# Reconciliation of Frequency and Time in FFT

Jianhua Zhou, 14-AUG-2012

## Introduction

Frequency domain S-parameters can be converted to timed-main using iFFT. The resulting time-domain waveform is the impulse response of the corresponding S-parameter element, under prescribed loading conditions at source and sink.

Suppose the original S-parameter has N frequency points excluding DC. Let nfp0 = N+1, nfp1=N where nfp1 is the number of frequency points excluding DC and, nfp0 is number of frequency points including DC. Obviously nfp0=nfp1 + 1. The frequency step is fstep and stop frequency is fstop. Usually fstop is an integer multiplier of fstep.

For example, a S-parameter file may have fstep = 50MHz, fstop = 20GHz. Then nfp1= fstop/fstep=2000.

nfp0 = 2001.

To assemble the S-matrix for ifft, mirror all the frequency points (except DC and fstop), we have:

nfptt = 1 + nfp1 + (nfp1 – 1);

the first 1 in above equation is the DC point, the item (nfp1-1) represent the fact that the last frequency point is not mirrored. As a result, the total frequency points are

nfptt = 2\*nfp1 = 4000

the list of frequencies are :

10MHz, 20MHz, ..., 20GHz, 20.01GHz, 20.02GHz, ..., 39.990 GHz

nfptt1 = 3999; nfptt0 = 4000

The total number of points excluding DC is 3999. INcluding DC it is 4000. f

frequency span fspan = fstep \* nfptt0 = 10MHz \* 4000 = 40GHz.

Note that even if the fstop\_total is 39.99GHz, the fspan is actually 40GHz. This is because 0Hz (DC) must be included in the total span. Imagine that each frequency point occupies a single fstep, then a total number of (3999+1) freq samples occupies a total span of (3999+1)\*fstep = 40GHz.

Note that matlab starts to store data from index 1. As a result, DC data is index #1 instead of 0 (matlab does not have index 0).