An Investigation of Bistatic Calibration Techniques

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Abstract—Several popular bistatic calibration techniques are investigated and comparisons made between the relative merits of the various techniques. The analysis addresses sensitivity to object alignment error, sensitivity to polarization impurity, and ease of implementation. Both theoretical concepts and practical considerations are discussed based on measurements accomplished at the European Microwave Signature Laboratory of the European Commission Joint Research Center, Ispra, Italy. This facility has the capability to produce far-field fully polarimetric precision bistatic measurements in a 30-cm-diameter quiet zone, suitable for comparing different calibration methods.

Index Terms—Bistatic, calibration, measurement, radar.

I. INTRODUCTION

The purpose of this paper is to investigate the performance of several existing and proven bistatic calibration techniques. The techniques are evaluated on the basis of several factors, namely: sensitivity of calibration to reference object alignment error, sensitivity to antenna polarization impurity, and ease and efficiency of implementation. The analysis of bistatic radar calibration objects is critical to the measurement process and is provided in our companion paper [1] as a distinct contribution.

The techniques examined in this effort are detailed in [2]–[6]. The difference between these methods lies mainly in their capability to capture the complete distortion characteristics set forth in the distortion error model. These are the major concerns for the accuracy and efficiency of a given calibration technique. Given the wide variance in measurement conditions from one measurement range to another, a particular calibration technique that is optimal for one range may be unreasonable for another. For this reason, calibration techniques that have been used in a wide variety of measurement facilities and scenarios are of interest.

The next section defines essential terms and relationships as well as provides background on the types and applicability of bistatic calibrations. Section III reviews the three selected calibration techniques that will be evaluated. Sections IV and V discuss the results of the measurements and compares the calibration methods, drawing conclusions on the performance of each.

II. BACKGROUND

A. Perspective

Focusing on its impact on calibration, our companion paper [1] refers to the measured scattering matrix \( M \) given by

\[
M = RST = \begin{bmatrix}
R_{HH} & R_{VH} \\
R_{HV} & R_{VV}
\end{bmatrix} \begin{bmatrix}
S_{HH} & S_{SV} \\
S_{VS} & S_{VV}
\end{bmatrix} \begin{bmatrix}
T_{HH} & T_{VH} \\
T_{HV} & T_{VV}
\end{bmatrix}
\]

(1)

where \( R \) and \( T \) are the subsystem distortion matrices, and \( S \) is the theoretical scattering matrix [5]. This paper examines their effect on the overall calibration equation.

B. Types and Applicability of Calibration

Multiple types of calibrations can be used for a given measurement. Selection of the calibration type depends on: 1) the capability of the measurement facility; 2) measurement conditions; and 3) the degree of accuracy required. Radar calibration can be categorized according to three basic types: amplitude and phase (Type-1), simple polarimetric (Type-2), and full polarimetric (Type-3).

1) Amplitude and Phase (Type-1) Calibration: Type-1 calibration applies a complex constant scale factor to each measured scattering matrix component. The scale factor is usually calculated by measuring an object with a known radar cross section (RCS) and phase center, and comparing the ratio of the measured and theoretical responses. Type-1 calibrations all have a common form. For each polarization channel (HH, VH, HV, and VV), the calibrated scattering coefficient is

\[
S_{\text{cal}} = \frac{S_{\text{tar}} - S_{\text{tar, bkg}}}{S_{\text{cal, tar, theo}}} \frac{S_{\text{cal, tar, theo}}}{S_{\text{cal, tar, bkg}}}
\]

(2)

where \( S_{\text{cal}} \) is the calibrated response of the object, \( S_{\text{cal, tar, theo}} \) and \( S_{\text{cal, tar, bkg}} \) are the responses of the calibration object and the object under test, respectively, and \( S_{\text{cal, tar, theo}} \) and \( S_{\text{cal, tar, bkg}} \) denote the corresponding background responses. \( S_{\text{cal, tar, theo}} \) is the theoretical response of the calibration object.

The advantage of using a Type-1 calibration technique is simplicity. Only one calibration reference object is necessary, and validating computations are easy to implement. There are several disadvantages of using only a Type-1 technique. The key disadvantage is that the calibration object must have a high RCS for every polarization so that the calibration is valid for the complete scattering matrix. As a result, Type-1 techniques are often only used to calibrate copolar channels. In
addition, Type-1 techniques do not account for distortion in the
transmitter and receiver subsystems.

2) Simple Polarimetric (Type-2) Calibration: Polarimetric
 calibration technique are often used to account for system
distortion. The Type-2 calibration technique, or simple polari-
metric calibration, accounts for zero-order antenna polarization
distortion effects. Zero-order effects are defined here as polari-
zation distortion due the difference between the two-way
transmit/receive gain between each polarization channel. Each
of the copolar subsystem distortion terms \( R_{HH}, T_{HH}, R_{VV},
T_{VV} \) cannot be determined distinctly, but can be found as
products of the receiver subsystem distortion \( R \) and transmitter
subsystem distortion \( T \) for each polarization channel combi-
nation. The distortion terms are expressed in a \( 4 \times 4 \) complete
system distortion matrix \( C \), which carries the same informa-
tion as the \( 2 \times 2 \) matrices \( R \) and \( T \). The \( C \) matrix has the form [7]

\[
C = \begin{bmatrix}
R_{HH} & R_{HV} \\
R_{HV} & T_{HH} & T_{HV} & T_{VV} \\
R_{VV} & T_{HV} & T_{VV} \\
R_{VH} & T_{HH} & T_{VH} & T_{VV}
\end{bmatrix}
\]

where the elements \( R_{ij} \) and \( T_{ij} \) correspond directly to the
elements of the \( R \) and \( T \) matrices mentioned earlier. For a simple
polarimetric calibration, only the elements lying on the diag-
onal of \( C \) are calculated. This is analogous to the products of
the elements lying on the diagonals of \( R \) and \( T \). All other terms
are determined separately; the combined matrix \( C \) must be used instead. Though a single object can be used, the
Type-2 calibration requires a minimum of two independent cal-
ibration measurements: a single reference calibration measure-
ment, for which the theoretical solution is precisely known; and
an additional depolarizing measurement for cross-polarization
correction, also with a known scattering matrix.

3) Full-Polarimetric (Type-3) Calibration: Full-polar-
metric calibration is able to solve for all eight coefficients of
the \( R \) and \( T \) matrices, and thus all 16 terms of the \( C \) matrix.
The zero and first-order subsystem distortion effects are all
accounted for using Type-3 calibration. First-order effects in-
clude the cross-polarization impurity of the individual transmit
and receive antennas due to imperfect rotational alignment of
the antenna along the radial axis, as well as cross-polarization
contamination inherent in the antenna itself.

The Type-3 technique is the best available for accuracy in cal-
ibration at the cost of complexity. A fully polarimetric technique
requires three calibration objects whose theoretical scattering
matrices are precisely known [6]. A fully polarimetric technique
must solve for the coefficients of the distortion matrices sepa-
ately, as opposed to a Type-2 technique. This neglects the de-
pendent nature of each distortion term on another. A rigorous
mathematical process is necessary in order to solve for the sub-
system distortion matrices simultaneously. Once the distortion
matrices are computed, the corrected scattering matrix for the
object under test is given by

\[
S = R^{-1}MT^{-1}
\]

where \( S \) is the corrected scattering matrix, and \( M \) is the mea-
sured matrix, with background subtraction performed. This rela-
tionship stems from (1), assuming that the subsystem distortion
matrices are invertible [5].

C. Measurement Environment

All the measurements for this experiment were conducted
in the European Microwave Signature Laboratory (EMSL) of
the European Commission’s Joint Research Centre, Ispra, Italy.
This laboratory provides a precise, versatile, and fully polar-
metric environment necessary for the measurements. Fig. 1 pro-
vides an exploded view of the facility. The horn antennae on the
radar sleds at “6” track on a vertical axis around the dome and
are located 10 m from the object positioner at “4.” Operating fre-
frequencies range from 0.5–26.5 GHz. In the range of frequencies
used for this experiment (6–14 GHz), this geometry provides a
quiet zone of approximately 30 cm in diameter.1

III. BISTATIC CALIBRATION METHODS

Three existing calibration methods were examined, repre-
senting each of the calibration types previously discussed. The
following paragraphs briefly describe each method.

A. Basic Type-1 Calibration

In Type-1 calibration, an object is selected which has a negli-
gible cross-polar return (a sphere or circular disk, for example).
The calibrated measurement values for each copolarization (HH
and VV) are computed from (2). Note a different calibration ob-
ject with a strong cross-polarization response would be required
to calibrate for VH and HV.

1http://www.jrc.cec.eu.int
B. EMSL Simple Polarimetric Calibration

The EMSL currently uses the Type-2 calibration method [7]. A circular disk is used for one of the reference objects. This object provides a high specular RCS, a well-defined phase center, and a sufficiently accurate theoretical prediction using physical optics (PO). However, the disk is somewhat difficult to align in the quasi-monostatic (small bistatic angle) configuration. The reference object is used to solve for the (1,1) and (4,4) elements of the $C$ matrix, i.e., the coefficients $R_{HH}T_{HH}$ and $R_{VV}T_{VV}$. The (2,2) and (3,3) elements of the matrix are then computed by correcting the amplitudes of the depolarizing object with the (1,1) and (4,4) coefficients already found, and computing the ratio of the measured cross-polar amplitude to the absolute corrected amplitude. The PO approximation for the monostatic scattering matrix of the disk, assuming a perfectly conducting surface is

$$\mathbf{S}_{\text{disk}} = \frac{2(\pi)^{3/2} r^2}{\lambda} \begin{bmatrix} j & 0 \\ 0 & j \end{bmatrix} = \begin{bmatrix} S_{HH}^{\text{disk}} & 0 \\ 0 & S_{VV}^{\text{disk}} \end{bmatrix},$$

(5)

where $r$ = the radius of the disk in meters, and $\lambda$ = the wavelength in meters. For matrix multiplication by a $4 \times 4$ matrix, the normal $2 \times 2$ scattering matrix format is modified to a $4 \times 1$ vector of the form

$$\mathbf{S}_{\text{disk}} = \begin{bmatrix} S_{HH}^{\text{disk}} \\ 0 \\ 0 \\ S_{VV}^{\text{disk}} \end{bmatrix}.$$  

(6)

The elements $C_{1,1}$ and $C_{4,4}$ are solved by relating the measured scattering matrix of the disk ($\mathbf{M}_{\text{disk}}$) to the theoretical prediction given by

$$M_{\text{disk}}^{HH} = C_{1,1} S_{\text{disk}}^{HH} + C_{1,2} S_{\text{disk}}^{VH} + C_{1,3} S_{\text{disk}}^{HV} + C_{1,4} S_{\text{disk}}^{VV},$$

$$M_{\text{disk}}^{VV} = C_{4,1} S_{\text{disk}}^{HH} + C_{4,2} S_{\text{disk}}^{VH} + C_{4,3} S_{\text{disk}}^{HV} + C_{4,4} S_{\text{disk}}^{VV},$$

(7)

For the circular disk, the cross-polar elements are negligible, and we assume that the system crosstalk elements $C_{1,4}$ and $C_{4,1}$ are negligible so the equation simplifies to

$$M_{\text{disk}}^{HH} = C_{1,1} S_{\text{disk}}^{HH},$$

$$M_{\text{disk}}^{VV} = C_{4,1} S_{\text{disk}}^{VV}.$$  

(9)

We can now rearrange this equation to solve for $C_{1,1}$ and $C_{4,4}$ and use these coefficients to find the corrected amplitude of the depolarizing object. This allows us to use the wire mesh as a calibration object without knowing its exact RCS. The EMSL uses a mesh of parallel wires as a depolarizer. Two measurements are made on the mesh: one in the vertical orientation and one with the mesh tilted $45^\circ$ from vertical. In the vertical orientation, it is reasonable to assume that only the VV component wave will be reflected, and all others will be transmitted through the mesh, giving the $4 \times 1$ scattering vector the form

$$\mathbf{S}_{\text{mesh,vert}} = S_{\text{mesh}} \begin{bmatrix} 0 \\ 0 \\ 0 \\ \cos^2\left(\frac{\theta}{2}\right) \end{bmatrix},$$

(11)

In the tilted configuration, the vector takes the form

$$\mathbf{S}_{\text{mesh,tilt}} = \frac{S_{\text{mesh}}}{2} \begin{bmatrix} 1 \\ -\cos\left(\frac{\theta}{2}\right) \\ -\cos\left(\frac{\theta}{2}\right) \\ \cos^2\left(\frac{\theta}{2}\right) \end{bmatrix} = \begin{bmatrix} S_{HH}^{\text{mesh,tilt}} \\ S_{VH}^{\text{mesh,tilt}} \\ S_{HV}^{\text{mesh,tilt}} \\ S_{VV}^{\text{mesh,tilt}} \end{bmatrix},$$

(12)

where $\theta$ = the bistatic angle. This approximation is valid for small bistatic angles. In the tilted orientation, the amplitude of the monostatic ($\theta = 0$) RCS of the mesh should be the same for all polarizations.

To find the corrected values of the mesh in the vertical orientation, we divide the VV-component of the measurement, i.e., the only nonzero component, by $C_{4,4}$, the element of $C$ corresponding to VV-polarization, i.e.,

$$S_{\text{VV, mesh, vert}} = \frac{M_{\text{VV, mesh, vert}}}{C_{4,4}}.$$  

(13)

From the corrected magnitude of $S_{\text{mesh,vert}}$, we can find $S_{\text{mesh}}$, the corrected monostatic scattering coefficient of the vertical mesh from

$$S_{\text{mesh}} = \frac{S_{\text{VV, vert}}}{\cos^2\left(\frac{\theta}{2}\right)}.$$  

(14)

Substituting (14) into (12), and selecting the HV and VH polarizations, we get

$$S_{\text{VH, mesh, tilt}} = \frac{S_{\text{VH, mesh, vert}}}{2\cos\left(\frac{\theta}{2}\right)},$$

$$S_{\text{VH, mesh, tilt}} = S_{\text{HH, mesh, tilt}}.$$  

(15)

(16)

This is all the information we need to solve for the remaining coefficients of the diagonal $\mathbf{C}$ matrix, i.e.,

$$C_{2,2} = \frac{M_{\text{VH, mesh, tilt}}}{S_{\text{HH, mesh, tilt}}},$$

$$C_{3,3} = \frac{M_{\text{HV, mesh, tilt}}}{S_{\text{HH, mesh, tilt}}}.$$  

(17)

(18)

After the four calibration coefficients have been computed, the calibration can be performed for a single frequency by the simple matrix multiplication

$$\mathbf{S} = \mathbf{C}^{-1}(\mathbf{M} - \mathbf{B})$$  

(19)

where $\mathbf{S}$ is the calibrated scattering matrix, $\mathbf{M}$ is the measured scattering matrix, and $\mathbf{B}$ is the scattering matrix of the background.

C. Generalized Dual-Antenna Calibration

This technique, proposed in [6] and expanded in [5], is the most general technique addressed in current literature. An advantage is that it makes few assumptions about the form of the scattering matrix of each object. It requires that one of the scattering matrices must be invertible and assumes that the scattering matrices are all symmetric. That is, it assumes that cross-polar components are equal. This is a valid assumption for most
passive reflectors in the monostatic or quasi-monostatic configurations, but is not a valid assumption for bistatic measurements in general. The dependence on the assumption essentially limits the use of this technique to dual-antenna systems calibrated in the quasi-monostatic configuration.

The main limitation of the technique, however, is the requirement that the theoretical scattering matrix of each of the three reference objects be exactly known. In addition, the technique is more mathematically complex than other calibration techniques. Luckily, creation of the mathematical routine is a one-time cost. For a detailed description of this technique, the reader may review the paper by Whitt et al. [6].

IV. RESULTS
A. Calibration Object Selection
A set of calibration objects was chosen based on their use in bistatic ranges of practical interest, and additional noncanonical objects were chosen for comparison. In general, the bistatic measurements were performed at a relatively small bistatic angle, assuming that for some objects, the ease and efficiency of monostatic calibration could be extended to small angle bistatic calibration. Measurements were performed for each of the two Tx/Rx combinations. A detailed evaluation of each object is provided in [1].

B. Basic Type-1 Calibration Technique
This simple technique is presented mainly as a reference for the calibration methods under comparison. An error analysis on the Type-1 technique is another term for an error analysis of the calibration object prediction itself, which one must determine in order to separate the shortcomings of the calibration from the shortcomings of the object prediction. For the analysis here and in the following sections, the test object for calibration is a metallic disk with a bistatic angle, or antenna separation, of 5°. The frequencies used in the measurements range from 6–14 GHz. The error analysis statistics (Table I) for the Type-1 technique are calculated only on the highest 1-GHz band of the measurement bandwidth, 13 to 14 GHz, in order to highlight the effect of misalignment at higher frequencies. The resulting sample populations consist of individual frequency samples.

Upon implementing a Type-1 calibration with the small disk, the statistics of Table I result. The cross-polar levels are indistinguishable from the noise because the cross-polar RCS of the disk prediction was approximated as zero. The disk misalignment was generated normal to the bistatic plane by first precisely aligning the disk with a laser, then using the measurement range’s azimuth positioner to create the alignment error.

In order to obtain accurate values for the calibrated cross-polar RCS, an object with high RCS for all four polarization channels must be used. A dihedral tilted 22.5° from a vertical orientation qualifies [1].

C. EMSL Simple Polarimetric Calibration Technique
The first object set used for the analysis of this calibration is the typical set used in the EMSL procedure. For the copolar amplitude reference object (Object 1), the small disk is used. For the cross-polar reference objects (Objects 2 and 3, respectively), the wire mesh is used in the vertical orientation, and subsequently with the wires aligned 45° counterclockwise from vertical. Table II displays the results of the calibration error analysis for this object set.

For the perfect alignment of the calibration objects, the simple polarimetric calibration offers a cross-polarization isolation (−42 dBsm) of about 3 dB more than the Type-1 calibration using the dihedral tilted at 22.5°. This can be compared with a copolarizing object such as the small disk, which yields a cross-polar RCS of −39 dBsm. The misalignment of the small disk (the most alignment-sensitive of the objects used in this measurement) was the single significant contributor to the overall measurement error.

For the Type-2 calibration as performed in the EMSL, the object set used in Table II is an appropriate set that can be used. The wire mesh is a known object to return high cross-polar RCS that is strongly correlated with the copolar RCS at a bistatic angle of more than 2°. The relationship can be approximated by cosine squared. The small disk, though very sensitive to alignment, returns the largest bistatic copolar RCS of any object, which enhances the signal-to-noise ratio in the calibration. The EMSL technique could be modified, however, to use the tilted dihedral as a cross-polarization reference object, if the calibration routine is adjusted to use a method of moments (MoM) prediction rather than an approximate prediction based on the vertical wire mesh. This would eliminate one measurement in the calibration—only the small disk and the tilted dihedral, in a single orientation, would need to be used.

D. Generalized Dual-Antenna Calibration Technique
This technique, abbreviated as the generalized calibration technique (GCT) in [6], was expected to yield the best results for ideal alignment conditions compared to accurate theoretical solutions. The effect of misalignment of one or more of the reference objects, however, was unknown. Fig. 2 displays the copolar error in a measurement of the metallic sphere calibrated with the GCT, using what is considered to be a nearly optimal object set—the (already defined) three objects used were the small disk (Object 1), the vertical dihedral (Object 2), and the

**TABLE I**

<table>
<thead>
<tr>
<th>Object Misalignment</th>
<th>VV-error</th>
<th>HH-error</th>
<th>VH-level</th>
<th>HV-level</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>0.17 ± 0.01 dB</td>
<td>0.10 ± 0.01 dB</td>
<td>-∞</td>
<td>-∞</td>
</tr>
<tr>
<td>1°</td>
<td>0.32 ± 0.04 dB</td>
<td>0.35 ± 0.01 dB</td>
<td>-∞</td>
<td>-∞</td>
</tr>
<tr>
<td>2°</td>
<td>1.24 ± 0.04 dB</td>
<td>1.28 ± 0.01 dB</td>
<td>-∞</td>
<td>-∞</td>
</tr>
</tbody>
</table>

**TABLE II**

<table>
<thead>
<tr>
<th>Object Misalignment</th>
<th>VV-error</th>
<th>HH-error</th>
<th>VH-level</th>
<th>HV-level</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1=0°, T2=0°, T3=0°</td>
<td>0.17 ± 0.01 dB</td>
<td>0.10 ± 0.01 dB</td>
<td>-42.0 dBsm</td>
<td>-42.0 dBsm</td>
</tr>
<tr>
<td>T1=1°, T2=1°, T3=1°</td>
<td>0.32 ± 0.04 dB</td>
<td>0.35 ± 0.01 dB</td>
<td>-41.4 dBsm</td>
<td>-41.4 dBsm</td>
</tr>
<tr>
<td>T1=2°, T2=0°, T3=0°</td>
<td>1.24 ± 0.04 dB</td>
<td>1.28 ± 0.01 dB</td>
<td>-40.8 dBsm</td>
<td>-40.8 dBsm</td>
</tr>
<tr>
<td>T1=2°, T2=2°, T3=2°</td>
<td>1.24 ± 0.04 dB</td>
<td>1.28 ± 0.01 dB</td>
<td>-40.1 dBsm</td>
<td>-40.2 dBsm</td>
</tr>
</tbody>
</table>
dihedral tilted at $22.5^\circ$ from vertical (Object 3). The normalized scattering matrices for each of these objects have the form

$$T_1 = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$  \hspace{1cm} (20)

$$T_2 = \begin{bmatrix} -1 & 0 \\ 0 & 1 \end{bmatrix}$$  \hspace{1cm} (21)

$$T_3 = \begin{bmatrix} -1 & -1 \\ 0 & 1 \end{bmatrix}.$$  \hspace{1cm} (22)

Every scattering matrix meets the requirement of mutual linear independence.

When misalignment is introduced into the calibration, the calibrated measurement will tend to overestimate the true prediction, and the overestimation will increase with frequency. This is shown in Fig. 3. Table III displays the mean and variance of the RCS error between the calibrated measurements and the prediction of the sphere. As mentioned previously, the statistics are only calculated on the highest 1-GHz band of the measurement, 13 to 14 GHz, in order to highlight the effect of misalignment on higher frequencies. As in the simple polarimetric calibration, the misalignment of the small disk was the single significant contributor to the overall measurement error.

The cross-polarization isolation for this case is about 7 dB higher than the simple polarimetric calibration (Table II). Realizing this, as well as observing from Table III that the penalty resulting from the misalignment of $T_1$ is considerably more than the penalty of the misalignment of $T_2$, it is apparent that while the objects’ sets are identical, the order in which the objects are implemented in the calibration is important. Only Object 1 is used in the absolute amplitude calibration in the GCT method. Therefore, for any given object set, the most accurate calibration will be that which uses the object with the most precise theoretical prediction, and uses it as Object 1. In order to optimize the cross-polar isolation in the measurement, one must determine which of Objects 2 and 3 have the most precise prediction, and which of the available equations derived in [6] should be used in the calibration routine to offer the best cross-polarization isolation.

V. CONCLUSION

A. Impact of Calibration Object Selection

It has been shown that the sensitivity of a particular calibration object to alignment error, though significantly affecting the error in the absolute amplitude calibration, has a less pronounced effect in the determination of the associated antenna polarization distortion matrices (PDMs). This has been demonstrated with the wire mesh and dihedral specifically, where a 2° misalignment in these objects affects a loss in cross-polarization isolation of about 2 dB.

B. Performance of Type-1, Type-2, and Type-3 Calibrations

For the measurement parameters of the EMSL, including antenna polarization purity, gain, and signal-to-noise ratio, it has been shown that the gain in cross-polarization isolation in using a Type-3 technique as opposed to a Type-1 technique is about 10 dB ($-10$ dBsm, as cited in Section IV-C, compared with $-49$ dBsm for the Type-3 technique). The absolute error in the copolar channels is nearly identical, provided that the alignment error and signal-to-noise ratio are kept relatively constant. In general, for any type of calibration, our measurements support the assumption the sources of absolute amplitude error and degradation of cross-polarization isolation are independent. Each calibration technique evaluated here follows the general paradigm that two objects with highly independent scattering matrices are necessary to characterize polarization distortion, and a single object with high copolar RCS is necessary to...
accurately determine the amplitude and phase constant applied to these PDMs.

Given any particular calibration object, it is not difficult to predict the effect of misalignment on the overall error of the calibration. There is a 1 : 1 correspondence between the decibel error per degree of misalignment and the average amplitude error of the copolar channels in the calibration.

These results were obtained in a single measurement environment with a high degree of alignment precision, dynamic range, and cross-polarization purity. Given the ideal conditions of this environment, these conclusions can be extended to any bistatic measurement scenario. For a less sophisticated or more specialized measurement facility, the specific results from the EMSL would most likely represent an upper limit to the gain or loss in measurement accuracy that is obtained by choosing a particular calibration method.

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REFERENCES


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