Pattern Reconstruction for Deviated AUT in Spherical Measurement by Using Spherical Waves

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1. Introduction

The fundamental requirement for characterizing an antenna is the acquisition of its three-dimensional radiation pattern in the angular domain. Antenna pattern measurement refers to the determination of the directional radiation pattern of an antenna under test (AUT), by measuring the amplitude and phase of the electromagnetic signal radiated from or received by the AUT.

Generally, antenna pattern is measured in its far-field or radiating near-field [1][2]. Far-field antenna measurement is a better choice for lower frequency antennas and where pattern cut measurements are required. Near-field antenna measurement is a better choice for higher frequency antennas and where complete pattern and polarization measurements are required.

The near-field test system measures the radiation pattern in radiating near-field region, then converts the near-field pattern into far-field pattern. The scanning geometries in near-field measurement are mainly planar, cylindrical and spherical surfaces [3]. Among the three, spherical scanning is the only geometry which could provide full pattern coverage. The principle of near-field to far-field transformation in spherical measurement is the spherical wave expansion, which has been extensively explored. The probe-corrected transmission formula for spherical near-field scanning was derived and developed in [4]–[8]. Later, spherical near-field antenna measurement has been studied comprehensively in theoretical and practical aspects in [9]. In recent decades, Satimo Stargate [10] developed modern spherical near-field measurement system and spherical wave is also used here for modelling antenna.

In actual spherical antenna measurement, due to the limitation of measurement set-up, the scanning may not be taken on whole sphere but only on some part of it; on the other hand, due to the limitation of measurement time, only coarse sampling interval is practical. Therefore, extrapolation and interpolation are needed to reconstruct the antenna pattern. For this purpose, in [11][12], the spherical wave representation of antenna radiation pattern and its band-limited property are applied to the constrained iterative restoration algorithm [13]. The convergence of the reconstructed signal towards the original signal in observation region is also proved.

The conventional algorithm, however, is vulnerable to the AUT location and the sampling condition. The minimum requirement of sampling points is related to the electrical size of AUT as well as its location in the measurement set-up [9]. Due to the array geometry or mechanical displacement, the AUT may deviate from the coordinate origin of the measurement set-up. The reconstruction of the deviated AUT requires more sampling points than when it is centred.

In this context, a novel pattern reconstruction algorithm is proposed for the deviated antenna. The contributions of this paper are threefold. First, the limitation of conventional algorithm on deviated AUT is identified, especially under severe sampling conditions. Second, this paper proposes an algorithm to overcome the limitation by resampling between coordinates using translational phase shift and rotation and translation of spherical waves. Third, this paper validates the proposed algorithm numerically.

The rest of this paper is organized as follows. In Sect. 2, the theory of spherical wave expansion technique, together with its connection with the sampling theorem, is introduced. In Sect. 3, the limitation of conventional algorithm on deviated AUT, especially under severe sam-

SUMMARY
To characterize an antenna, the acquisition of its three-dimensional radiation pattern is the fundamental requirement. Spherical antenna measurement is a practical approach to measuring antenna patterns in spherical geometry. However, due to the limitations of measurement range and measurement time, the measured samples may either be incomplete on scanning sphere, or be inadequate in terms of the sampling interval. Therefore there is a need to extrapolate and interpolate the measured samples. Spherical wave expansion, whose band-limited property is derived from the sampling theorem, provides a good tool for reconstructing antenna patterns. This research identifies the limitation of the conventional algorithm when reconstructing the pattern of an antenna which is not located at the coordinate origin of the measurement set-up. A novel algorithm is proposed to overcome the limitation by resampling between the unprimed and primed (where the antenna is centred) coordinate systems. The resampling of measured samples from the unprimed coordinate to the primed coordinate can be conducted by translational phase shift, and the resampling of reconstructed pattern from the primed coordinate back to the unprimed coordinate can be accomplished by rotation and translation of spherical waves. The proposed algorithm enables the analytical and continuous pattern reconstruction, even under the severe sampling condition for deviated AUT. Numerical investigations are conducted to validate the proposed algorithm.

key words: antenna pattern reconstruction, spherical wave expansion, deviated AUT, translational phase shift, rotation and translation of spherical waves
pling conditions, is illustrated. In Sect. 4, proposed algo-

rithm is introduced to overcome the limitation, and validated
throughout numerical examples. The time dependence $e^{j\omega t}$ is

used throughout this paper.

2. Spherical Wave Expansion Technique

Spherical wave functions (SWF) are homogeneous solutions
to the vector Helmholtz equation in the spherical coordi-
nates. Any radiation pattern outside the minimum sphere of
an antenna can be expanded into a weighted sum of spheri-
cal wave functions, that is, spherical wave expansion (SWE)
[9]:

$$E(r, \theta, \phi) = k \sqrt{\eta} \sum_{s=1}^{2} \sum_{n=1}^{N} \sum_{m=-n}^{n} Q_{nm} F_{nm}^{(s)}(r, \theta, \phi)$$  \(1\)

where:

$m$: mode indices for $\phi$ direction

$n$: mode indices for $\theta$ direction

$F_{nm}^{(s)}(r, \theta, \phi)$: SWF, TE ($s = 1$) and TM ($s = 2$) modes

compose of a complete orthogonal set, $c$ is the index
for spherical functions

$Q_{nm}$: spherical wave coefficient (SWC)

$k \sqrt{\eta}$: coefficient to ensure the normalization condition

that unit SWC corresponds to 1 W$^2$ $\lambda$, $k$ is the wavenumber

$N$: truncation number

The expanded series can be truncated at a finite number
which is determined by the radius of the antenna’s minimum
sphere. The minimum sphere of an antenna is defined as
the smallest possible spherical surface, which is centred at
the coordinate origin and could just encloses the antenna
completely.

The advantage of SWE over plane wave model, is that
the radiation pattern could be represented by a finite number
of spherical vector waves within certain accuracy. The highest
spatial frequency for any radiating field is determined by
its wavelength as $1/\lambda$. According to the sampling theorem,
the minimum sampling interval of the field is $\lambda/2$, therefore
the sampling number of the field is no more than $[2kr_0]/2$
per circumference of the antenna’s minimum sphere. Here $r_0$
is the radius of the minimum sphere, and the brackets indicate
the floor function, i.e. the largest integer smaller than or equal
to $kr_0$. To represent the radiating field, the spherical
wave number should be no less than $[2kr_0]$. Therefore the
bandwidth, the truncation number $N$ in other words, should
be at least $[kr_0]$. By increasing the bandwidth, the evanes-
cent components of the field can be retained. In this work,
the truncation number is defined as $N \geq [kr_0]$. Since $r_0$ is
very sensitive to the coordinate origin and the AUT location,
$N$ is also sensitive to them.

Generally, the SWCs are unknown, and antenna pattern
at certain observing sphere is measured to calculate the
SWCs; once the SWCs are known, antenna pattern can be
calculated anywhere outside the antenna’s minimum sphere.

There are two common approaches to obtain SWC: inner
product method [9] and least square solution method [14].
It is worth noting that for least square solution method, the
equator zone pattern should be emphasized by weighting the
uniform sampling over the sphere. In this paper, the sine
function value of the elevation angle is used as the weight-
ning factor.

3. Limitation of Conventional Algorithm on Deviated AUT

The measured samples of AUT pattern are conventionally
reconstructed by iterative SWE algorithm [11]–[13]. How the
coarseness and incompleteness of the samples influence the
reconstruction accuracy will be investigated. Note that the
sampling interval and measurement range are the main
parameters to be examined.

3.1 Influence of Sampling Interval on Reconstruction Ac-

curacy

To simply study the influence of sampling interval on recon-
struction accuracy, a set of pattern samples over the whole
scanning sphere is given: $E(\theta_i, \phi_i), \theta_i \in [0 : \Delta \theta : \pi], \phi_i \in
[0 : \Delta \phi : (2\pi - \Delta \phi)]$. Conventionally, SWCs can be calcu-
lated from the complete samples, then interpolation can be
accomplished along with the pattern recalculation by SWE.

According to the sampling theorem, the sampling num-
ber per circumference should be at least twice the truncation
number. Therefore, the sampling interval $\Delta \theta$ or $\Delta \phi$
should be no more than $\pi / 2$. Since the truncation number is propor-
tional to the AUT’s minimum sphere radius $r_0$, the required
sampling interval is also determined by $r_0$. The bigger the
$r_0$ is, the smaller the sampling interval should be required.

In actual measurement, AUT is not necessarily located
at the coordinate origin of the measurement set-up. In terms
of an antenna array, since it should be measured as a whole,
the pivot is often set as the coordinate origin. Therefore
some antenna elements are deviated from the origin. In
terms of a single antenna, its phase center is generally set as
the coordinate origin of the measurement set-up. However,
there are circumstances where the single antenna deviates
from the coordinate origin. For example, when a horn an-
tenna acts as a probe in spherical antenna measurement, it is
measured while being attached to the end of the mechanical
arm and is deviated from the origin. For an antenna, the min-
imum sphere radius when it is deviated from the origin (the
deviated AUT), is obviously bigger than when it is located at
the origin (the centred AUT). Therefore, the required sam-
pling interval for the deviated case should be smaller than
that when it is centred.

Considering a half-wave dipole which is located at the
coordinate origin as is shown in Fig. 1, its minimum sphere
radius is $\lambda/4$. Considering the same dipole deviated from
the origin along $x$-axis by distance $A$ as is shown in Fig. 2,
its minimum sphere radius is $\sqrt{(\lambda/4)^2 + A^2}$. In the case that
$A = \lambda/2$ and $A = 0.1$, the truncation numbers for the centred
and deviated dipole are \( N \geq 1 \) and \( N \geq 3 \) respectively.

The normalized mean square error of a reconstructed pattern \( E^{\text{rec}} \) is defined as its difference with the reference pattern \( E^{\text{ref}} \) normalized by the amplitude of the reference pattern:

\[
\delta = \frac{|\Delta E|^2}{|E^{\text{ref}}|^2} = \frac{\int_{0}^{2\pi} \int_{\theta_1}^{\theta_2} \left( |E_{\theta}^{\text{ref}} - E_{\theta}^{\text{rec}}|^2 + |E_{\phi}^{\text{ref}} - E_{\phi}^{\text{rec}}|^2 \right) \sin \theta \, d\theta \, d\phi}{\int_{0}^{2\pi} \int_{\theta_1}^{\theta_2} \left( |E_{\theta}^{\text{ref}}|^2 + |E_{\phi}^{\text{ref}}|^2 \right) \sin \theta \, d\theta \, d\phi} \tag{2}
\]

In terms of simulation, \( E^{\text{ref}} \) is the theoretical or simulated antenna pattern. In terms of actual measurement, \( E^{\text{rec}} \) is set as the measured pattern, and the normalized mean square error can only be examined within the measurement range.

Given different sampling number per circumference, i.e. different sampling intervals, the normalized mean square errors of the reconstructed patterns by conventional algorithm can be obtained, as is shown in Fig. 3.

The following can be summarized:

- If sampling interval is small enough, the reconstruction error will converge to the truncation error together with some measurement error.
- Bigger truncation number leads to smaller convergent reconstruction error, but requires smaller sampling interval.
- Specifically, when truncated at \( N = \lfloor kn \rfloor \), for the deviated case, although the truncation number is bigger than that of the centred case, the reconstruction accuracy is lower and it requires more sampling points.
- The Nyquist sampling condition, \( 2N \) points per circumference, i.e. sampling interval of \( \frac{\pi}{N} \), is not definitely sufficient for convergence; but \( \frac{2\pi}{N} \) is always enough.

In conclusion, there is a trade-off between the required sampling interval and the truncation number: for larger \( N \), the convergent reconstruction error is smaller but more samples are needed to represent the higher spherical wave modes. For a AUT, the deviated case requires bigger truncation number and more sampling points than the centred case, but the reconstruction accuracy is not necessarily higher.

3.2 Influence of Measurement Range on Reconstruction Accuracy

To study the influence of the measurement range on reconstruction accuracy, a typical set of incomplete samples on some part of the scanning sphere is given: \( E(\theta_1, \phi_1), \theta_1 \in [0 : \Delta \theta : \theta_{\text{scan}}], \phi_1 \in [0 : \Delta \phi : (2\pi - \Delta \phi)] \), where \( \theta_{\text{scan}} \) represents the measurement range in the elevation dimension. Given sufficient sampling interval, the main task for the reconstruction of the incomplete samples should be extrapolation.
The conventional iterative SWE algorithm for antenna pattern extrapolation [11], [12] can be summarized as:

1. extend the incomplete samples by zero-padding to cover the entire sphere
2. calculate the SWCs by using extrapolated data
3. calculate the new pattern by SWE using the SWCs achieved in the former step
4. update the calculated pattern data by replacing the measured samples within the scanning area

Step 2 to step 4 are repeated iteratively.

In actual measurement, AUT is not necessarily located in the coordinate origin. Consider the centred and deviated dipole in Fig. 1 and Fig. 2 again. Given absolutely sufficient sampling interval $\Delta\theta = \Delta\phi = \pi N$ and different measurement ranges, the normalized mean square errors of the reconstructed patterns by conventional algorithm are shown in Fig. 4.

Similar points can be summarized as follows:

- If measurement range is large enough, the reconstruction error will converge to the truncation error together with some measurement error.
- Bigger truncation number results in smaller convergent reconstruction error, but requires larger measurement range. As is shown in Fig. 4, for the centred dipole, when reconstruction with $N = 3$, the measurement range of the samples should be at least around 120 degrees; while when $N = 5$, the measurement range of the samples should be at least around 140 degrees.
- Specifically, when truncated at $N = [kr_0]$, the minimum requirement of measurement range for the deviated case is larger than that of the centred case, but the convergent reconstruction accuracy is lower.
- According to the sampling theorem, the un-measured range on the scanning sphere should be no more than the biggest allowable sampling interval $\frac{\pi}{N}$, thus the measurement range for elevation and azimuthal dimension should be no less than $\pi(1 - \frac{1}{N})$ and $2\pi(1 - \frac{1}{N})$ respectively.

In conclusion, there is a trade-off between the truncation number and the measurement range: bigger truncation number leads to higher convergent reconstruction accuracy, but larger measurement range is required to represent the higher spherical wave modes. For a AUT, the deviated case requires larger measurement range than the centred case, but the reconstruction accuracy may be lower.

3.3 Limitation of Conventional Algorithm on Deviated AUT

As is analysed in the former two sections, by conventional algorithm, the deviated AUT requires smaller sampling interval and larger measurement range than when it is located at the coordinate origin. However, the deviated case does not necessarily produce higher convergent reconstruction accuracy. Especially under severe sampling condition, it is possible that the conventional algorithm could function well for the centred AUT, but could not reconstruct the deviated AUT accurately.

Therefore, the performance of the conventional algorithm on deviated AUT is limited. More precisely, the conventional algorithm is vulnerable to the sampling condition and the AUT location in the measurement set-up.

4. Proposed Algorithm

An algorithm is proposed to overcome the limitation of conventional algorithm on deviated AUT, as is shown in Fig. 5. Firstly, we check whether the AUT is located at the coordinate origin of the measurement set-up, by observing its measured phase pattern as well as its size and geometry. For the deviated case, samples are transferred from the unprimed coordinate to the primed coordinate where the AUT is centred. The resampling is done by means of translational phase shift technique with the assumption that the transferred distance is much smaller than the observing distance. Next, the iterative SWE is used to reconstruct the transferred samples in the primed coordinate, where the AUT minimum sphere radius is always minimized regardless of its location in measurement set-up. After pattern reconstruction in primed coordinate, the reconstructed pattern should be transferred back to the unprimed coordinate. This resampling is conducted by applying the rotation and translation of spherical waves.

4.1 Deviation Estimation

The coordinate where the AUT is measured is denoted as the unprimed coordinate, and the coordinate where the AUT is located at the coordinate origin is denoted as the primed coordinate. Whether the AUT is centred or not, can be observed from its measured phase pattern. The phase pattern in unprimed coordinate is denoted as $E_{\text{phase,unprim}}(\theta, \phi)$, and the AUT phase pattern in primed coordinate is denoted as
In the case of the deviated AUT, the incomplete and coarse measured samples from unprimed coordinate to primed coordinate where AUT is located at the coordinate origin of the measurement set-up are transferred to the primed coordinate by translational phase shift, so the amplitude pattern stays the same and the phase pattern is shifted due to translation. Assumption is made that the observing distance is much bigger than the shifted distance. By virtual transfer of the AUT location to the primed coordinate where it is centred, the minimum sphere radius will always be minimized and decided simply by the antenna size regardless of its original location. In the primed coordinate, the requirements for both the sampling interval and measurement range will be minimized. Since the reconstruction in the primed coordinate is analytical, the pattern could be directly transferred back to the unprimed coordinate by translational phase shift. However, to achieve analytical and continuous transfer of whole pattern from primed coordinate back to unprimed coordinate, rotation and translation of spherical waves techniques can be used.

4.3 Rotation and Translation of Spherical Waves

Since the analytical and continuous pattern is the target, rotation and translation of spherical waves are the right tool to transfer the complete pattern from the primed coordinate back to the unprimed coordinate.

Arbitrary translations of coordinate system can be accomplished by a succession of three operations: rotation, axial translation, and inverse rotation. To achieve the radiation pattern in the unprimed coordinate systems, the representative spherical wave functions could be rotated, translated and inversely rotated. In [9], both the rotation and translation of spherical waves are provided; although only z-directed axial translation is described, it is sufficient for the coordinate translation.

Firstly, the rotation of spherical waves is introduced. Euler angles (χ, α, β) are introduced to describe the rotation from one coordinate system to the other. In the rotation process, firstly rotate about the initial z-axis with angle φ₀ and obtain the coordinate denoted as (x', y', z'); next rotate about the y'-axis with angle θ₀ and obtain the coordinate denoted as (x'', y'', z''); then rotate about z''-axis with angle φ₀ and obtain the rotated coordinate. Through rotation, the spherical wave function \( F_{\text{unprim}}^{c}(r, \theta, \phi) \) in the initial coordinate can be obtained as the combination of spherical waves defined in the rotated coordinate \((r', \theta', \phi')\) [9]:

\[
F_{\text{unprim}}^{c}(r, \theta, \phi) = \sum_{\mu=-n}^{n} \sum_{m=-\mu}^{\mu} d_{\mu m}^{c}(\theta_0) F_{\mu m}^{c}(r', \theta', \phi')
\]

where the rotation coefficient \( d_{\mu m}^{c}(\theta_0) \) is a real function of \( \theta_0 \):

\[
d_{\mu m}^{c}(\theta_0) = \sqrt{\frac{(n+\mu)!(n-\mu)!}{(n+m)!(n-m)!} \left( \frac{\sin \theta_0}{2} \right)^{|\mu|} \left( \frac{\sin \theta_0}{2} \right)^{-|m|}} P_{\mu m}^{n+\mu, n-\mu}(\cos \theta_0)
\]

and \( P_{n}^{(\alpha, \beta)}(x) \) is the Jacobi polynomial.

Secondly, the translation of spherical waves is introduced. The initial coordinate \((r, \theta, \phi)\) is translated in the positive direction of z-axis by a distance \( A \) and obtain the translated coordinate \((r', \theta', \phi')\). The spherical wave function \( F_{\text{unprim}}^{c}(r, \theta, \phi) \) in the initial coordinate can be obtained by a combination of spherical waves defined in the translated
coordinate \((r', \theta', \phi')\):

\[
F_{nm}^{(c)}(r, \theta, \phi) = \sum_{r'=1}^{2} \sum_{\nu=0}^{\infty} C_{\nu}^{(c)}(kA) F_{\nu}^{(c)}(r', \theta', \phi')
\]

when \(r' < |A|\), and

\[
F_{nm}^{(c)}(r, \theta, \phi) = \sum_{r'=1}^{2} \sum_{\nu=0}^{\infty} C_{\nu}^{(1)}(kA) F_{\nu}^{(c)}(r', \theta', \phi')
\]

when \(r' > |A|\).

The condition \(r' > |A|\) is met according to the former assumption. Function \(C_{\nu}^{(c)}(kA)\) is the translation coefficients:

\[
C_{\nu}^{(c)}(kA) = \frac{1}{2} \sqrt{\frac{(2n+1)(2\nu+1)}{n(n+1)}} \frac{(u+v)!}{(u+\mu)!} \frac{(v+\mu)!}{(n+\mu)!} \\
(-1)^v (-j)^{\nu} \sum_{\mu=0}^{\nu} \left[ (-j)^{\mu} \delta_{\mu,\nu} (n+1) + \nu (u+1) - \mu (p+1) + \delta_{\mu,\nu} (-2ju\delta) \right]
\]

\[
(2\nu + 1) \sqrt{\frac{n+\mu}{n+\nu}} \frac{(u+v)!}{(u+\mu)!} \frac{(v+\mu)!}{(n+\mu)!} \left[ \begin{array}{ccc} n & u & p \\ 0 & 0 & 0 \end{array} \right] \frac{1}{12} \left( -j \right)^{\nu} \left[ \begin{array}{ccc} n & u & p \\ 0 & 0 & 0 \end{array} \right] z_{j}^{(c)}(kA)
\]

where \(\left[ \begin{array}{ccc} n & u & p \\ 0 & 0 & 0 \end{array} \right] \) is the \(3 - j\) symbols, and \(z_{j}^{(c)}(kA)\) is the spherical function.

Finally, the resampling of radiation pattern in different coordinates can be accomplished by using both rotation and translation of spherical waves. The unprimed coordinate \((r, \theta, \phi)\) is obtained through: rotating about the \(z\)-axis in the primed coordinate \((r', \theta', \phi')\) by \(\phi_0\), and obtain the coordinate denoted as \((x', y', z')\), then rotating about the \(y'\)-axis by \(\theta_0\), and obtain the coordinate denoted as \((x'', y'', z'')\), then translating along \(z''\)-axis by distance \(A\) and obtain the coordinate denoted as \((x'''', y'''', z''''')\), then rotating about the \(y''''\)-axis by \(-\theta_0\), and obtain the coordinate denoted as \((x'''''', y'''''''', z''''''''')\), at last rotating about the \(z''''''''\)-axis by \(-\phi_0\), and obtain the unprimed coordinate of the measurement set-up. Note that \(\phi_0 = \tan^{-1}(\frac{\Delta \phi}{\Delta z})\), \(\theta_0 = \tan^{-1}(\frac{\Delta \theta + \Delta \phi}{\Delta z})\),

\[A = \sqrt{\Delta x^2 + \Delta y^2 + \Delta z^2}\]. Then the transferring of pattern from the primed coordinate back to the unprimed coordinate can be obtained by:

\[
E(r', \theta', \phi') = k \sqrt{n} \sum_{\nu} Q_{\nu} F_{\nu}^{(c)}(r', \theta', \phi')
\]

\[
= k \sqrt{n} \sum_{\nu} Q_{\nu} \sum_{\mu=-\nu}^{\nu} e^{-j\nu\phi_0} d_{\nu,\mu}(\theta_0) \sum_{r'=1}^{2} \sum_{\nu=0}^{\infty} C_{\nu}^{(c)}(kA) e^{i\nu\phi} d_{\nu,\mu}(-\theta_0) F_{\nu}^{(c)}(r', \theta, \phi)
\]

The mean square error of the reconstructed pattern; obviously, the proposed method works better.
frequency 11.00 GHz and observing distance 45.5λ. The coordinate origin of the measurement set-up is the pivot of the array antenna, therefore each element is deviated from the origin by about λ distance. The measured samples are distributed from 0 degree to 120 degrees in elevation dimension and from 0 degree to 354 degrees in azimuthal dimension, with sampling interval of 6 degrees. Since the truncation number for each deviated element should be at least 7, the required measurement range should be at least about 150 degrees. Therefore the sampling condition is severe. By the proposed algorithm, the truncation number in the primed coordinate should be at least 3, therefore the sampling condition is acceptable in the primed coordinate. Fig. 13 shows the normalized mean square error of the reconstructed pattern within the measurement range, and Fig. 14 shows an example of the measured pattern and the reconstructed pattern by proposed algorithm. The proposed algorithm decreases the reconstruction error. However, the convergent reconstruction error by the proposed algorithm is not that ideal. The problem is twofold. First, due to the limitation of the sampling interval and measurement range, the truncation number used in the primed coordinate may not be sufficient. Second, in spherical antenna measurement, the electromagnetic signal radiated from the AUT is received by a probe, and the measurement error may not be negligible due to the shake of the mechanical arm to which the probe is attach. As is shown in Fig. 14, the measured pattern is a little distorted due to the shake of the arm.
Fig. 10 $E_\theta$ E-plane pattern of Yagi-Uda antenna

Fig. 11 $E_\theta$ H-plane pattern of Yagi-Uda antenna

Fig. 12 Normalized mean square error of the reconstructed pattern of the Yagi-Uda antenna

5. Conclusion

The acquisition of the full radiation pattern is fundamental for characterizing an antenna. Due to the limitations of antenna measurement, the achieved samples may either be incomplete or coarse, so extrapolation and interpolation are needed to reconstruct the pattern analytically and continuously. The conventional reconstruction algorithm employs iterative SWE with band-limited constraint, however, it is found to be sensitive to AUT location in the measurement set-up, especially under severe sampling condition. If the AUT is deviated from the coordinate origin of the measurement set-up, the conventional algorithm requires larger measurement range and smaller sampling interval than the centred case. To overcome the limitation, an algorithm that offers the resampling between coordinates was proposed. For deviated AUT, the measured samples can be transferred to the primed coordinate where the AUT is centred, utilizing translational phase shift. Then the iterative SWE can be conducted by using the truncation number decided by the centred AUT in the primed coordinate. The reconstructed pattern in the primed coordinate should be transferred back to the unprimed coordinate and it can be accomplished by...
utilizing rotation and translation of spherical waves. The proposed algorithm was validated by numerical examples. This research mainly benefits the pattern reconstruction of deviated AUT from spherical measurement results.

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References


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