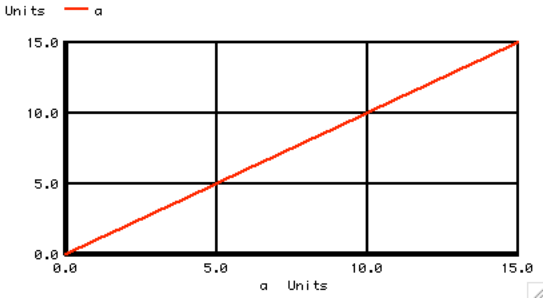
*=========FFT/IFFT_CHECK_OUT==========

TRANSFORM FROM TIME TO SPECTRUM AND BACK AGAIN.
SIGNAL CAN NOW BE FILTERED IN SPECTRUM FORMAT.
IS IT POSSIBLE TO CREATE IMAGINARY TIME?

This is a checkout of the new fft/ifft functions.
The vector function comes in handy when plotting
waveforms in terms of an index.

==========

```
let     a = vector(16)
set     pensize = 2
plot    a vs a
```



*=========Need_complex_inputs==========

Often fft/ifft functions require a complex input with the
complex value set to zero. This makes sense since
the same code does both the fft and ifft. This fft
will accept both real and complex inputs.

The following is how to turn a real input into a
complex input.

==========

```
let         ac = a+j(0)
print       a     ac
```

Constant values
constants Tue Dec 16 22:28:46 GMT 2008

Index	a	ac
0	0.00000e+00	(0.00000e+00, 0.00000e+00)
1	1.00000e+00	(1.00000e+00, 0.00000e+00)
2	2.00000e+00	(2.00000e+00, 0.00000e+00)
3	3.00000e+00	(3.00000e+00, 0.00000e+00)
4	4.00000e+00	(4.00000e+00, 0.00000e+00)
5	5.00000e+00	(5.00000e+00, 0.00000e+00)
6	6.00000e+00	(6.00000e+00, 0.00000e+00)
7	7.00000e+00	(7.00000e+00, 0.00000e+00)
8	8.00000e+00	(8.00000e+00, 0.00000e+00)
9	9.00000e+00	(9.00000e+00, 0.00000e+00)
10	1.00000e+01	(1.00000e+01, 0.00000e+00)
11	1.10000e+01	(1.10000e+01, 0.00000e+00)
12	1.20000e+01	(1.20000e+01, 0.00000e+00)
13	1.30000e+01	(1.30000e+01, 0.00000e+00)
14	1.40000e+01	(1.40000e+01, 0.00000e+00)
15	1.50000e+01	(1.50000e+01, 0.00000e+00)

*=========The_output_Format_depends_on_Input_Format==========

```
print     fft(a)  fft(ac)
```

constants Tue Dec 16 22:28:46 GMT 2008

Index	fft(a)	fft(ac)
0	7.50000e+00	(7.50000e+00,-0.00000e+00)
1	-1.00000e+00	(-5.00000e-01, 2.51367e+00)
2	-5.02734e+00	(-5.00000e-01, 1.20711e+00)
3	-1.00000e+00	(-5.00000e-01, 7.48303e-01)
4	-2.41421e+00	(-5.00000e-01, 5.00000e-01)
5	-1.00000e+00	(-5.00000e-01, 3.34089e-01)
6	-1.49661e+00	(-5.00000e-01, 2.07107e-01)
7	-1.00000e+00	(-5.00000e-01, 9.94562e-02)
8	-1.00000e+00	(-5.00000e-01,-4.89859e-16)
9	-1.00000e+00	(-5.00000e-01,-9.94562e-02)

```
10       -6.68179e-01  (-5.00000e-01,-2.07107e-01 )
11       -1.00000e+00  (-5.00000e-01,-3.34089e-01 )
12       -4.14214e-01  (-5.00000e-01,-5.00000e-01 )
13       -1.00000e+00  (-5.00000e-01,-7.48303e-01 )
14       -1.98912e-01  (-5.00000e-01,-1.20711e+00 )
15       -5.00000e-01  (-5.00000e-01,-2.51367e+00 )
```

If the input is real as for a , the output will be formated such that the real values are stored at odd index values, and values that follow it are the imaginary parts. For instance the fft(a) at index = 1 is -1. The value at index = 2 is -5.02734e+00. This corresponds to the first frequency bin as having a complex value of -1.00000e+00 -j*5.02734e+00. The next frequency bin is -1.00000e+00 -j*2.41421e+00.

If the input is complex as for ac, the output is stored in a euler identity format which will be discussed later. Both fft(a) and fft(ac) contain the same data. They are just formated differently.

***==========DC_Works====================**

```
let          b = unitvec(16)
let          bc = b+j(0)
print        fft(b)   fft(bc)
```

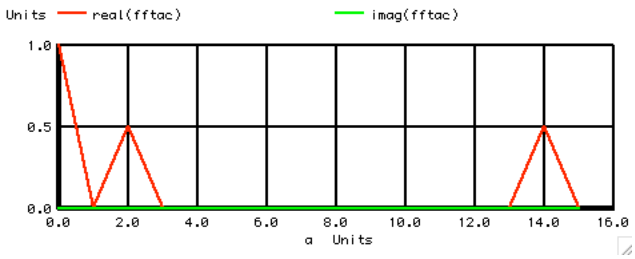
```
--------------------------------------------------------------------------------
Index     fft(b)       fft(bc)
-- hit return for more, ? for help --
--------------------------------------------------------------------------------
0         1.00000e+00  ( 1.00000e+00,-0.00000e+00 )
1        -7.69589e-17  (-3.84795e-17,-7.65404e-18 )
2         1.53081e-17  (-3.69570e-17,-1.53081e-17 )
3        -7.39140e-17  (-1.14551e-17,-7.65404e-18 )
4         3.06162e-17  (-3.06162e-17,-3.06162e-17 )
5        -2.29102e-17  (-5.11427e-18,-7.65404e-18 )
6         1.53081e-17  (-6.34082e-18,-1.53081e-17 )
7        -6.12323e-17  (-1.52248e-18,-7.65404e-18 )
8         6.12323e-17  ( 0.00000e+00,-6.12323e-17 )
9        -1.02285e-17  ( 1.52248e-18,-7.65404e-18 )
10        1.53081e-17  ( 6.34082e-18,-1.53081e-17 )
11       -1.26816e-17  ( 5.11427e-18,-7.65404e-18 )
12        3.06162e-17  ( 3.06162e-17,-3.06162e-17 )
13       -3.04497e-18  ( 1.14551e-17,-7.65404e-18 )
14        1.53081e-17  ( 3.69570e-17,-1.53081e-17 )
15        0.00000e+00  ( 3.84795e-17,-7.65404e-18 )
```

First to check out is the DC term. It should happen at index = 0 and be real.

Next a cosine is added.

***==========DC_Plus_cos_AC====================**

```
let       numb = length(ac)
print     numb
let       indx       = 0
repeat    $&numb
let       ac[indx]   = cos(indx*360/8)+1 +j(0)
let       indx       = indx +1
end

let       fftac      = fft(ac)
plot      real(fftac)  imag(fftac)  vs a           title DC_Plus_COS
```



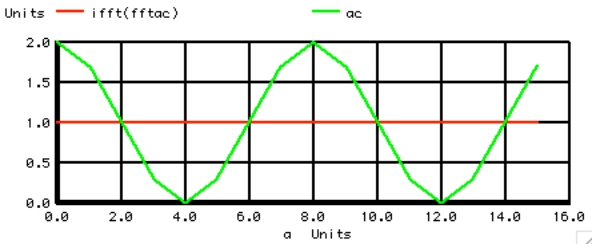

```
numb =   1.60000e+01
```

For this version of FFT, apparently the -jw terms are stored at the frequency bins above nyquist. Since there are 16 data points, the true bins are from 0 to 8. The values for a unit cosine comes out at 1/2. So it appears to use the following function.

Cos(w) = exp(jw)/2 + exp(-jw)/2

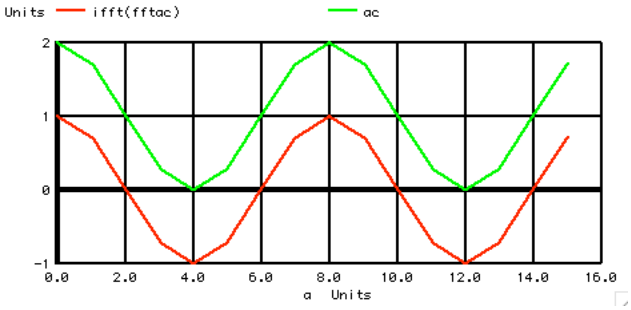
In this case jw is unit 2, and -jw is bin 16-2

```
*==========DC_Plus_cos_Remove_AC====================

let     fftac[2]    = (0,0)
let     fftac[14]   = (0,0)
let     ifftac      = ifft(fftac)
plot    ifftac      ac              vs a            title COS_REMOVED
```



The jw terms for the cosine wave can be removed and the inverse fft or ifft should produce a pure DC wave. Both the jw and -jw need to be removed to remove the cosine wave.

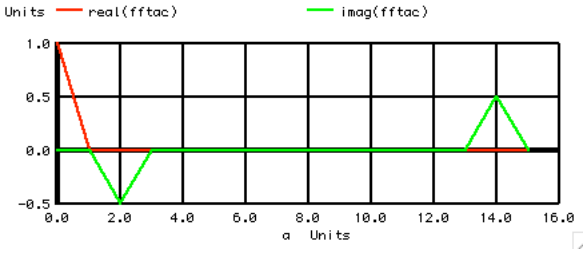
```
*==========DC_Plus_cos_Remove_DC====================
let     indx        = 0
repeat $&numb
let     ac[indx]    = cos(indx*360/8) +1  +j(0)
let     indx        = indx +1
end

let     fftac       = fft(ac)
plot    real(fftac)  imag(fftac)  vs a

let     fftac[0]    = (0,0)
let     ifftac      = ifft(fftac)
plot    ifftac      ac              vs a              title COS_With_DC_REMOVED
```



When the DC term is removed from the fft output, the inverse fft or ifft should produce a pure AC wave.

Note the imaginary part of the DC term must be zero.

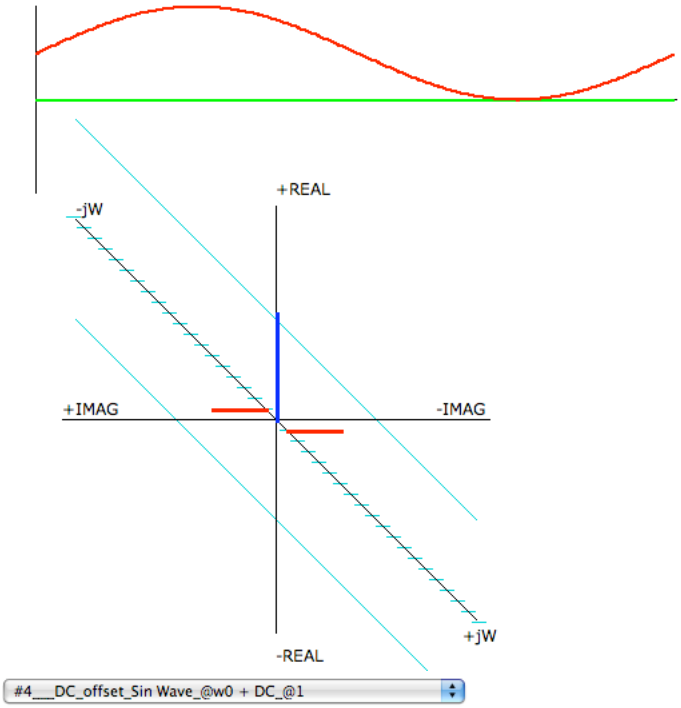
```
*==========DC_Plus_sin_AC====================
let     indx        = 0
repeat $&numb
let     ac[indx]    = sin(indx*360/8) +1 +j(0)
let     indx        = indx +1
end

let     fftac       = fft(ac)
plot    real(fftac)  imag(fftac)  vs a           title DC_Plus_SIN
```



It looks like the polarities and magnitude for the jw terms are all Euler. The imaginary terms for a sine wave are more like a video mirror image of each other.

$$Sin(w) = exp(jw)/2*j + exp(-jw)/2*j$$

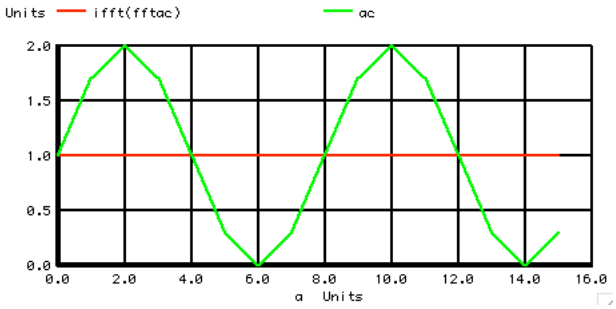
A 3D plot shows how the DC term and the sine wave relate.



http://www.idea2ic.com/PlayWithJavascript/3D_FFT8v.html

*==========DC_Plus_sin_Remove_AC====================

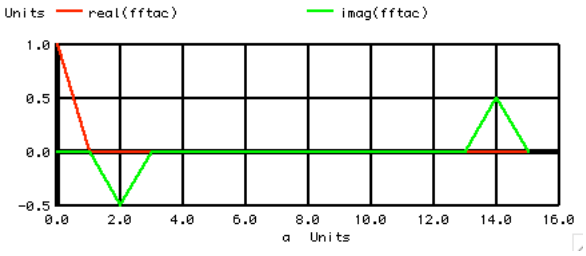
```
let     fftac[2]    = (0,0)
let     fftac[14]   = (0,0)
let     ifftac      = ifft(fftac)
plot    ifft(fftac)                 vs a
```



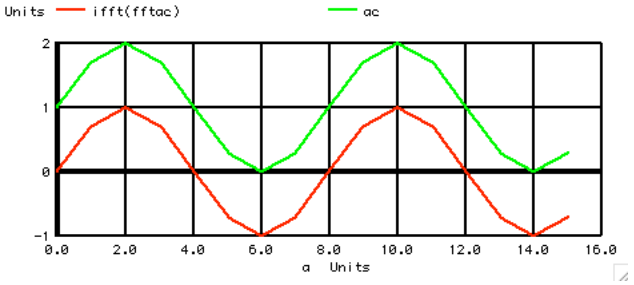
The jw terms for the Sine wave can be removed and the inverse fft or ifft should produce a pure DC wave. Both the jw and -jw need to be removed to remove the Sine wave.

*==========DC_Plus_sin_Remove_DC====================

```
let     indx        = 0
repeat $&numb
let     ac[indx]    = sin(indx*360/8)+1 +j(0)
let     indx        = indx +1
end
let     fftac       = fft(ac)
plot    real(fftac)  imag(fftac)  vs a          title DC_Plus_SIN
```



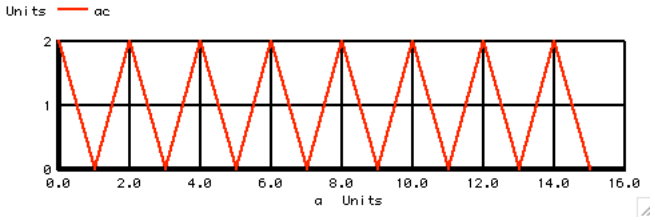

```
let    fftac[0]   = (0,0)
let    ifftac     = ifft(fftac)
plot   ifft(fftac) ac                  vs a       title SIN_With_DC_REMOVED
```



When the DC term is removed from the fft output, the inverse fft or ifft should produce a pure AC wave.

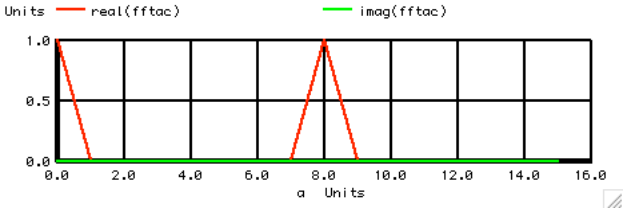
Note the imaginary part of the DC term must be zero.

```
*==========DC_Plus_COS_NYQUIST====================
let    indx       = 0
repeat $&numb
let    ac[indx]   = cos(indx*360/2)+1 +j(0)
let    indx       = indx +1
end

plot   ac         vs a
```



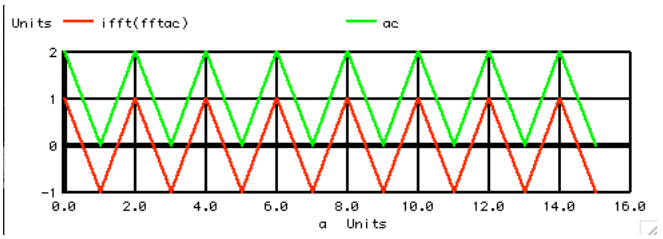
Since there are only 16 data points, maximum number of cycles that can be detected is 8 using a cosine.

```
*==========COS_NYQUIST====================

let    fftac      = fft(ac)
plot   real(fftac)  imag(fftac)  vs a
```

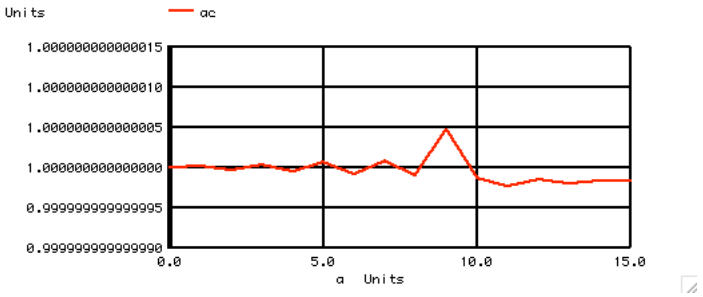


Bin number eight is doing the same thing as bin zero. The two half_gain jw terms add up to one went w goes to zero. Those two terms are right on top of each other. They appear to be doing this at bin 8 as well.

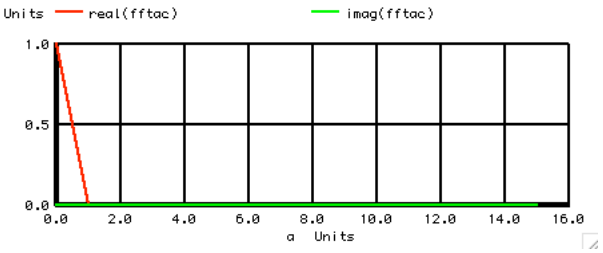
```
*==========DC_Plus_COS_NYQUIST_LESS_DC====================

let    fftac[0]   = (0,0)
let    ifftac     = ifft(fftac)
plot   ifft(fftac)               vs a
```



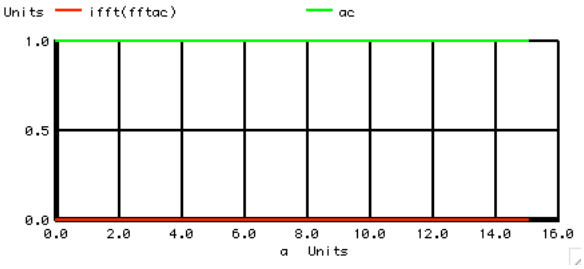

```
*==========DC_Plus_SIN_NYQUIST====================
let     indx        = 0
repeat  $&numb
let     ac[indx]    = sin(indx*360/2)+1 +j(0)
let     indx        = indx +1
end

let     fftac       = fft(ac)
plot    real(fftac)  imag(fftac)  vs a

let     fftac[0]    = (0,0)
let     ifftac      = ifft(fftac)
plot    ifft(fftac)                vs a
```



For a sine wave, all the 16 points are sampling when the sine wave is at zero. So the imaginary term a unit 8 must equal zero.

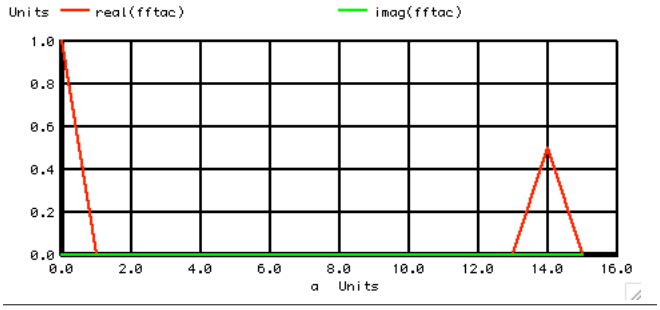


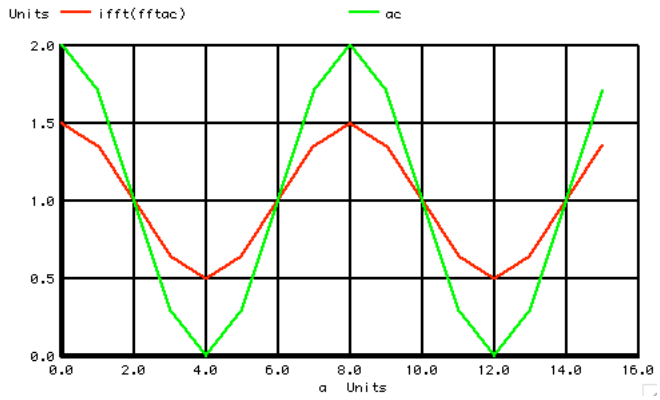
Like for the cosine wave, the opposite polarity jw terms of a sine wave stack up on top of each other at bin 0 and bin 8. So they cancel out to zero.




```
*==========REMOVE_ONE_JW_TerM====================

let           indx = 0
repeat        $&numb
let ac[indx]= cos(indx*360/8)+1 +j(0)
let indx =    indx +1
end

let fftac=    fft(ac)
```

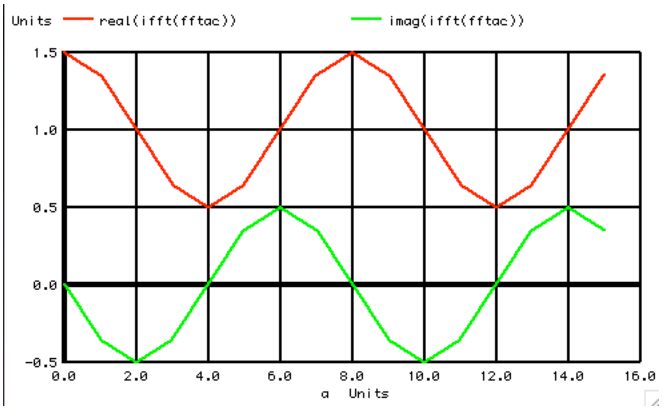
```
let fftac[2]= (0,0)
plot          real(fftac) imag(fftac)  vs a     title DC_Plus_Cos

let  ifftac = ifft(fftac)
plot ifft(fftac) ac  vs a                       title ONE_BIN_REMOVED
```





Subtracting just one of the jw terms you would think would follow something like this equation..

e(jw) = cos(w) -j*sin



Apparently it does...

Wonder what imaginary time could be used for?

==========Full_Netlist_For_Copy_Paste==========

```
FFT_tests
.control
let a = vector(16)
*plot a vs a
set pensize = 2
*=========Need_a_complex_input====================
let ac = a+j(0)
print a ac
*plot fft(a) vs a
*plot real(fft(ac)) imag(fft(ac)) vs a
print fft(a) fft(ac)

*=========DC_Works====================
let b = unitvec(16)
```

```
let bc = b+j(0)
*plot fft(b) vs a                              title DC_WORKS
print fft(b) fft(bc)

*=========DC_Plus_cos_Remove_AC====================
let     numb = length(b)
print   numb

let     indx = 0
repeat  $&numb
let     ac[indx]= cos(indx*360/8)+1 +j(0)
let     indx = indx +1
end

let     fftac=fft(ac)
plot    real(fftac)          imag(fftac)  vs a   title DC_Plus_COS

let     fftac[2]=(0,0)
let     fftac[14]=(0,0)
let     ifftac = ifft(fftac)
plot    ifftac ac vs a                         title COS_REMOVED

*=========DC_Plus_cos_Remove_DC====================
let     indx = 0
repeat  $&numb
let     ac[indx]= cos(indx*360/8)+1 +j(0)
let     indx = indx +1
end

let     fftac=fft(ac)
let     fftac[0]=(0,0)
let     ifftac = ifft(fftac)
plot    ifftac ac  vs a                        title COS_With_DC_REMOVED

*=========DC_Plus_sin_Remove_AC====================
let indx = 0
repeat $&numb
let ac[indx]= sin(indx*360/8)+1 +j(0)
let indx = indx +1
end

let fftac=fft(ac)
plot real(fftac) imag(fftac)  vs a           title DC_Plus_SIN

let fftac[2]=(0,0)
let fftac[14]=(0,0)
let ifftac = ifft(fftac)
plot ifft(fftac) ac  vs a                      title SIN_REMOVED

*=========DC_Plus_sin_Remove_DC====================
let indx = 0
repeat $&numb
let ac[indx]= sin(indx*360/8)+1 +j(0)
let indx = indx +1
end

let fftac=fft(ac)
let fftac[0]=(0,0)
let ifftac = ifft(fftac)
plot ifft(fftac) ac  vs a                       title SIN_With_DC_REMOVED

*=========DC_Plus_cos_Nyqusit_Remove_DC====================
let indx = 0
repeat $&numb
let ac[indx]= cos(indx*360/2)+1 +j(0)
let indx = indx +1
end

plot ac vs a                                  title Nyq_COS

let fftac=fft(ac)
plot real(fftac)  imag(fftac)  vs a           title Nyq_FREQ_COS
let fftac[0]=(0,0)
let ifftac = ifft(fftac)
plot ifft(fftac) ac  vs a                      title COS_With_DC_REMOVED
*=========DC_Plus_sin_Nyqusit_Remove_DC====================
let indx = 0
repeat $&numb
let ac[indx]= sin(indx*360/2)+1 +j(0)
let indx = indx +1
end

plot ac vs a                                 title Nyq_SIN

let fftac=fft(ac)
plot real(fftac)  imag(fftac)  vs a          title Nyq_FREQ_SIN
let fftac[0]=(0,0)
let ifftac = ifft(fftac)
plot ifft(fftac)  ac vs a                      title COS_With_DC_REMOVED

*=========DC_Plus_COS_Remove_One_BIN====================
let indx = 0
repeat $&numb
let ac[indx]= cos(indx*360/8)+1 +j(0)
let indx = indx +1
end

let fftac=fft(ac)
let fftac[2]=(0,0)
plot real(fftac) imag(fftac)  vs a             title DC_Plus_Cos

let ifftac = ifft(fftac)
```

```
plot ifft(fftac) ac  vs a                       title ONE_BIN_REMOVED

plot real(ifft(fftac)) imag(ifft(fftac))   vs a      title ONE_BIN_REMOVED

.endc
.end
```