SNIFT

Software package for Spherical Near-Field Far-Field Transformations with Full Probe Correction

Historical development

The theoretical background for spherical near-field antenna measurements and transformations was developed by Frank Jensen (1970), and later improved and extended by Flemming Holm Larsen (1980).

The latter work resulted in the first practical implementation of a working algorithm for probe-corrected spherical near-field antenna measurements in 1977. The break-through was brought about by Larsen's sophisticated refinement of a data processing scheme originally proposed by Wacker (1975).

A detailed exposition of the mathematical foundations of the transformation algorithm as well as spherical near-field antenna measurements in general may be found in the book by Hansen (1988). Note, however, that the use of the software does not assume an expert's knowledge of spherical wave theory and transformations. A certain familiarity with a few basic concepts is desirable though, but not mandatory.

The SNIFT program, originally written by Flemming Holm Larsen in 1982 (Larsen, (1983)), rests its foundation on Larsen's ground-breaking work. During its lifetime the software has undergone several extensions and improvements. It is in everyday use at several measurement facilities around the world.

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Software description

The primary function of the SNIFT program is to transform a near field of an antenna, sampled (scanned) in a regular measurement grid on an imaginary spherical surface, to the far field of the antenna, whilst taking full account of both the polarization and directive properties of the measuring probe in the transformation. This is, however, just a special case of the transformation of an electromagnetic field from one spherical surface to another, concentric, spherical surface, both of which may be in the antenna's near field. Both near and far fields are described in usual spherical coordinates at points spaced equidistantly in θ and ϕ.

One of the unique and salient features of SNIFT is the ability to perform a full correction for the influence of the measuring probe antenna (the **input probe**), provided certain restrictions are imposed on the probe. These may be expressed as a requirement to the probe pattern to contain only spherical modes with azimuthal index $m = \pm 1$, which is equivalent to a simple $\cos(\phi)$ and $\sin(\phi)$ variation of the probe pattern. In practical terms this is satisfied by rotationally symmetric horns and waveguides excited by the fundamental TE_{11} cylindrical mode in a circular waveguide, which subsequently implies that the probe's E- and H-plane patterns together with its on-axis polarization characteristics are sufficient to completely specify the probe.

In order to calculate a probe-corrected far field of an antenna from measured near-field data, the SNIFT program must be run twice. First, the probe radiation pattern, either near field or far field, is measured and read by the program, which then calculates the **probe's receiving spherical wave coefficients** and stores these in a file. Second, the program is executed with the test antenna measured near field as input data. During the execution, the formerly calculated **probe coefficients** are read from file and used in the probe-correction parts of the transformation of the near field to the far field.

Formally, the output field from SNIFT – whether it is a near field or a far field - is calculated as the signal received by a measuring antenna (the **output probe**), which must also satisfy the $m = \pm 1$ requirements as for the input probe. In the most frequent case, one is interested in the electric field radiated from the test antenna. This is accomplished by specifying an electric Hertzian dipole as the output probe. Similarly, the magnetic field from the test antenna may be obtained by having a magnetic Hertzian dipole as the output probe. The use of the elemental Hertzian dipole probes both as input and output probe corresponds to transformations without probe correction. It is worth noting that there are no penalties in efficiency, accuracy and storage requirements by using the SNIFT probe correction scheme with the concepts of input and output probes, as compared to relying on the non-probe correction case or approximate models of probes. On the contrary it offers additional

advantages, such as an easy way to calculate the tangential H-field from the tangential E-field known on a spherical surface.
Another example is the transformation from far field to near field; however, here the user must be aware of the fundamental difficulties inherent in construction of the near field close to the antenna from the far-field data.

The field computed by SNIFT will at all points have an accuracy of 70 dB or better, relative to the isotropic level of the field, provided that both the input field is known and the sampling theorem is fulfilled with the same accuracy. Earlier investigations of near-field far-field transformations indicate that the computed far field in all cases will be at least as accurate as the input field.

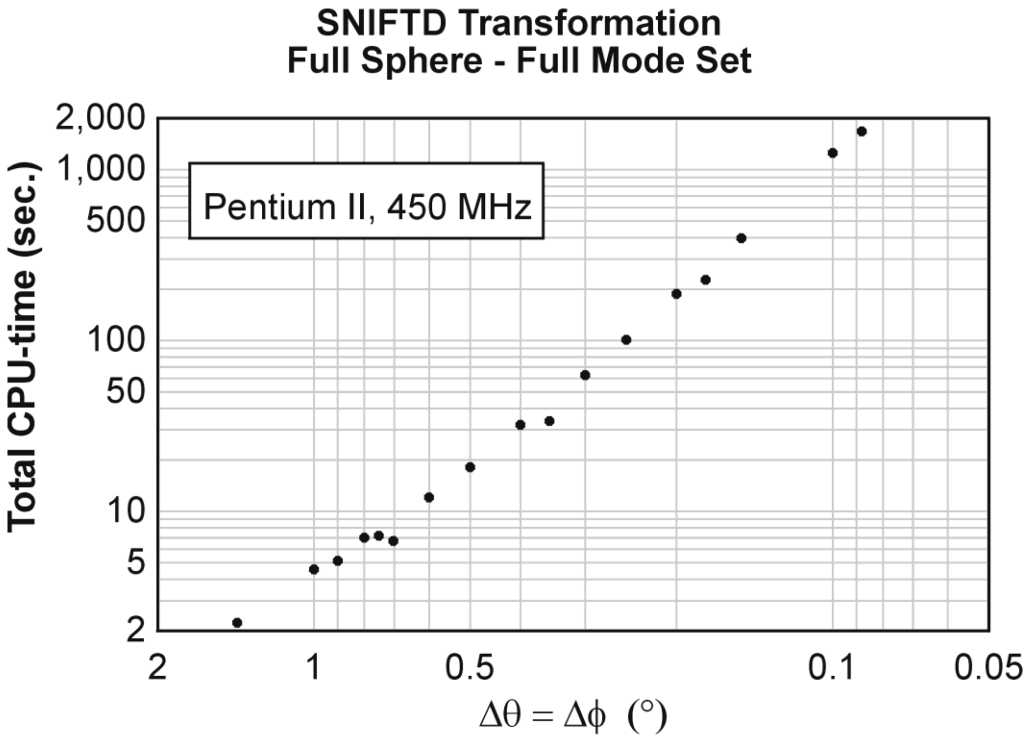
The program employs double precision arithmetic in the parts in which numerical inaccuracies otherwise might become significant, and in the recursion relations, underflow as well as overflow protection schemes have been implemented. This ensures a very stable algorithm, and in practice antennas with diameters exceeding several hundred wavelengths have been handled with accurate determination of all involved spherical harmonics. Numerical investigations show that much larger antennas can be handled with the same accuracy.

The measured data are accepted for full sphere as well as for partial sphere measurements. Although very large antennas and/or very dense samplings of the near field represent vast amounts of data, this does not necessarily translate into a corresponding request for huge amounts of computer memory. Since its initial implementation in the days where computer memory was a limited resource, the SNIFT program has been equipped with a data segmentation scheme that allows the user to do near-field far-field transformations on very large antennas with only a small amount of available computer memory. This scheme is automatically invoked if the amount of memory allocated in the program is too small for the case being considered. Hence SNIFT does not impose restrictions on the maximum size of the test antenna, i.e. the number of measurement points. Any limitation will be dictated by the available disk space to hold the measured, the intermediate and the transformed data.

The table below shows some representative cases and their associated memory requirements. The numbers are for full sphere data with the sample increments indicated, and a corresponding full spherical mode set in the transformation, and no data segmentation invoked. It is seen that the memory requirements are easily fulfilled with nowadays computers.

$\Delta\theta = \Delta\phi$ (°)	Test antenna diam. (λ)	Memory requirem. (MBytes)
0.50	~ 110	~ 4
0.15	~ 375	~ 45
0.10	~ 550	~ 100

The algorithm implemented in SNIFT is computationally very efficient. The figure below shows typical CPU-times for a SNIFT transformation of a set of full sphere data with a full spherical mode set being calculated. The timing results do not include the time to read and write the field from and to disk file.



Computer time needed for a full transformation on a 450 MHz computer. As modern computers are about 10 times faster, then the time for the transformation is negligible compared to the time needed for the measurements.

Commercial packages to process and manipulate the output data and produce high quality 2D and/or 3D graphics, e.g. MATLAB, IDL, etc. are readily available for almost any platform.

Companion program ROSCOE

When performing antenna measurements the antenna test engineer is often confronted with the problem, that the test antenna can only be mounted on the antenna positioner in a manner which makes the measurement coordinate system (CS) to not coincide with the 'natural' antenna coordinate system in which the field is desired. Obviously, one

can calculate the field in the antenna CS from the data in the measurement CS by interpolation. However, for many purposes this may not be sufficiently accurate, since it does require a rather dense data grid, and accordingly an amount of data much larger than what is actually required based on the sampling theorem.
This problem has been solved by the companion program ROSCOE, an integral part of the SNIFT software package. ROSCOE implements an algorithm for rotating the spherical wave coefficients, calculated in a SNIFT transformation, from one CS to another, rotated CS. The rotation of the CS is defined by the usual 3 Eulerian angles adopted in Spherical Wave Theory (Hansen (1988)). The rotations carried out by ROSCOE are exact, in the sense that neither interpolations nor approximations are involved, since the new coefficients may be expressed in closed form, in terms of the old ones, albeit not through simple expressions. Yet the rotation of coefficients is stable and efficient.

The new 'rotated' coefficients are written to a disk file and subsequently read by the SNIFT program, which finally calculates the field in the rotated co-ordinate system.

It is worth noting that inherent to this process, and at no additional costs, is an easy and exact reconstruction of fields into a much denser grid. Even extrapolation of fields (e.g. from truncated measurements) is possible, although one should definitely exercise a certain amount of caution in such cases.

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