 11 + 12)			245,620.00	88,298.00

PC-04/4

SUBJECT REF NO AO/1-1289/80/NL/PP/(SC)	**TRAVEL AND SUBSISTENCE PLAN** **Summary**	ORIGINATOR Eindhoven Univ. of Technology DATE OF ISSUE 10/2/81

ORIGINATOR	EUROPEAN		TRANSATLANTIC		% of originator cost	COMMENTS
	No. of trips	COST (AU)	No. of trips	COST (AU)		
Eindhoven University	8	316.00				Meetings at ESTEC (4 times for 2 engineers)
TOTAL		316.00				

Notes :

Appendix IV
to the
Invitation to Tender
N° AO/1-1289/80/NL/PP(SC)

GEOGRAPHICAL DISTRIBUTION FORM

The tenderer is requested to complete the table below showing the amounts and percentages of work included in the tender against each of the countries listed below :

Countries	Name of tenderer or proposed sub-contractor	Amount in Accounting Units	Percentage of total amount of tender
BELGIUM			
DENMARK			
FRANCE			
GERMANY			
ITALY			
NETHERLANDS	Eindhoven Univ.	88,298.00	100
SPAIN			
SWEDEN			
SWITZERLAND			
UNITED KINGDOM			
IRELAND			
AUSTRIA			
CANADA			
NORWAY			
USA			
OTHERS			
Total price of tender in Accounting Units :		88,298.00	100%

The tenderer is requested to include two completed copies in his tender. The third copy is for his file.

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to the
Invitation to Tender
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NETHERLANDS	Eindhoven Univ.	88,298.00	100
SPAIN			
SWEDEN			
SWITZERLAND			
UNITED KINGDOM			
IRELAND			
AUSTRIA			
CANADA			
NORWAY			
USA OTHERS			
Total price of tender in Accounting Units :		88,298.00	100%

The tenderer is requested to include two completed copies in his tender. The third copy is for his file.