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Correction technique on indoor RCS measurements

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CORRECTION TECHNIQUE ON INDOOR RCS MEASUREMENTS.

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ABSTRACT

For antenna and radar measurements it is desirable that the illuminating field is an ideal plane wave. A pseudo-plane wave can be created in a Compact Antenna Test Range (CATR) with two cylindrical reflectors that are positioned perpendicular to each other. However this pseudo-plane wave will never be an exact plane wave. Diffraction from the reflector edges, direct radiation from the feed, multiple reflections and residual scattering from the absorbers will disturb the plane wave. This not ideal plane wave will influence Radar Cross Section (RCS) measurements in the CATR.

A correction technique for correcting high accuracy measurements, performed in the CATR, is developed and described in this report. It is possible to decrease the influences of the not ideal plane wave on the RCS measurements. A mathematical relation is found which relates the RCS pattern, to be expected when working with an ideal plane wave, to the real measured RCS pattern and the pseudo plane wave. The quality of this pseudo plane wave is stored in the so called correction coefficients. The mathematical relation is worked out in a computer algorithm. It is tested with numerical simulations and with experiments. The results are very satisfactory, specially when the disturbances are not too large. It has been shown that the correction technique is a powerful tool for performing high accuracy RCS measurements in a CATR.
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1. INTRODUCTION

A Radar Cross Section (RCS) correction method has been tested on a two-reflector Compact Antenna-Test Range (CATR) of the Eindhoven University [1].

A CATR is designed to produce a pseudo-plane wave in a limited region, the so-called testzone. This room is covered with RF-absorbers. The CATR at the University uses two parabolic cylinders that are positioned perpendicular to each other. When a spherical source illuminates these cylinders, it produces a planar wave front in the aperture of the main reflector. Obviously, this field is not an exact plane wave. The purity of the wavefront is affected by diffraction from reflector edges, direct radiation from the feed, multiple reflections and residual scattering from the absorbers. Summing and cancelling occurs perturbing the planar wavefront, an undesired outcome. The field in the test zone is also dependent on the frequency and the feed pattern.

When an RCS measurement in such a range is performed, there will occur an error due to the non-planar wave.

In this report a correction method shall be described which can be used to increase the accuracy of an RCS measurement performed in a CATR. Numerical simulations as well as real measurements will be discussed.

The report is structured in 8 chapters.

Background information about Radar Cross Section is contained in Chapter 2. Keywords are: monostatic-, bistatic scattering, $\sigma$, dBsm, RCS of a rectangular plate.

Chapter 3 deals with the mathematics behind the correction technique. The numerical simulations of the correction algorithm are described in Chapter 4. Investigation of the behaviour of the algorithm under different circumstances has been carried out. Numerical simulations are worked out to reach this goal.

The hardware system configuration and its operation, for performing RCS measurements, will be discussed in Chapter 5.

In Chapter 6 the relations between, and the working of all the used programs are described. Block diagrams of all programs are shown, to visualize their working.
In Chapter 7 actual results of the correction technique on RCS measurements of different bars are set out and discussed. The experiments are performed at different frequencies (4, 10 and 17 GHz), with and without a timegate. A disturbance will be mounted on the main reflector.
2. Concepts of Radar Cross Section (RCS)

2.1 Definitions of Radar Cross Section

When an obstacle is illuminated by an electromagnetic wave energy is dispersed in all directions. The spatial distribution of energy depends on the size, shape and composition of the obstacle, and of frequency and nature of the incident wave. The redistribution of energy is called scattering, and the obstacle itself is often called target or a scatterer.

When the scattered energy is received at the source of the radiation, it is called monostatic scattering (Fig. 2.1). Bistatic scattering refers to the situation when the transmitter and the receiver are located at different positions (Fig. 2.2).

![Fig. 2.1. Monostatic scattering.](image1)

![Fig. 2.2 Bistatic scattering](image2)

The spatial distribution of scattered energy is characterized by a cross section, a fictitious area property of the target. This area is called Radar Cross Section (RCS). The symbol $\sigma$ denotes the RCS of a target.
A theoretical definition of radar cross section implies an incident plane wave at the target by assuming an infinite range [2], [3]:

$$\sigma = \lim_{R \to \infty} 4\pi R^2 \left| \frac{E_r^2}{E_i^2} \right|$$  \hspace{2cm} (2-1)

Where  

- $E_r$ = electric field magnitude at the receiver  
- $E_i$ = electric field magnitude incident at the target.

The unit of radar cross section is square meters ($m^2$) and is often expressed in decibels (dBsm) relative to an object with an RCS of one square meter, $\sigma_0$.

$$\sigma (\text{dBsm}) = 10 \log_{10} \left[ \frac{\sigma (m^2)}{\sigma_0 (m^2)} \right]$$  \hspace{2cm} (2-2)

If the radius $a$ of a sphere is large in terms of wavelength, typically for $a \gg \frac{\lambda}{2\pi}$, then a sphere with a geometric projected area of $1m^2$ has an RCS of 0 dBsm. In this case the RCS of a sphere is independent on frequency, therefore a sphere is an excellent calibration target.

### 2.2 Radar Cross Section of a rectangular plate

There are several methods of estimating the radar cross section of rectangular flat plates [4], [5].

The most familiar approximation technique is geometrical optics (GO) which is the high frequency limit of zero wavelength in which the scattering phenomenon is treated by means of classical ray tracing.

An approximation technique which utilizes electromagnetic properties is physical optics (PO). The surface of an object is divided into incremental units, and current densities are calculated for each unit. The re-radiated fields from each illuminated unit are then calculated and summed to yield the orientation dependent radar cross section of the object.
Geometrical theory of diffraction (GTD) is an approximation which extends the usefulness of GO for regions where diffracted fields are important, such as in shadow areas.

Using the PO approximation technique we assume that the surface of the plate is large in terms of wavelength and the conductivity will be considered to be infinite.

If we use P.O. then the radar cross section of a flat rectangular plate may be approximately described by the expression [4], [6]:

\[
\sigma(\theta, \varphi) = \frac{4\pi A^2}{\lambda^2} \left[ \frac{\sin \left( \frac{ka}{2} \left[ \sin \theta - \sin \varphi \right] \right)}{\frac{ka}{2} \left[ \sin \theta - \sin \varphi \right]} \right]^2 \cos^2 \theta \tag{2-3}
\]

where

- \(\lambda\) = physical area of the plate
- \(a\) = length of the plate parallel to the \(x\)-axis
- \(b\) = length of the plate parallel to the \(y\)-axis
- \(\theta\) = incident angle from broadside
- \(\varphi\) = scattering angle from broadside
- \(\lambda\) = wavelength
- \(k = \frac{2\pi}{\lambda}\)

Fig. 2.3. Bistatic scattering (rectangular plate).

The plate will be considered to lie in the \(x-y\) plane. The wave coming from the transmitter, and the scattered wave going to the receiver are lying in the \(xz\)-plane.
In the monostatic case is \( \varphi = -\theta \). Eq. 2-3 becomes

\[
\sigma (\alpha) = \frac{4\pi A^2}{\lambda^2} \left[ \frac{\sin [ka \sin(\alpha)]}{ka \sin (\alpha)} \right]^2 \cos^2 \alpha
\]  

(2-4)

where \( \alpha = \theta = -\varphi = \) aspect angle

Near normal incidence expression (2-4) becomes

\[
\sigma (\alpha) = \frac{4\pi A^2}{\lambda^2} \left[ \frac{\sin (ka \sin(\alpha))}{ka \sin (\alpha)} \right]^2
\]  

(2-5)

If we examine Eq. 2-4 and 2-5 we observe that near normal incidence \( \sigma \) is inversely proportional to \( \lambda^2 \). The results are independent of the polarization of the incident field, and is valid for plates large compared with wavelength. The factors in Eq. 2-4 and 2-5 have the form \( (\sin r)/r \). The mainlobe width decreases with increasing plate size, for a fixed frequency.
3. RCS CORRECTION TECHNIQUE

When the RCS of some targets has to be measured, we assume that it will be illuminated by a planar wave. In practice it is not possible to obtain a perfect plane wave on a collimating range. Consequently, for high accuracy measurements it is necessary to develop a technique which takes account of this pseudo-plane wave character, and corrects the RCS measurement.

3.1 Fundamental relationships

We shall consider the relationship between the amplitude and phase of the scattered field and the distribution of the illuminating field. For the sake of simplicity, we shall limit our considerations to the one-dimensional case, therefore we take a bar as our target.

When the bar is illuminated by a nonplanar wave, the complex amplitude of the scattered field is a function of its angle of rotation $\alpha$ with respect to the $y$-axis (Fig.3.1).

$$S(\alpha) = \int_{-L/2}^{L/2} E_t(x) E_{cr}(x) e^{2j\kappa \sin \alpha} dx$$ (3-1)

where
- $\alpha$ = aspect angle
- $x$ = distance
- $S(\alpha)$ = scattered field
- $E_{cr}(x)$ = illuminating field produced by the collimeter
- $E_t(x)$ = theoretical field distribution across the target when illuminated by a plane wave
- $L$ = length bar.

![Fig.3.1. Definition of the co-ordinates.](image-url)
It is assumed that $E_t(x)$ and $E_{cr}(x)$ are linear polarised fields.

Substitution of: $u = 2k \sin \alpha$ in Eq. 3-1 results in:

$$S(u) = \frac{L}{2} \int_{-\frac{L}{2}}^{\frac{L}{2}} E_t(x) E_{cr}(x) e^{jux} \, dx$$

(3-2)

If we suppose that the illuminating wave is an ideal planar wave:

$$E_{cr}(x) = 1 \quad \text{for} \ |x| \leq \frac{L}{2}$$

then $S(u)$ becomes $D(u)$:

$$D(u) = \frac{L}{2} \int_{-\frac{L}{2}}^{\frac{L}{2}} E_t(x) e^{jux} \, dx$$

(3-3)

It may be seen that the responses $S(u)$ and $D(u)$ are Fourier transforms. We extend the boundaries of both integrals to infinity:

$$S(u) = \int_{-\infty}^{\infty} p_L(x) g(x) E_t(x) e^{jux} \, dx$$

(3-4)

and

$$D(u) = \int_{-\infty}^{\infty} p_L(x) E_t(x) e^{jux} \, dx$$

(3-5)

where $g(x)$ is a periodical extension of the function $E_{cr}(x)$ for $|x| \leq \frac{L}{2}$, and $p_L(x) = 1$ for $|x| \leq \frac{L}{2}$ and $p_L(x) = 0$ for $|x| > \frac{L}{2}$.

We are interested in determining $D(u)$, the real scattered field, which is proportional to the RCS of the target. However, we measure $S(u)$ and $g(x)$. For this reason an algorithm which relates $D(u)$ to $g(x)$ and $S(u)$ shall be derived.
We introduce a function $Q(u)$, the so called correction spectrum:

$$Q(u) = \int_{-\infty}^{\infty} \frac{1}{g(x)} e^{jux} \, dx$$  \hspace{1cm} (3-6)$$

We now can write:

$$D(u) = S(u) * Q(u) = \int_{-\infty}^{\infty} S(v)Q(u-v)dv$$  \hspace{1cm} (3-7)$$

$Q(u)$ is the spectrum of the periodically extended function $\frac{1}{g(x)}$, which can be written as a sum of $\delta$-functions:

$$Q(u) = \sum_{n=-\infty}^{\infty} q_n \delta(u - \frac{2\pi}{L} n)$$  \hspace{1cm} (3-8)$$

where

$$q_n = \frac{\sqrt{L}}{L} \int_{-L/2}^{L/2} \frac{1}{g(x)} e^{j\frac{2\pi}{L} nx} \, dx$$  \hspace{1cm} (3-9)$$

$q_n$ are the correction coefficients.

We now can rearrange Eq.3-7 with consideration of Eq.3-9:

$$D(u) = \sum_{n=-\infty}^{\infty} q_n \int_{-\infty}^{\infty} S(v) \delta(u - v - \frac{n2\pi}{L}) \, dv$$

$$= \sum_{n=-\infty}^{\infty} q_n \int_{-\infty}^{\infty} S(v) \delta(u - v - \frac{n2\pi}{L}) \, dv$$
\[ \phi_{\text{scattered}} = \sum_{n=-\infty}^{\infty} q_n S(u - n \cdot 2\pi/L) \]  \hspace{1cm} (3-10)

The scattered field can be determined by summing the values of the response, sampled at equidistant points and multiplied by the corresponding Fourier coefficients of a function which is inversely proportional to the distribution of the illuminating field along the target.  

In reality, the amplitude and the phase of the scattered field are measured with an error, while the target is scanned over a limited angular section. In this case, the pattern can be obtained approximately by using the same expression and limiting the summation to the set of points located within the angular sector \((-u_0, u_0\) in which the response was measured:

\[ \tilde{D}(u) = \sum_{|u-n2\pi/L| \leq u_0} q_n \tilde{S}(u - n \cdot 2\pi/L) \]  \hspace{1cm} (3-11)

Where \( \tilde{S}(u) \) is the approximately measured scattered field and \( \tilde{D}(u) \) is the approximately reconstructed pattern.

### 3.2 Limitations of the correction algorithm

We will investigate the limitations of the correction algorithm. One of the assumptions we have made is the fact that the illuminating field is independent of \( z \). In practice this is almost true. Fig.3.2 shows a calculated field distribution along the axis of the compact antenna test range. The measurements were carried out at a distance of approximatively 4-6 m from the main reflector. The axial field variation is negligible over this range.
Since the sector in which the measurements are conducted is limited, it is needed to truncate the infinite sum, Eq. 3-10. We are able to write an expression which contains the difference between the true and reconstructed patterns:

\[
\Delta \tilde{D}(u) = \sum_{|u-n2\pi/L|>u_0} q_n \tilde{S}(u - n.2\pi/L)
\]  

Eq. 3-12 shows that \(\Delta \tilde{D}(u)\) will decrease when \(\tilde{S}(u)\) becomes smaller outside the measured interval \((u > u_0)\) compared to \(\tilde{S}(u)\) inside the interval. \(\Delta \tilde{D}(u)\) also will decrease when the difference between the illuminating field and the field of a plane wave becomes smaller.

For a perfect plane wave we can write:

\[
q_0 = 1 \\
q_n = 0 \quad \text{for } n \neq 0
\]

From the considerations above it is obvious that corrections will be better when the investigated target has a more directive scattering pattern.
3.3 Determination of the illuminating field

There are several ways to determine the illuminating field. One possibility is probing the field with a horn. Another method utilizes a large straight bar. The bar is used as a scatterer of the electromagnetic (em) energy. The field $E_t(x)$ for a straight bar is constant, therefore Eq.(3-4) can be written as:

$$
\tilde{S}(u) = \int_{-\infty}^{\infty} \tilde{E}(x) e^{jux} \, dx
$$

(3-13)

$$
\tilde{E}(x) = 2\pi \int_{-\infty}^{\infty} \tilde{S}(u) e^{-jux} \, du
$$

(3-14)

Where $\tilde{E}(x) =$ illuminating field
$\tilde{S}(u) =$ measured scattered field

Eq. 3-13 and 3-14 relate the illuminating field $\tilde{E}(x)$ to the scattered field $\tilde{S}(u)$.

We will apply these formulas to derive the illuminating field $\tilde{E}(x)$ when the scattered field $\tilde{S}(u)$ is known (measured). It is obvious that $\tilde{E}(x)$ is a Continuous Fourier Transform (CFT) of $\tilde{S}(u)$. The fastest way to calculate this transform is by using a Fast Fourier Transform (FFT) algorithm, see Chap. 6.4.
In order to get some insight in the correction algorithm and its accuracy we will perform some numerical simulations. The problem was simulated on an Olivetti M24 personal computer.

4.1 Scheme of the simulation

We will assume a certain illuminating field. This field will be a superposition of two plane waves coming from different directions (Fig.4.1). One main plane wave, coming from $\theta = 0$ (boresight) and one coming from $\theta = \theta_0$, this component will cause the disturbance.

![Fig.4.1. Illuminating field.](image)

Now we can put targets (bars) in the testzone, and examine the scattered field as a function of rotation (Fig.4.2). This angle is called $\alpha$. We assume that the bars are perfectly straight and rectangular in shape. The scattered field is a superposition of a monostatic and a bistatic case.
The scattered field is proportional to the square root of the RCS. In case of monostatic scattering we can write (see eq 2-4):

$$S_1(\alpha) = C_1 \frac{\sin (k a \sin(\alpha))}{k a \sin(\alpha)} \cos \alpha$$  \hspace{1cm} (4-1)

In the second case we will substitute $\theta = \theta_o - \alpha$ and $\varphi = \alpha$ in Eq.(2-3):

$$S_2(\alpha) = C_2 \frac{\sin \left[ \frac{k a}{Z} [\sin(\theta_o - \alpha) - \sin \alpha] \right]}{\frac{k a}{Z} [\sin(\theta_o - \alpha) - \sin \alpha]} \cos(\theta_o - \alpha)$$  \hspace{1cm} (4-2)

The total scattered is defined as:

$$S(\alpha) = S_1(\alpha) + S_2(\alpha)
= C_1 \frac{\sin (k a \sin(\alpha))}{k a \sin(\alpha)} \cos \alpha +
C_2 \frac{\sin \left[ \frac{k a}{Z} [\sin(\theta_o - \alpha) - \sin \alpha] \right]}{\frac{k a}{Z} [\sin(\theta_o - \alpha) - \sin \alpha]} \cos(\theta_o - \alpha)$$  \hspace{1cm} (4-3)

We will do two "measurements". First we measure the scattered field of a large bar, length $= L_1$ and next we measure the scattered field of a smaller
The illuminating field will be determined with Eq.3-14 and the first measurement. Now we are able to calculate the correction coefficients $q_n$ (Eq.3-9) for the correction. Finally, we can do the correction on the smallest bar (Eq.3-11).

We can also assume that the scattered field is a superposition of two $\sin x/x$ functions, one corresponding with the plane wave coming from boresight and one corresponding with the disturbance. Although this scattered field is a very rough approximation to reality, we will use it for the simulations. We will do this because a sinc function is the Fourier Transform of a rectangular function. If $E(x)=1$ for $|x| \leq L/2$ and 0 for $|x| > L/2$, then $S(\alpha)$ will be a sinc function in Eq.3-1.

The scattered field will look like:

$$S(u) = C_1 \frac{\sin (0.5 \ a \ u)}{0.5 \ a \ u} + C_2 \frac{\sin \left( 0.5 \ a \ (u-u_{\text{dis}}) \right)}{0.5 \ a \ (u-u_{\text{dis}})}$$

(4-4)

Where $a =$ length bar; $u_{\text{dis}} = 2k \sin (0.5 \ \theta_0)$.

4.2 Results of the bistatic simulations

In order to get the simulated scattered field we substitute $u = 2k \sin \alpha$ in Eq. 4-3. We now do have $S(u)$, the calculated points are equidistant in the $u$-domain. The expression $u = 2k \sin \alpha$ is worked out for some numerical values in table 4.1.

With Eq.3-8 we can relate the correction coefficients $q_n$ to $u$, the relation is $u = n \frac{2\pi}{L}$. In the next paragraphs the correction coefficients are shown as a function of $u$. 

bar, length $L_2$ ($L_2 < L_1$).
The values of the parameters substituted in Eq.4-3 are:

\[ a = 1.25 \, ; \, 1.55 \, ; \, 2.00 \, \text{m (length bar)} \]
\[ b = 0.06 \, \text{m (height bar)} \]
\[ \lambda = 0.03 \, \text{m (wavelength, frequency = 10GHz)} \]
\[ C_1' = \frac{2ab \sqrt{\pi}}{\lambda} \]
\[ C_2 = 0.1 \, C_1 \]
\[ \theta = 50^\circ \, ; \, 20^\circ \, (\text{disturbance angle}) \]

Fig.4.3 is an illustration of the basic idea behind the simulations and the correction technique.

BK50U003.REP, Fig.4.3a and BM50U001.REP, Fig.4.3b are the computed scattered fields. Fig.4.3c shows the near field \( E(x) \) computed from BM50U001.REP, the scattered field of the 1.55 m bar.

The next step is computing the correction coefficients from \( E(x) \), Fig.4.3d. Finally the scattered field of the 1.25 m bar is corrected with the correction coefficients shown in Fig.4.3e.

During the simulations some parameters are changed, so we can see what influence they do have on the corrections. The following variables are varied:
Fig. 4.3. An illustration of the correction technique:

a. RCS-pattern bar 1.25 m,
b. RCS-pattern bar 1.55 m,
c. Near field $E(x)$ calculated from RCS-pattern 1.55 m bar,
d. Correction coefficients,
e. Corrected RCS-pattern, correction of pattern Fig. 4.3a.
1. The scan angle of the 1.25 m bar is varied (-30°/30°, -60°/60°, -80°/80°), while the scan angle of the 1.55 m bar is constant (-60°/60°).

2. The scan angle of the 1.55 m bar is varied (-30°/30°, -60°/60°, -80°/80°), while the scan angle of the 1.25 m bar is constant (-30°/30°).

3. The disturbance angle is varied (50°, 20°).

4. The number of correction coefficients is varied.

5. The length of the target, which is used for calculating the correction coefficients is varied (1.55 and 2.00 m).

We will now discuss the different simulations, which have been described above.

**Fig. 4.4. Corrected RCS patterns, angle sections: BK5OC001.REP -30°/30°, BK5OC002.REP -60°/60°, BK5OC003.REP -80°/80°.**
1. The scan angle of the 1.25 m bar is varied while the scan angle of the 1.55 m bar is constant.

With the same correction coefficients we did correct the scattered patterns of a 1.25 m bar which are calculated over different angular sections. The results are shown in Fig.4.4. It seems to be that the influence of the width of the angular section of the pattern to be corrected is negligible.

2. The scan angle of the 1.55 m bar is varied while the scan angle of the 1.25 m bar is constant (-30°/30°). In contrast with the previous simulation we correct the scattered field of a 1.25 m bar with different correction coefficients.

The 1.55 m bar is rotated over three different intervals: -30°/30°, -60°/60°, -80°/80°. The corresponding correction coefficients and corrected patterns are drawn in Fig.4.5.

It is obvious that there are differences between the correction coefficients. This results in different correction patterns. The correction coefficients, corresponding to the largest angle interval (B55Q003.REP), give the best correction (B55C021.REP). Examining Eq.3-14 can explain these differences. The integral (Eq.3-14) is taken over an infinite interval. During the simulations however, S(u) is only defined over a finite interval. The smaller we take this interval the more information is lost, the worse the correction will be.

3. The disturbance angle is changed. So far all the simulations are done with a disturbance coming from an angle of 50°. We will now change this angle to 20°. The simulated RCS-patterns of the 1.25 and 1.55 m bars are drawn in Fig.4.6., the scan intervals of both patterns are -60°/60°.

The corrected pattern (B20C001.REP) looks better than the corresponding, 50° disturbance, corrected pattern (B55C002.REP, Fig.4.3e).

We may conclude that the smaller the angle of disturbance the better the corrections become. A possible explanation is the fact that for small values of θo, Eq.4-3 turns to a superposition of two sinc functions. The correction of a scattered field consisting of two sinc functions is better than the correction of a bistatic scattered field. We will discuss this in paragraph 4.3.
Fig. 4.5. An RCS-pattern of a 1.25m bar is corrected with different correction coefficients. The correction coefficients are corresponding with different angle intervals:

- BM5Q002.REP (-30°, 30°)
- BM5Q001.REP (-60°, 60°)
- BM5Q003.REP (-80°, 80°)

On the right side of the corr.coeff. the corresponding corrected patterns are drawn.
Fig. 4.6. Disturbance angle is 20°. BK20U001.REP: the RCS-pattern 1.25 m bar; BM20U001.REP: RCS-pattern 1.55 m bar; BM20Q001.REP: correction coefficients; BK20C001.REP: corrected RCS-pattern.
4. The number of correction coefficients is varied.

For correcting an RCS-pattern we need a number of correction coefficients $q_n$. Because we are dealing with a limited summation for the corrections (Eq.3-11) there is an upper and lower bound for $n$. The summation boundaries of eq 3-11 determine the maximum and minimum needed $q_n$'s:

$$\left| u - n \frac{2\pi}{L} \right| \leq u_o$$

$$-\frac{L(u-u_o)}{2\pi} \leq n \leq \frac{L(u-u_o)}{2\pi}$$

$u$ is located in the sector $(-u_o, u_o)$, so:

$$-\frac{L}{\pi} u_o \leq n \leq \frac{L}{\pi} u_o$$

$$n_{\min} = -\frac{L}{\pi} u_o$$

$$n_{\max} = \frac{L}{\pi} u_o$$

So far all the corrections were done with a number of correction coefficients according to Eq.4-5. During this simulation we will vary the number of correction coefficients. In Fig.4.7, BM50Q001.REP, the correction coefficients $q_n$ for $-150 < n < 150$ are drawn.

We will perform four different corrections. First we correct BK50U002.REP with the maximum number of correction coefficients. BK50U002.REP is the RCS of a 1.25 m bar scanned over an angular section $(-60^\circ, 60^\circ)$:

$u_o = 362$, $n_{\max} = 144$, $n_{\min} = -144$. The corrected pattern is BK50C002.REP.

The next 3 corrections are done with $q_n$'s which meet the requirements:

$-50 \leq n \leq 125$, $-20 \leq n \leq 50$ and $-20 \leq n \leq 25$. The corrected patterns are BK50C032.REP, BK50C042.REP and BK50C062.REP respectively. Only BK50C062.REP differs considerably from the other corrected patterns. We can conclude that the second peak in the correction coefficients contains the most information needed for the correction. The other smaller peaks are of minor importance.

In Fig.4.3d BM50Q001.REP is drawn as a function of $u$. The second peak in this figure appears at the same $u$ as the disturbance in BK50U002.REP. We can conclude that if we want to correct an RCS pattern over an angular section, $(-u_1, u_1)$ then we need at least the correction coefficients $q_n$ where $n_{\min} = -u_1 \frac{L}{2\pi}$ and $n_{\max} = u_1 \frac{L}{2\pi}$.
Fig. 4.7. The number of correction coefficients is varied.

BK50C002.REP maximum number of $q_n$'s used

BK50C032.REP: $-50 \leq n \leq 125$

BK50C042.REP: $-20 \leq n \leq 50$

BK50C042.REP: $-20 \leq n \leq 25$
Fig. 4.8. corrections with a 2.00 m bar.

5. The length of the largest bar, which is used for determining the correction coefficients, is varied. Instead of a 1.55 m bar we now will use a 2.00 m bar. The new correction coefficients and the corresponding corrected pattern BK50C052.REP are drawn in Fig. 4.8. BK50C052.REP is the corrected pattern of BK50U002.REP in Fig. 4.7. The correction is better than those which are done with the 1.55 m bar. The reason for this is the fact that the scattered pattern of the 2.00 m bar has a larger directivity. This means that both slopes of the envelope of the scattered pattern of the 2m bar are steeper. A consequence of this quality is that an angular section of the same size contains more information in case of a 2m bar than in case of a 1.55 m bar. This results in a better correction.
4.3 Results of the simulation with the sinc functions

The simulated scattered field is obtained from Eq.4-4. The values of the parameters during the simulations are the same as in Chap. 4.2. Eq.3-14 determines \( E(x) \), when \( S(u) \) is known. \( E(x) \) is the inverse Fourier transform of \( S(u) \).

If \( S(u) \) is equal to Eq.4-4 then we can write \( E(x) \) as:

\[
E(x) = p_L(x) \left[ c_1 + c_2 e^{j\omega_{\text{dis}} x} \right] 
\]

(4-6)

Where:

- \( p_L(x) = 1 \) for \( |x| \leq L/2 \)
- \( = 0 \) for \( |x| > L/2 \)
- \( \omega_{\text{dis}} = 2k \sin(0.5 \theta_0) \)

\( S(u) \) and \( E(x) \) are drawn in Fig.4.9a (SK50U002.REP) and 4.9b (PWZ125.REP). The correction coefficients (PWZ125.REP) are computed from PWZ125.REP. Fig.4.9d (SK50C002.REP) shows the corrected pattern. This is almost a perfect sinc function, this means that the correction is almost perfect. The reason for this excellent correction is the fact that \( S(u) \) is the Fourier transform of \( E(x) \).

The next simulation is done similar to the previous simulations. The near field \( E(x) \) is calculated by means of an FFT of the scattered field of a large (L=1.55m) bar. The correction coefficients, \( q_n \), are calculated from \( E(x) \), and are drawn in Fig.4.9e (SM50Q002.REP). Finally we correct SK50U002.REP with these coefficients. The result is SK50C002.REP, Fig.4.9f.

We can see that the correction is not perfect. The reason for this is the way in which we have determined the near field. If we determine the near field with an FFT we will again lose a part of the information, see Chap.4.2 point 2. A consequence of this is that the correction coefficients are different, compare PWZ125.REP with SM50Q002.REP in Fig.4.9. and that in the end the corrections are different, Fig.4.9d and 4.9f.
Fig. 4.9. Simulations with sinc functions:
a. RCS-pattern of 1.25 m bar,
b. near field calculated according to Eq. 4.6,
c. corr. coeff. corresponding to the near field drawn in Fig. 4.9b.
d. correction of RCS-pattern Fig. 4.9a with the corr. coeff. drawn in Fig. 4.9c,
e. corr. coeff. calculated by means of an FFT,
f. correction of pattern Fig. 4.9a with corr. coeff Fig. 4.9e.
4.4 Conclusions concerning the simulation

It seems to be that the correction algorithm is a powerful tool for correcting RCS measurements. The determination of the correction coefficients by means of an FFT is satisfactory.
5. MEASUREMENT SET-UP

In this chapter we present a description of the measurement procedures which are used to obtain an RCS measurement versus aspect angle of a straight rectangular bar. The hardware system configuration and its operation will also be discussed.

5.1 System configuration

A simplified block diagram of the RCS measurement system is shown in Fig. 5.1. The main components of the system are:

* The Compact Antenna-Test Range (CATR),
* HP8510A network analyzer,
* HP8340A synthesized sweeper,
* HP8511A frequency converter,
* Micro-PDP 11/23 controller,
* Orbit positioner system.

Most components of the measurement system were located outside the anechoic chamber, but in close proximity. Only the target mount, reflectors, feed horns and positioner remained in the chamber.

The Compact Antenna-Test Range (CATR). The RCS measurements are done in a two-reflector CATR of the Eindhoven University [1]. A dimension plan view is drawn in Fig. 5.2. The anechoic chamber was covered with RF-absorbers, type Emerson & Cuming CV6, CV4 and VHP12.

The CATR consists of two parabolic cylindrical reflectors of which the focal lines are placed perpendicular to each other. When this two-reflector system is fed by a spherical source a planar wave front is produced in the test zone (or sweet spot) of the anechoic room.
Fig. 5.1. Hardware configuration.

Fig. 5.2. Top view of the anechoic chamber.
Measurements for RCS were made with the HP8510A vector network analyzer as the main component of the system.

The HP8510A is a vector network analyzer designed to make vector measurements. It measures magnitude and phase characteristics of linear networks such as filters, amplifiers, attenuators, and antennas. The incident signal is compared with the signal transmitted through the device or reflected from its input.

In RCS applications, the paths from transmitting feed horn via both reflectors, reflection from target, back via the reflectors and finally returning to the receiving horn is the "network" considered by the HP8510A. A signal transmitted from the HP8510A would produce electrical delay information and consequently electrical length information. Analysis of the swept frequency or stepped frequency response by Fourier transformation yields position and value of "impedance changes" or scatterers with respect to a reference plane.

With the HP8510A we are able to do error corrections on RCS measurements. The correction removes the empty-room effects from the measurement, so that the measured data only contains reflections from the target itself. The frequency response of the complete system (excluding target) can be corrected and the corrected data can be calibrated to give dBsm values.

Gating is another feature of the HP8510A. A gate is a time filter that can be used to selectively view the effects of individual time domain responses. In converting back to the frequency domain, only the effects of the reflections inside the gate are viewed. In radar measurements this can be used to eliminate multipath responses that are caused by the target.

HP8511A frequency converter.

The HP8511A frequency converter is the most universal test set for antenna and radar measurements. It is primarily designed for measurements other than the standard S-parameter measurements. The HP8511A provides the input/output ports to connect the device under test, signal separation to separate the reference and test signals, and RF to 20 MHz conversion.

Combining the HP8511A frequency converter with the HP8510A Network Analyzer results in a four channel receiver/signal processor that operates over the frequency range 45 MHz to 26.5 GHz.
Some system performance specifications of the HP8510A/8511A combination:

**Dynamic Range:**

Test Channel Inputs: From -10 dBm equal to and below 18 GHz, or -15 dBm above 18 GHz, to -95 dBm at 250 MHz, -90 dBm at 18 GHz, or -85 dBm at 26.5 GHz. With an averaging factor of 100 the bottom to the range is -110 dBm to -100 dBm. Noise floor is measured in a 10 kHz bandwidth with 20% of span smoothing applied.

Reference Channel Input(s): For proper phase lock, signal level can be in the range of -10 dBm, equal to and below 18 GHz, or -15 dBm, above 18 GHz, to -50 dBm.

**Crosstalk:**

>80 dB isolation between inputs (100 dB typical).

**Frequency Response (ratio measured of any two inputs):**

- Deviation from straight line: ± 0.5 dB. Slope: ± 1.5 dB.
- Deviation from linear phase: ± 5.0 degrees.

**Phase Accuracy (phase vs. phase):** With input at -16 dBm,

± 0.001 deg/deg, not to exceed 0.04 deg at 250 MHz.

± 0.002 deg/deg, not to exceed 0.06 deg at 26.5 GHz.

**HP8340A synthesized sweeper.**

The HP8340A is a synthesized frequency source for a frequency range from 10 MHz to 26.5 GHz. It has three modes of operation: single point mode (or CW-mode), step mode and the ramp mode.

In the single point mode the source will be tuned to a CW frequency. In the step mode frequencies are generated at equidistant discrete frequencies between the start and stop frequency. In the ramp mode a standard analog sweep is selected. With greater than 5 MHz sweep width, the source is phase-locked at the start frequency, then swept with open loop YIG oscillator tuning accuracy and repeatability. The source is phase-locked at all frequencies for less than 5 MHz sweep widths. During the measurements the ramp mode is used.

**Control computer.**

The control computer is a Digital Equipment Corporation (DEC) μPDP-11/23 processor with 512 kbytes RAM memory, 10 Mbytes Winchester disk, dual floppy drive and IEQ11-A dual IEEE-488 controller board.

The operating system is the real-time multi-user μRSX-11.
Orbit positioner system.
The Orbit positioner system consists of an azimuth antenna test positioner, a positioner controller and a power unit.

Peripherals.
- DEC VT241 color graphics terminal,
- DEC LA210 matrix printer,
- HP7475 pen plotter.
5.2 The data acquisition

The program used for the data acquisition is the ARCS program. ARCS (Automated Radar Cross Section measurement System) is a software package for acquiring RCS data, processing this data and displaying the data using advanced graphics utility programs. ARCS is developed at March Microwave Systems b.v. in Nuenen, the Netherlands. For more information see references [12] and [7].

Figure 5.3 shows schematically the data processing from data acquisition to the RCS versus aspect angle. Rectangles represent data, rectangles, with round corners represent data conversion steps and broken arrows represent input from the measurement set-up.

The output data of the measurements are stored in files using the standard

March structure.

Fig.5.3. Data processing from data acquisition to RCS versus aspect angle.
5.3 Description of the targets

During the measurements we have used four different targets, three bars and one sphere. The sphere was used for the calibration of the RCS measurement. The diameter of the sphere is 35.6 cm and the RCS is $-10 \text{ dBsm}$. The purpose of the calibration is to obtain a correction and calibration set that is used to:

- a. correct the measured frequency domain response of a target so that the errors caused by its surroundings and the measurement equipment are removed;
- b. obtain data that represent absolute RCS values in square meters (sm);
- c. move the position of the zero-range plane from the test set ports to a predefined reference plane in the target area.

When the diameter of a sphere is much larger than the wavelength, it will be a suitable reference target, because the RCS will be constant with frequency.

The bars were used to obtain RCS-versus aspect angle patterns which are, in the hypothetical case, symmetric around the boresight. On account of this property it is simple to verify the quality of the ultimate RCS correction. The dimensions of the aluminium bars are drawn in Fig.5.4.

![Fig.5.4. Targets used for the RCS measurements.](image)

One of the bars is tapered off on both ends. Doing this we succeed in getting a better determination of the correction coefficients.
We show this in an example. Suppose we are dealing with a rectangular plate or bar. The near field of this bar will be a rectangular function (Fig. 5.5b). The abrupt ends of the bar cause discontinuities in the near field. If we do subsequently an analytic Fourier transformation (Eq. 3-13) on this data we get a real sinc function (Fig. 5.5c):

Near field:

\[ E(x) = \begin{cases} 1 & x \leq b \\ 0 & x > b \end{cases} \quad (5-1) \]

Scattered field:

\[
S_{\text{rec}}(u) = \int_{-\infty}^{\infty} E(x) e^{jux} \, dx = \int_{-b}^{b} e^{jux} \, dx
\]

\[
= \frac{2b \sin(ub)}{bu} = \frac{2b}{\pi} \text{Sinc}(ub/\pi) \quad (5-2)
\]

In case of the tapered bar Fig. 5.5e we suppose a near field which looks like Fig. 5.5f. The near field can be written as:

\[
E(x) = \begin{cases} 0 & |x| > b \\ 0.5 \left[ 1 + \cos \left( \frac{\pi (x + ab)}{b(1-a)} \right) \right] & -b \leq x < -ab \\ 1 & -ab \leq x < ab \\ 0.5 \left[ 1 + \cos \left( \frac{\pi (x - ab)}{b(1-a)} \right) \right] & ab \leq x < b \end{cases} \quad (5-3)
\]
Fig. 5.5 A rectangular bar versus a tapered bar.

a. near field rectangular bar Eq. 5-1,
b. near field tapered bar Eq. 5-3,
c. scattered field rectangular bar Eq. 5-2,
d. scattered field tapered bar Eq. 5-4,
e. FFT scattered field rectangular bar,
f. FFT scattered field tapered bar.
We will call this a Tukey tapered field [8]. The scattered field can again be calculated with Eq.3-13.

\[ S_{\text{tap}}(u) = \int_{-\infty}^{\infty} E(x) e^{jux} \, dx \]

\[ = \frac{\sin bu}{u} + \frac{\sin abu}{u} + \]

\[ \frac{1}{4} e^{-j\gamma ab} \frac{1}{J(\gamma+u)} \left( e^{-j(\gamma+u)b+\alpha} - e^{-j(\gamma+u)b} \right) + \]

\[ \frac{1}{4} e^{j\gamma ab} \frac{1}{J(-\gamma+u)} \left( e^{-j(-\gamma+u)b+\alpha} - e^{-j(-\gamma+u)b} \right) + \]

\[ \frac{1}{4} e^{-j\gamma ab} \frac{1}{J(-\gamma+u)} \left( e^{j(-\gamma+u)b+\alpha} - e^{-j(-\gamma+u)\alpha} \right) + \]

\[ \frac{1}{4} e^{j\gamma ab} \frac{1}{J(\gamma+u)} \left( e^{j(\gamma+u)b+\alpha} - e^{-j(\gamma+u)\alpha} \right) \]

where \( \gamma = \frac{\pi}{b(1-\alpha)} \)

In Fig.5.5 the example is worked out with some numerical values. It is very significant that the envelope of the scattered pattern of the tapered bar \( S_{\text{tap}}(u) \) is much steeper than the envelope of the scattered pattern \( S_{\text{rec}}(u) \) of the rectangular bar.

In practice we will measure the scattered pattern over a limited angle \((-\theta_0 \text{ to } \theta_0)\). With the limited section we will determine the accessory near field. We use an FFT algorithm to achieve this. In case of a tapered bar this transformation gives better results because outside the limited angle section \( S_{\text{tap}}(u) \) is much lower than inside the section. \( S_{\text{rec}}(u) \) however, is relatively high outside the limited section. During the FFT we cut off this information therefore the results are worse.

This tapering technique is similar to the windowing technique for the harmonic analysis with the Discrete Fourier Transform.
The target is mounted on a conical styrofoam column (Fig. 5.6). This column offers low background return [7]. Another advantage of using a conical column is that its RCS is independent of the aspect angle [4].

Fig. 5.6. Target mount.

The styrofoam column is fixed on top of the Orbit positioner.
5.4 The disturbance attribute

As a test for the RCS correction algorithm an artificial disturbance is generated. In order to obtain this disturbance an aluminium (65 x 2 x 2 cm³) bar is mounted on the left side of the main reflector (Fig. 5.7).
6. ORGANIZATION OF THE CORRECTION PROGRAMS

6.1 Introduction

In this chapter the computer programs, which are used for correcting the measured, or simulated RCS versus aspect angle patterns, are discussed. All programs are written in Fortran-77. Special attention is paid to the compatibility of the programs for different computers. It is possible to use the programs under the operating systems MS-DOS, μRSX or VMS.

A set of programs is developed for the RCS correction. Fig. 6.1 shows the relations between the different programs.

![Diagram showing the relations between the programs.](image)

Fig. 6.1. Relations between the programs.

S(α) is the measured or simulated RCS pattern as a function of α.
S(u) is the measured or simulated RCS pattern as a function of u.
D(u) is the corrected RCS pattern as a function of u.

$q_n$ are the correction coefficients and $E(x)$ is the Fourier transform of $S(u)$.

The input and output data of all programs is structured according to the March standard. This means that there are a report and a data file. The report file is an ASCII-file which contains a description of the data file. The data file is a binary file containing the complex data.

The extensions of the program names are omitted, because they are depending on the used operating system. There are three different extensions: ".FOR", ".FTN", ".FRI". All programs with the extension ".FOR" can be used under VMS, and some under μ-RSX. The ".FTN" programs can only be used under μ-RSX. The .FRI programs are used under MS-DOS.

The ARCS program is already discussed in Chap.5.2. The rest of the programs will be discussed in the next paragraphs.

6.2 The program ANGTOU

ANGTOU is a conversion program. It converts an input file of RCS versus aspect angle to RCS versus $u$, where $u = 2k \sin \alpha$ (see Chap.3.1). Fig.6.2 shows a flow diagram of the computer program.

The output file of the ARCS program contains, for several frequencies, traces of RCS versus aspect angle. The data points are equidistant in the angle domain. The correction algorithm (Eq.3-11) however needs data which is equidistant in the $u$-domain. The program ANGTOU takes care of this conversion. The user of the program has to select one of the measured frequencies.
Fig. 6.2. Flow diagram ANGTOU.

Offset correction is another feature of the program. As a result of misalignment of the target it often happens that the maximum of the RCS pattern doesn't appear at boresight. Therefore an offset correction has to be done. The offset correction operates as follows: First it will search for the maximum amplitude point, after this it calculates the -15 dB amplitude and searches to both sides of the maximum for the nearest data points.
With linear interpolation the exact corresponding angles of the -15 dB points are determined (Fig. 6.3). The new boresight point is the point which is closest to the middle of the two -15 dB points. Now the data file will be readjusted. On both sides of the middle point there will be an equal number of points, the rest will be cut off. The output file contains an RCS versus $u$ pattern of a chosen frequency.

![Diagram](image)

**Fig. 6.3.** Offset correction.

### 6.3 The programs JRCSU and JRCSU2

The programs JRCSU and JRCSU2 generate RCS vs. $u$ patterns. They are used for simulations. Fig. 6.4 shows a flow diagram of the programs.

It is possible to add a disturbance to the patterns. The disturbance is caused by a plane wave coming from a certain direction. The pattern computed in JRCSU2 is based on formula 4-3, the bistatic case. The pattern computed in JRCSU is based on formula 4-4, the superposition of two sinc functions.
6.4 The program PWZSWSPOT

PWZSWSPOT is a program which computes the correction coefficients \( q_n \), and the near field \( E(x) \). The input file contains an RCS versus \( u \) pattern. The output file contains the \( q_n \) coefficients, corresponding to a fixed length \( L \), versus \( n \) and \( E(x) \) versus \( x \).

Fig.6.5 shows a flow diagram of the program.
Fig. 6.5. Flow diagram PWZSWSPOT
E(x) is calculated by means of a Fast Fourier Transform (FFT), see Chap.3.3. FFT is a special algorithm for calculating the Discrete Fourier Transform (DFT). The FFT algorithm can reduce the time involved in finding a DFT.

The RCS pattern of a target is represented as a function of discrete u positions and therefore the Fourier transform is a DFT. This is opposed to the Continuous Fourier Transform (CFT), in which the function to be transformed is known at any arbitrary point. There are differences between the results of the CFT and the DFT. These differences are a result from the constraint that DFT has to operate on sampled waveforms defined over finite intervals.

The three problems most often encountered in using the DFT appear to be aliasing, leakage and picket-fence effect [8],[10],[11]. Special techniques are used to improve the results from the DFT.

A characteristic of the DFT is that the number of points of the input sequence is equal to the number of points of the output sequence. The FFT algorithm which is used to transform the u-domain into the range domain has the additional requirement that the number of points has to be a power of two:8,16,32,64...

If the available number of points does not meet this requirement, then the input sequence can be padded with data points equal to zero in order to obtain the desired number of points.

This technique also improves the result from the DFT, since the spacing between samples in the output sequence is reduced, giving a smoother function and reducing the processing error.

Assume that we measure a function in the u-domain. The u-span is U, the spacing between points is Δu. The range domain transform of f(u) is F(x), the total range span is X and the spacing between range samples is Δx, see Fig.6.6. The following relations apply:

\[ Δu = \frac{1}{X} \quad \text{and} \quad Δx = \frac{1}{U} \quad (6-1) \]

![Fig.6.6. Range and u domain relations.](image)
If we pad the u-domain data with zeroes to a span of, say, 2U, then the spacing in the u-domain and thus the total range span remain unchanged, but the spacing in the range domain is halved from 1/U to 1/2U meters. This is shown in Fig.6.7.

2U

\[ \text{zeroes} \quad \Delta u \quad \text{zeroes} \]

\[ u \]

\[ \Delta x = 1/2U \]

\[ x \]

**Fig.6.7. Zero padding.**

The padded frequency domain function can be thought to be obtained from the original u-domain data by multiplying by a rectangular window W(u).

If we have an odd number of samples over the rectangular window then the DFT will give good results. Is however the number of samples even then the DFT deviates from the CFT.

Suppose W(u) is a continuous rectangular function. The transform of this function is the sinc function. W(u) is an even function. Therefore the transform W(x) is a real function: its imaginary part is equal to zero.

We now consider the discrete case. We suppose that W(u) exist of 8 data points padded with 8 zeroes to obtain a 16-point function. If we compute the DFT of W(u) there will be an important difference between the output in the discrete and continuous situation. The discrete transform has an imaginary component that is not equal to zero. This imaginary component is caused by the asymmetry in the discrete rectangular function. The sampled rectangular function can be decomposed into its even and odd parts as shown in Fig.6.8.
Fig. 6.8. Even and odd component of the rectangular window function.

The transform of the even component has an imaginary part that is zero; the transform of the odd component has a real part that is zero.

Another technique used for improving the results of the FFT is reversing the order of the complex in- and output array of the FFT algorithm.

If the original order of a complex N-point array is:

1, 2, ..., N/2-1, N/2, N/2+1, ..., N-1, N

this is changed to:

N/2+1, ..., N-1, N, 1, 2, ..., N/2-1, N/2

In the program PWZSWSPOT an offset correction, as set out in Chap. 6.2, is used. The remaining offset, the difference between middle point and new boresight point (Fig. 6.3), will be corrected.

An offset in the u-domain causes a phase shift in the range domain. If the offset is known then the phase shift is also known. The input of the FFT algorithm has a well-known offset, this results in a well-known phase shift in the range domain. The phase shift is removed from the range domain by multiplication by a phase term.

The programs also compute the correction coefficients $q_n$ (Eq. 3-9). This equation relates the correction coefficients to a length $L$. PWZSWSPOT calculates a fixed number of correction coefficients.
The fixed number of coefficients is calculated according to Eq. 3-11. The summation boundaries determine the maximum and minimum needed $q_n$'s:

$$|u-n \frac{2\pi}{L}| \leq u_0$$
$$\frac{L}{2\pi} (u-u_o) \leq n \leq \frac{L}{2\pi} (u+u_o)$$

(6-2)

$u$ is located within the sector $(-u_o, u_o)$. So:

$$-\frac{L}{\pi} u_o \leq n \leq \frac{L}{\pi} u_o$$

(6-3)

In the program PWZSWSPOT is: $n_{\text{min}} = -\frac{L}{\pi} u_o - 5$ and

$$n_{\text{max}} = \frac{L}{\pi} u_o + 5$$

The correction coefficients are calculated according to Eq. 3-9. $\frac{L}{\pi} u_o$ do not have to be an integer, therefore, $n_{\text{min}}$ and $n_{\text{max}}$ are both increased by some number. In our case 5 responses a good safety margin.

6.5 The programs JOSCOR2U and CORTES

The programs JOSCOR2U and CORTES are the correction programs. They take care of the actual RCS correction.

The input of the programs are an RCS pattern and the complementary correction coefficients.

The programs normalize the RCS pattern and the correction coefficients. The data points are normalized to the maximum amplitudes.

Eq. 3-11 is the basis of the correction algorithm. For the correction of one data point a lot of other points are needed. The spacing between these points has to be $2\pi/L$. Most of the time these data points are not in the data array, so we are forced to reconstruct these points. This is done with a linear interpolating technique.

After the correction the corrected pattern is scaled back. The new maximum is set to the original maximum.

The program CORTES corrects with a number of correction coefficients chosen by the programmer. The program JOSCOR2U, however, corrects with a maximum number of correction coefficients (Eq. 3-11 and Eq. 6-3).
Fig. 6.9. A flow diagram of JOSCOR2U and CORTES.
7. ANALYSIS OF THE MEASUREMENTS

7.1 Introduction

In this chapter we will discuss the RCS-measurements. Our main interest is of course going to the behaviour of the correction algorithm on the RCS measurements.

The measurement set-up is described in chapter 6.

The most important variables during the measurements are:
- The frequency: 4, 10 and 17 GHz.
- The targets: see chap.5.4
- The disturbance on the main reflector (chap.5.5)
- The time gate: gate off or gate on. When the gate is on then the gate span is 2 meter.

The used filenames will contain information about their contents. Fig.7.1 shows the way the information is stored.

Although all data is complex we only show the amplitude on a logarithmic scale, because this is the most illustrative way to see what happens.

The polarization of the transmitter and receiver is in most cases horizontal. Only the measurements where the frequency is 10GHz and the gate is off are done with vertical polarization. This is explicitly described in all the corresponding file names, there will always be a 'V' in the fifth position.
The maximum theoretical RCS-values in dBsm of the targets are written down in Table 7-1. The following formula is applied:

\[
\sigma_{\text{max}} = 10 \log_{10} \left( \frac{4\pi A^2}{\lambda^2} \right)
\]  

(7-1)

where \( A \) = area of the target (m²) and \( \lambda \) = wavelength

<table>
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<th>FREQUENCY (GHz)</th>
<th>4.0</th>
<th>10.0</th>
<th>17.0</th>
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<td>Target</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.25 m</td>
<td>11.0</td>
<td>19.0</td>
<td>23.6</td>
</tr>
<tr>
<td>1.55 m</td>
<td>12.8</td>
<td>20.8</td>
<td>25.4</td>
</tr>
<tr>
<td>2.50 m</td>
<td>15.9</td>
<td>23.8</td>
<td>28.5</td>
</tr>
</tbody>
</table>

Table 7-1. Maximum RCS-values in dBsm.

In the next chapters we will successively discuss the measurements and corrections of 4, 10 and 17 GHz.
7.2 Measurements 4 GHz

The measurements are done with the ARCS-program. This program creates a measurement report for every measurement which is done. Fig.7.2 shows the most important parameters of the measurement report.

**CALIBRATION**

Target ref. type: SPHERE  dim.: 35.5 cm  theor. RCS: -10.0 dBsm

**BP 8510**

Frequency start: 3.5000000 GHz  No. of frequencies: 401
stop: 4.5000000 GHz  Source mode: RAMP
center: 4.0000000 GHz  Sweep time: 100 ms
span: 1.0000000 GHz  Source power: 15.0 dBm

Polarization change: MANUAL  No. of averages: OFF
b2/ai: HH  next: OFF
a2/ai: OFF  next: OFF

**ACQUIRE RCS VS. ASPECT ANGLE**

Gate: ON  center: 0.00 m  Store: 11
span: 2.00 m  of center 401 points
shape: NORMAL  Frequency low: 3.50 GHz

Subtraction: ON  high: 4.50 GHz

**POSITIONER**

axis  name from to incr vel. acc. mode
(dg)  (dg)  (dg) (dg/s) (dg/ss)

SCAN 6 Aspect ang -45.00 45.00 0.20 1.00 1.00 STEP

Fig.7.2. Part of an ARCS measurement report

During a series of measurements all these parameters are fixed except for the gate and the span of the scan angle. In most cases this span is equal to 90°, but there are also measurements where the span is 50° (start: -25°, stop: 25°).

Although we measure several frequencies in the vicinity of 4 GHz (see Fig.7.2) we only will examine the 4 GHz measurements.

We will discuss three different measurement series:

- 1. Frequency 4 GHz, no gate, no disturbance on the mainreflector.

All the corresponding filenames are recognizable by: G...N..4.REP
Fig. 7.3. Measurement series: 4GHz, no gate, no disturbance. G25SNUU4 measured RCS-pattern 2.5m. bar, G25SNQK4 corresponding near field, G25SNQK4 lowest pattern, correction coefficients for correcting 1.25 m bar.
Fig. 7.4. Measurement series: 4GHz, no gate, no disturbance. G125NC04 is the result of correcting G125NUU4 with the correction coefficients G25SNQK4 derived from the RCS-pattern of the 2.5m tapered bar.
Fig. 7.5. Measurement series: 4GHz, no gate, no disturbance. G155NCO4 is the result of correcting G155NUU4 with the correction coefficients derived from the RCS-pattern of the 2.5m tapered bar.
-2. Frequency 4GHz, gate, no disturbance on the mainreflector.
   All the corresponding filenames are recognizable by: G...G..4.REP

-3. Frequency 4GHz, gate, disturbance on the mainreflector.
   All the corresponding filenames are recognizable by: G...G..6.REP

-1. Frequency 4GHz, no gate, no disturbance, corresponding figures: 7.3, 7.4 and 7.5.

The corresponding filename of the pattern is written upper left of each drawing. The names with UU in it are the measured ones. They are the output of the program "ANGTOU" (Chap.6.2).

If we examine the measured RCS-patterns we hardly can recognize a sinc function, the theoretical RCS of a bar. There is too much disturbance in the testzone. This disturbance is caused by several different mechanisms. The direct radiation from the feed to the bar causes the strongest disturbance. We can see the results of this radiation between 10° and 30° in all three measured patterns.

Another cause of disturbance is "multipath reflection", which means that there are several paths for a ray to go from the transmitting horn into the room, to the bar and back to the receiving horn. Most likely the disturbance in the vicinity of -20° in G25SNUU4.REP is caused by multipath reflection.

At last we mention the fact that the field in the testzone never will be uniform, because we are still in the near field of an antenna, the main reflector. The variations in the amplitude and phase are negligible in case of no gating.

The maximum of the measured RCS-patterns agrees with the calculated values (tab.7-1). Only the maximum of the 2.5 m tapered bar deflects a little bit. The reason for this is probably the fact that a part of the bar is outside the testzone.

In order to perform the corrections on the scattered fields of the 1.55 and 1.25 m bars we will compute the near field and the correction coefficients from G25SNUU4.REP. We will do this with the program PWZSWSPOT (Chap.6.4). The results are drawn in Fig.7.3. Only the correction coefficients for the 1.25 m bar are drawn. The corrections are presented in Fig.7.4 and 7.5.

If we examine these correction patterns we see that there is some correction but still we don't have a sinc function. Probably there is too much disturbance in the testzone for doing a perfect correction.
- Frequency 4GHz, gate 2m, no disturbance, corresponding figures: 7.6 up to and including 7.9.
These measurements are equal to the ones described above, only we now use a 2 m gate.

The gating feature provides a way to remove the effects of unwanted reflections. Only the electromagnetic rays, which are running a certain time in the room, are contributing to the ultimate response of the target. A gate of 2 meter means that every reflection of an object 1 meter before or 1 meter behind the bar is registered. Still there is a possibility of unwanted multipath responses, because it's possible that there are paths going from transmitter-bar-receiver which are almost of the same length as the main path.

If we examine the measurements and compare them to the non gated ones, it is obvious that the disturbances are reduced. Still there are unwanted responses. The RCS-pattern of the 2.5m shaped bar is most illustrative. We can see the effect of the shaping. It is very significant that the envelope of the RCS-pattern (G25SGUU4.REP Fig.7.6) of the tapered bar is much steeper than the envelope of the other RCS-patterns, in particularly the right envelope. On the left side of the maximum we can see a disturbance (-25°).

This disturbance is also present in the RCS-pattern of the 1.55 m bar(G155GUU4.REP, Fig.7.8) but is more hidden between the sidelobes. The 1.55 m bar contains almost as much information as the 2.5 m bar. Comparing the near fields and the computed correction coefficients gives convincing proof for this statement. The near field of the 2.5 m bar (Fig.7.6) is of course wider than the near field of the 1.55 m bar (Fig.7.9). However the part from -0.65 to 0.65 meter is almost equal, this is the region which is needed for computing the correction coefficients.

We have performed three corrections:
-a. Correcting the RCS-pattern of the 1.25 m bar (G125GUU4.REP) with the correction coefficients deduced from the 2.5 m bar (G25SGUU4.REP) the result is drawn in Fig.7.7.
-b. Correcting the RCS-pattern of the 1.25 m bar (G125GUU4.REP) with the correction coefficients deduced from the 1.55 m bar (G155GUU4.REP) the result is drawn in Fig.7.9.
-c. Correcting the RCS-pattern of the 1.55 m bar (G155GUU4.REP) with the correction coefficients deduced from the 2.5 m bar (G25SGUU4.REP) the result is drawn in Fig.7.8.
Fig. 7.6. Measurement series: 4GHz, gate 2m, no disturbance. G25SGUU4 measured RCS-pattern 2.5m bar, G25SGQK4 corresponding near field, G25SGQK4 lowest pattern, correction coefficients for correcting 1.25 m bar.
Fig. 7.7. Measurement series: 4GHz, gate 2m, no disturbance. G125GO04 is the result of correcting G125GOU4 with the correction coefficients G25SGQK4 derived from the RCS-pattern of the 2.5m tapered bar.
Fig. 7.8. Measurement series: 4GHz, gate 2m, no disturbance. G155GCU4 is the result of correcting G155GCU4 with the correction coefficients derived from the RCS-pattern of the 2.5m tapered bar.
Fig. 7.9. G155GQK4: Near field 1.55m bar, corresponding with Fig. 7.8. G155GQK4 (pattern in the middle): correction coefficients. G125GCK4 is the result of correcting G125GUU4 with the correction coef. 1.55m bar.
All three corrections are giving good results, so we can conclude that the correction technique works. The corrected patterns from the corrections a. and b. are looking very similar, apparently it is sufficient to compute the correction coefficients from the RCS-pattern of a 1.55 m bar.

-3. Frequency 4GHz, gate 2m, disturbance on the mainreflector, corresponding figures: 7.10 up to and including 7.12. We now have mounted a disturbance on the main reflector as described in Chap.5.4. This is the only difference with the previous measurements. If we compare these two series we see only slight differences between them. The RCS-pattern of the 2.5 meter tapered bar is a little bit different nearby -9°, compare G25SGUU4.REP Fig.7.6 to G25SGUU6.REP Fig.7.10. These slight differences have almost no consequences on the corrections. We only have performed two corrections:

- a. Correcting the RCS-pattern of the 1.25 m bar (G125GUU6.REP) with the correction coefficients deduced from the 2.5 m bar (G25SGUU6.REP) the result is drawn in Fig.7.11.

- b. Correcting the RCS-pattern of the 1.25 m bar (G125GUU6.REP) with the correction coefficients deduced from the 1.55 m bar (G155GUU6.REP) the result is drawn in Fig.7.11.

Again the corrected patterns are looking very similar.
Fig. 7.10. Measurement series: 4GHz, gate 2m, disturbance. G25SGUU6 measured RCS-pattern 2.5m bar, G25SGQK6 corresponding near field, G25SGQK6, lowest pattern, correction coefficients for correcting 1.25 m bar.
Fig. 7.11. Measurement series: 4GHz, gate 2m, disturbance. Gl25GC06 is the result of correcting Gl25GUU6 with the corr.coeff. G25SGQK4, derived from the 2.5m tapered bar. Gl25GCK6 is corrected with 1.55m bar.
Fig. 7.12. G155GQK6: Near field 1.55m bar, corresponding with Fig. 7.8. G155GQK4 (pattern in the middle): correction coefficients. G125GCK4 is the result of correcting G125GUU4 with the correction coef. 1.55m bar.
7.3 Measurements 10GHz

The 10GHz measurements are a repetition of the 4GHz measurements. Again we have performed three series of measurements.
-1. Frequency 10GHz, no gate, no disturbance on the mainreflector.
   All the corresponding filenames are recognizable by: X...V..1.REP
-2. Frequency 10GHz, gate, no disturbance on the mainreflector.
   All the corresponding filenames are recognizable by: X...G..2.REP
-3. Frequency 10GHz, gate, disturbance on the mainreflector.
   All the corresponding filenames are recognizable by: X...G..3.REP

Fig.7.13 shows the main parameters during the measurements. Some of them are changed during the measurements. If these changes are important we will mention them.

CALIBRATION

Target ref. type: SPHERE dim.: 35.5 cm theor. RCS: -10.0 dBsm

HP 8510

Frequency start: 9.0000000 GHz stop: 11.0000000 GHz center: 10.0000000 GHz span: 2.0000000 GHz No. of frequencies: 401 Source mode: RAMP Sweep time: 100 ms Source power: 15.0 dBm No. of averages: OFF Window: NORMAL


ACQUIRE RCS VS. ASPECT ANGLE

Gate: ON center: 0.00 m span: 2.00 m shape: NORMAL Store: 11 of center 101 points Frequency low: 9.75 GHz high: 10.25 GHz step: 0.05 GHz

Subtraction: ON

POSITIONER

axis name from to incr vel. acc. mode
(dg) (dg) (dg) (dg/s) (dg/ss)
SCAN 6 Aspect ang -45.00 45.00 0.15 1.00 1.00 STEP

Fig.7.13. Part of an ARCS measurement report.
Fig. 7.14. Measurement series: 10GHz, no gate, no disturbance. X25SVUU1 measured RCS-pattern 2.5 m bar, X25SVQK1 corresponding near field, G25SVQK1, pattern below, corr. coeff. for correcting RCS-pattern 1.25 m bar.
Fig. 7.15. Measurement series: 10GHz, no gate, no disturbance. X125VC01 is the result of correcting X125UU1 with the corr.coeff. X25VQK1, derived from X25UU1, the RCS-pattern of the 2.5m tapered bar.
-1. Frequency 10 GHz, no gate, no disturbance on the mainreflector, corresponding figures: 7.14 and 7.15.

This is the only time we have vertical polarisation of the receiving- and transmitting horn.

X25SVUU1.REP, Fig.7.14, is the RCS-pattern of the tapered bar. In the angle interval 10° to 27° we see the influence of the direct radiation of the feed to the bar.

Nearby -25° we see the same multipath reflection as the one we saw at the 4 GHz measurements.

Another disturbance is caused by a multipath reflection at circa -7°. Although this disturbance is more hidden it is also visible at the 4 GHz measurements.

There is only one correction done. The RCS-pattern of the 1.25 m bar (X125VUU1.REP, Fig.7.15) is corrected with the correction coefficients deduced from the RCS-pattern of the 2.5 m tapered bar (Fig.7.14). The result is drawn in Fig.7.15 (X125VC01.REP).

If we examine this corrected pattern we see that in the interval (-10°,10°) the correction is done properly. Outside the interval however, the correction is less successful. Most likely the disturbance was too strong.

-2. Frequency 10 GHz, gate 2 m., no disturbance on the mainreflector, corresponding figures: 7.16, 7.17 and 7.18.

X25SGUU2.REP (Fig.7.16) is the RCS-pattern of the tapered bar. We can see that the disturbance is reduced compared to the non gated measurements (X25SVUU1.REP), in particular the right sight of the pattern looks good. On the left side, nearby -25°, we still see disturbance. The disturbance nearby -9°, however, has almost disappeared, the corresponding multipath reflection is reduced by the gate.

If we examine the RCS-pattern of the 1.25 m bar (X125GUU2.REP, Fig.7.17) it strikes the eye that there is a regular path of the lower side lobes, they are going up and down. The reason for this regularity can be the influence of the target mount. If we have a perfect mount then the scattered energy is independent of its aspect angle. If we perform an RCS measurement with such a mount then the subtraction takes care that we measure no response of the mount at all. However if we don’t have a perfect mount, then the scattered energy can vary very slowly as a function of the aspect angle. We can see this scattered field as a constant contribution which is added to the RCS of the target.
Fig. 7.16. Measurement series: 10GHz, gate 2m, no disturbance. X25SGUU2 measured RCS-pattern 2.5m bar, X25SGQK2 corresponding near field, G25SGQK2, pattern below, corr.coeff. for correcting RCS-pattern 1.25 m bar.
Fig. 7.17. Measurement series: 10GHz, gate 2m, no disturbance. X125GC02 is the result of correcting X125GUU2 with the corr.coeff. X25SGQK2, derived from the 2.5m tapered bar. X125GCK2 is corrected with 1.55m bar.
Fig. 7.18. Measurement series: 10GHz, gate 2m, no disturbance, X155GCO2 is the result of correcting X155GUU2 with the corr.coeff. derived from 2.5m bar. X155GQK2 is near field 1.55m bar.
The result is a sinc function with different zero-passings. When we take the logarithm of such a function this results in the regular path of the lower side lobes.

Another remarkable phenomenon is the path of the envelope. The middle part of the envelope looks like the normal envelope of a sinc function, but for larger angles the envelope has an unexpected curve. The reason for this phenomenon can be the fact that for larger angles the open ends of the bar are contributing to the response.

We have performed three corrections:

-a. Correcting the RCS-pattern of the 1.25 m bar (X125GUU2.REP) with the correction coefficients deduced from the 2.5 m bar (X25SGUU2.REP). The result is drawn in Fig.7.17 (X125GCO2.REP).

-b. Correcting the RCS-pattern of the 1.25 m bar (X125GUU2.REP) with the correction coefficients deduced from the 1.55 m bar (X155GUU2.REP). The result is drawn in Fig.7.17 (X125GCK2.REP).

-c. Correcting the RCS-pattern of the 1.55 m bar (X155GUU2.REP) with the correction coefficients deduced from the 2.5 m bar (X25SGUU2.REP). The result is drawn in Fig.7.18 (X155GCO2.REP).

The results are very satisfactory. If we compare X125GCK2.REP to X125GCO2.REP in Fig.7.17 we can see small differences. In contrast to the 40Hz measurements we can see that correcting with correction-coefficients deduced from the 2.5 m tapered bar gives better results.

-2. Frequency 10GHz, gate 2 m, disturbance on the main reflector, corresponding figures: 7.19, 7.20 and 7.21.

The disturbance attribute is again mounted on the main reflector. In contrast with the 4 GHz measurements this disturbance has a lot of influence on the field in the testzone. In the RCS-pattern of the 2.5 m shaped bar (X25SGUU3.REP, Fig.7.19) we see the influence of the disturbance very evident.

We have performed two corrections:

-a. Correcting the RCS-pattern of the 1.25 m bar (X125GUU3.REP) with the correction coefficients deduced from the 2.5 m bar (X25SGUU3.REP) the result is drawn in Fig.7.20 (X125GCO3.REP).

-b. Correcting the RCS-pattern of the 1.55 m bar (X155GUU3.REP) with the correction coefficients deduced from the 2.5 m bar (X25SGUU3.REP) the result is drawn in Fig.7.21 (X155GCO3.REP).
Fig. 7.19. Measurement series: 10GHz, gate 2m, disturbance. X25SGUU3 measured RCS-pattern 2.5m bar, X25SGQK3 corresponding near field, X25SGQK3, pattern below, corr.coeff. for correcting RCS-pattern 1.25 m bar.
Fig. 7.20. Measurement series: 10GHz, gate 2m, disturbance. X125GC03 is the result of correcting X125GUU3 with the corr.coef. X25SQGK3, derived from the RCS-pattern of the 2.5m tapered bar.
Fig.7.21. Measurement series: 10GHz, gate 2m, disturbance. X155GC03 is the result of correcting X155GU03 with the corr.coeff. derived from the RCS-pattern of the 2.5m tapered bar.
If we examine the results we see that the correction of the 1.25 m bar is better than the correction of the 1.55 m bar. A reason for this can be the fact that the length of the 1.25 m bar is smaller than the 1.55 m bar. For computing the correction coefficients for the correction of the RCS-pattern of the 1.25 m bar we need a smaller part of the near field (X25SGQK3.REP, Fig.7.19). The middle part of the near field is always better determined than the edges. Different positions of the targets on the mount may also affect the corrections.

7.4 Measurements 17 GHz

At last we will discuss the 17 GHz measurements. The measurement procedure is similar to that of the 4 and 10 GHz measurements. We only will describe two series of measurements:

-1. Frequency 17 GHz, gate, no disturbance on the main reflector.
   All the corresponding filenames are recognizable by: P...G..1.REP

-2. Frequency 17 GHz, gate, disturbance on the main reflector.
   All the corresponding filenames are recognizable by: P...G..2.REP

Fig.7.22 shows the main parameters. Some of them are changed during the measurements.

**CALIBRATION**

Target ref. type: SPHERE  dim.: 35.5 cm  theor. RCS: -10.0 dBm

**HP 8510**

Frequency start: 16.0000000 GHz  No. of frequencies: 401
stop: 18.0000000 GHz  Source mode: RAMP
center: 17.0000000 GHz  Sweep time: 100 ms
span: 2.0000000 GHz  Source power: 15.0 dBm
Polarization change: MANUAL  No. of averages: OFF
b2/al: HH  Window: NORMAL
next: OFF
a2/al: OFF
next: OFF

**ACQUIRE RCS VS. ASPECT ANGLE**

Gate: ON  center: 0.00 m  Store: 11
span: 2.00 m  of center 51 points
shape: NORMAL  Frequency low: 16.875 GHz
Subtraction: ON  high: 17.125 GHz
step: 0.025 GHz

**POSITIONER**

axis name from to incr vel. acc. mode
      (dg) (dg) (dg) (dg/s) (dg/ss)
SCAN 6 Aspect ang -45.00 45.00 0.10 1.00 1.00 STEP

Fig.7.22. Part of an ARCS measurement report
Fig. 7.23. Measurement series: 17GHz, gate 2m, no disturbance. P25SGUUL measured RCS-pattern 2.5m bar, P25SGQK1 corresponding near field, P25SGQK1, pattern below, corr.coeff. for correcting RCS-pattern 1.25 m bar.
Fig. 7.24. Measurement series: 17GHz, gate 2m, no disturbance. P125GCO1 is the result of correcting P125GU1 with the corr.coff. P25SQQK1, derived from the RCS-pattern of the 2.5m tapered bar.
-1. Frequency 17 GHz, gate, no disturbance on the main reflector, corresponding figures: 7.23 and 7.24.

P25SGUU1.REP (Fig.7.23) is the RCS-pattern of the 2.5 m shaped bar. The disturbance nearby -25° is present again.

The ripple in the near field (P25SGQK1.REP Fig.7.23) is reduced.

Only the RCS-pattern of the 1.25 m bar (P125GUU1.REP, Fig.7.24) is corrected. The result is drawn in Fig.7.24 (P125GC01.REP).

Once again the correction is successful, in particular the correction of the middle section.


The 2.5 m shaped bar is measured over the angle interval (-25°, 25°), the RCS-pattern and corresponding near field and correction coefficients are drawn in Fig.7.25.

P125GC02.REP (Fig.7.26) is the corrected pattern of the RCS-pattern (P125GUU2.REP) of the 1.25 m bar.

The disturbance nearby -7° is corrected very well, but the disturbance nearby -20° gives more problems. Probably the disturbance is too strong for performing a perfect correction.
Fig. 7.25. Measurement series: 17GHz, gate 2m, disturbance. P25SGUU2 measured RCS-pattern 2.5m bar, P25SGQQK2 corresponding near field, P25SGQK2, pattern below, corr.coeff. for correcting RCS-pattern 1.25 m bar.
Fig. 7.26. Measurement series: 17GHz, gate 2m, disturbance. P125GC02 is the result of correcting P125GUU2 with the corr. coeff. P25SGQK2, derived from the RCS-pattern of the 2.5m tapered bar.
8. CONCLUSION

This report has shown, both in theory and in practice, that we have developed a useful correction technique for correcting Radar Cross Section measurements in a compact antenna test range.

The following remarks can be made:

1. The RCS correction gives good results for all three frequencies investigated (4, 10 and 17GHz).

2. Correction of small angles ($|\alpha| < 10^\circ$) gives very good results, almost independent of the disturbance.

3. Disturbances, at larger angles ($|\alpha| > 10^\circ$) cause more difficulties. Still the correction technique gives proper results, specially when we are dealing with a gated measurement where the disturbances are not too strong. When a disturbance is coming from a small angle, then the RCS pattern will be a superposition of two sinc functions (chap.4.2 point 3 and eq.4.4). In this case the correction technique will give very good results. However is the disturbance coming from a larger angle then the RCS pattern is not any more a superposition of two sinc functions, but a superposition of a sinc function and a function which looks like a sinc function (eq.4-2). Now the corrections will be more difficult.

The open ends of the bar also influence the corrections, but they are of minor importance. For example examine fig.7.20 and 7.21, it is obvious that the disturbance, caused by a multiple reflection, is dominant to the effects of the open ends.

4. Gating improves the results of the correction technique.
5. Determining the illuminating field with an RCS-measurement of a bar works very satisfactory. Advantage of this method, compared to probing the illuminating field with a horn is first of all its simplicity. We only have to replace the target in the measurement set-up. Another advantage is the fact that nothing essential is changed in the room. If we will probe the illuminating field with a horn, then we have to rebuild the measurement set-up. This doesn’t only take extra time, but we also will influence the field in the test zone.

Experiments have been carried out with probing the field with a horn. The results were not satisfactory, and therefore no attention is paid to it in this report.

6. When we compare the results of the corrections of the 1.25m bar, done with correction coefficients deduced from the 2.5m shaped bar to the corrections done with correction coefficients deduced from the 1.55m bar, we can see only slight differences, specially at 4GHz.
REFERENCES


[4]: ibid., pp. 113-154.


