A General and Effective Clutter Filtering Strategy for Quiet Zone Evaluation in Tri-reflector Compact Range

Jingjuan Wang[1], **Cheng Yang**[1], **Yuan Yao**[1], **Xiaoming Liu**[1], **Junsheng Yu**[1], **and Xiaodong Chen**[2]

[1]School of Electronic Engineering
Beijing University of Posts and Telecommunications, Beijing, China
[2]School of Electronic Engineering and Computer Science
Queen Mary University of London, London, UK

Abstract— A clutter filtering strategy is presented to evaluate the performance of the quiet zone of a tri-reflector compact range. The method is based on the band limitation properties of the scattered fields to filter the noise in quiet zone. Priori information on the source, such as its size, geometry, and location, are required in this approach. By exploiting a simple low-pass filter, this filtering strategy can partially filter out the environmental clutter. Numerical results are presented to confirm the effectiveness of the method.

1. INTRODUCTION

Nowadays, millimeter and sub-millimeter wave technique is widely applied in fields such as remote sensing, radio astronomy. In order to verify the performance of millimeter and sub-millimeter system, accurate measurement should be performed. Compact range (CR) is a promising method for electrically large antenna measurement where a pseudo-plane wave region can be generated for the accurate measurement.

The performance of CR mainly depends on the amplitude and phase ripple in the quiet zone. Environment clutter is one of those interference sources that affect the performance of the quiet zone, especially in millimeter and sub-millimeter band. Method of moment (MoM) is famous for its simple principle and has been widely used to reduce clutter noise [1]. However, in the case of CR, MoM has to simulate all the processes such as wave packet generation, diffraction, and absorption, which causes complexity and large calculating quantity. Besides, for each new project all the properties have to be simulated all over again. It is highly desirable to develop a fast and simple method independent of these processes. The aim of this paper is to provide a brief and general method to diminish quiet zone clutter noise in CR system, exploiting the concept of effective bandwidth of scattered field and the theory of digital signal processing.

2. TRI-REFLECTOR COMPACT RANGE

The basic principle of CR is to collimate the radiated field from a horn feed and to transform it into a pseudo plane wave by lens or reflectors. The design of a tri-reflector CR is based on the theory of GO ray tracing. The proposed CR consists of a spherical main reflector, two shaped sub-reflectors and a Gaussian beam horn. Figure 1 shows the diagram of the designed tri-reflector CR. Usually the aperture of the main reflector is defined as its projection on x-y plane. However, considering the diffraction effect the actual aperture should be larger [1]. It is acceptable to represent the actual aperture by $r_e = r + 5\lambda$ since the length of the serrated edge of CR is usually 5λ.

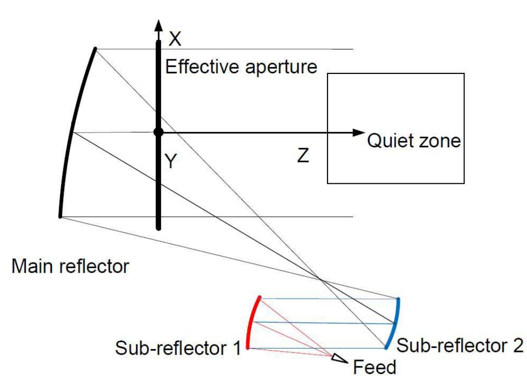

Figure 1: Diagram of the designed tri-reflector CR.

3. FILTERINGSTRATEGYAPPLIED ON CR

This filter strategy is a supplementary solution for sophisticated measurement facility and requires prior information of the AUT, such as electrical size, geometry, location, etc.. The clutter noise can be filtered out since the prior information confines the electric field that the main reflector can generate.

The filer strategy is implemented by applying a filtering algorithm to a reduced fieldmultiplying the measured field by a proper phase factor can get the reduced field. And due to Bucci's research [2, 3], the reduced field can be precisely represented by a band-limited function whose bandwidth depends on AUT's electrical size, geometry, and location. Figure 2 gives a brief demonstration of this filtering problem.

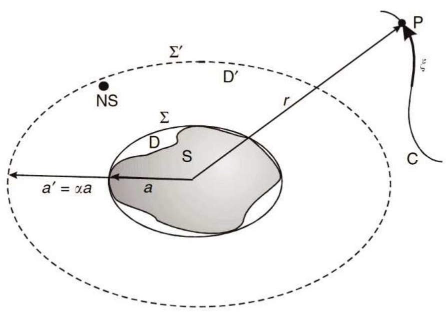

Figure 2: Geometry of filtering problem.

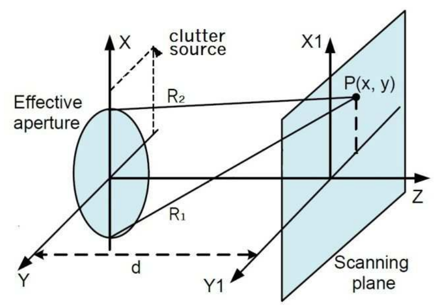

Figure 3: Geometry relevant to CR filter strategy.

Assuming S is the signal source contained in the D domain within a surface Σ, and NS is the clutter noise contained in D' domain within a surface Σ', ξ is the curvilinear abscissa along C. Since bandwidth W is proportional to dimension, by projecting the reduced field on the band-limited function of the main reflector, clutter noise can be filtered out with a simple low-pass filter.

In the case of CR, the AUT is the main spherical reflector, and the field is simulated on a scanning plane. Figure 3 shows the geometry of the scanning system and Figure 4 gives the flow chart of the filtering algorithm in the case of CR.

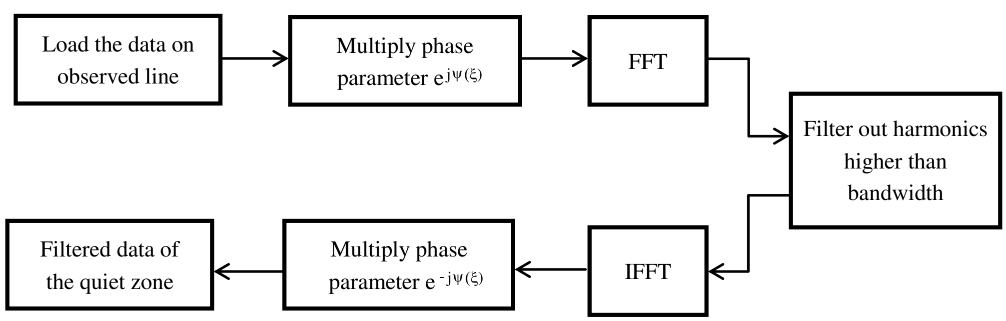

Figure 4: The flowchart of the filtering algorithm in case of CR.

Firstly, phase function is constructed as [4]

$$\psi = \beta\alpha\upsilon - \beta\alpha \tag{1}$$

where $\upsilon = R_1 + R_2$, α is the actual aperture of the reflector and β is the propagation constant. Thus, the reduced field can be represented by

$$F(\xi) = E(\xi) \exp[j\psi(\xi)] \tag{2}$$

The reduced field is an analytical function and can be approximated by a band-limited function whose bandwidth is

$$W = \beta\alpha/2\pi \tag{3}$$

To control the representation error of the field in quiet zone the enlargement bandwidth factor x_1 is introduced. The band-limited error decreased fast with x_1 and can be neglected when x_1 is a little larger than one. Besides this, to get an optimal result, the oversampling factor x_2 is also required to be selected to prevent aliasing caused by sample deficiency. With x_1 and x_2, effective bandwidth $w = x_1 * x_2 * W$ is constructed. The next step is to get the corresponding azimuth spectrum with an FFT algorithm and set harmonics higher than the effective bandwidth to zero with a simple sharp-window filter. Finally an IFFT algorithm is used to recover the quiet zone field.

4. NUMERICAL EXAMPLES AND DISCUSSIONS

To evaluate the process, the filtering strategy is applied to the quiet zone. The aperture of the main reflector is 1 m, and the diameter of the quiet zone is 0.7 m. The clutter caused by the reflector support can be simulated by a Gaussian beam horn placed 0.7 m away from the main reflector center, shown in Figure 3. The whole CR system works at 340 GHz. Commercial simulation software GRASP-10.0 is used to obtain the required field in quiet zone.

First, the quiet zone field without the clutter noise is simulated at a half wave-length interval. Then the field data is collected again with the clutter noise. Enlargement bandwidth factor x_1 and oversampling factor x_2 are chosen as 1.65 and 1.2 respectively. After the collection of the required data, an FFT algorithm is used to get the corresponding spectrum, shown in Figure 5.

The dotted vertical line represents the effective bandwidth w. It can be seen in Figure 5 that a large part of the clutter noise energy falls outside the radiation field bandwidth of the main reflector which is $(-w, w)$. The performance of quiet zone with and without the effect of clutter is shown from Figure 6 to Figure 9. And the performance of the amplitude ripple, cross-polar isolation, and phase ripple with and without the proposed filtering strategy on the entire cut are shown in the Table 1.

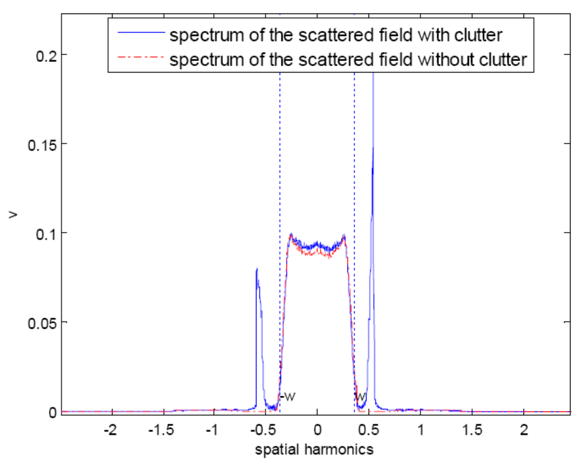

Figure 5: Amplitude of spectrum of reduced field.

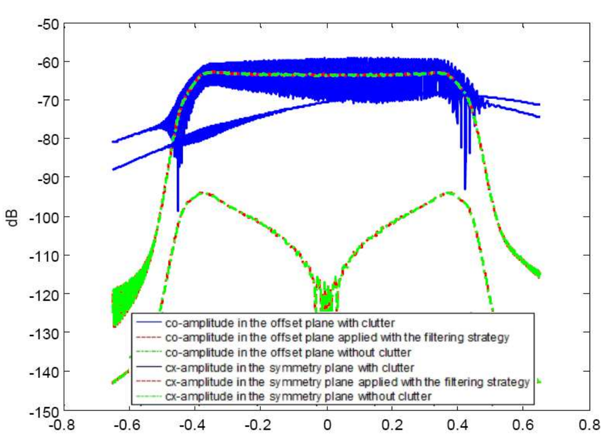

Figure 6: Amplitude of the quiet zone field in the offset plane.

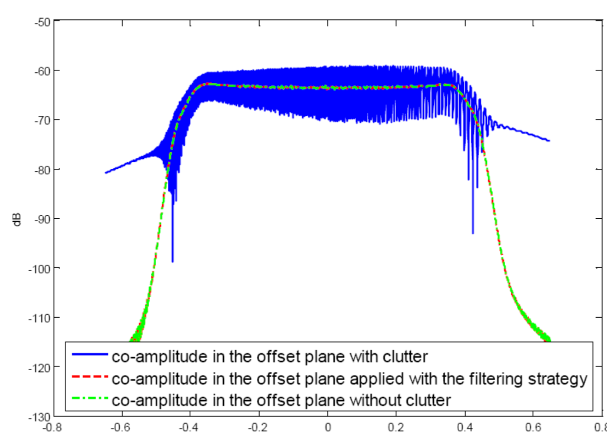

Figure 7: CO-amplitude of the quiet zone in the offset plane.

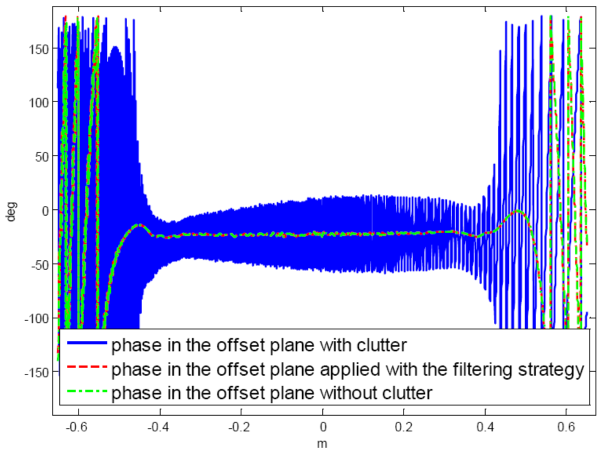

Figure 8: Phase of the quiet zone in the offset plane.

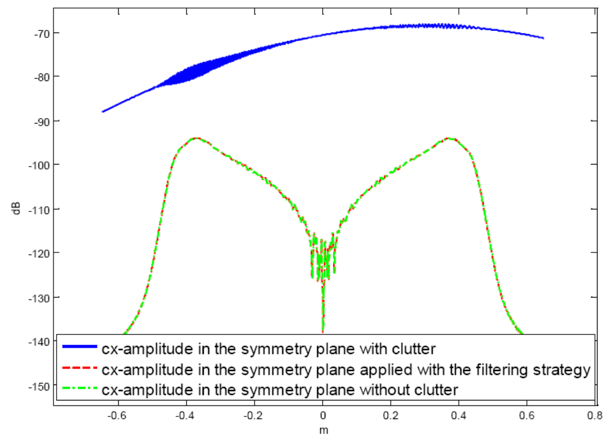

Figure 9: CX-amplitude of the quiet zone field in the offset plane.

Table 1: CR performance in different situation.

performance evaluation	amplitude ripple (dB)	cross-polar isolation (dB)	phase ripple (degree)
Without clutter	0.8435	33.0218	5.1096
With clutter	15.0974	−5.5150	89.8523
Filtered data	0.8529	33.0114	5.8712

5. CONCLUSION

The problem of diminishing the effect of clutter noise in the CR system has been investigated and solved. A clutter filtering strategy is presented to evaluate the performance of the quiet zone of a tri-reflector compact range with the clutter. The method is based on the band limitation properties of the scattered fields. By exploiting a simple low-pass filter, the noise in the quiet zone can be filtered. This filtering strategy can partially filter out the environmental clutter. Numerical results are presented to confirm the effectiveness of the method.

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