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Communication Systems Engineering/Marketing

Submisssion to IEEE 802.4.L
Atlanta Meeting, May 1990

Analysis of the Impact of Propogation from Multip[illegible]ces on the Complex Output of the Complex Conjugate Demodulator Proposed in IEEE 802.41/89-16 entitled "DQPSK Spread-Spectrum Modulation/Demodulation"

Prepared By
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Note: This submission is made in order to put certain aspects of system operation into perspective. It is not the intent of Knowledge Implementations, Inc. by virtue of this disclosure to surrender any proprietary rights which it may have in any system, subsystem, or program described in this document.

At this time it looks unlikely that I will be attending the meeting of IEEE 802.4.L to be held in Atlanta so I have forwarded this information to you for your review. Between meetings some work concerning the channel characteristics when multiple antennae are introduced into the environment was done. The attached represents some of the information obtained in that analysis. Unless someone can find something inherently wrong with the methodology or results of this analysis it appears that attempts to operate a multi-antennae system utilizing the DQPSK modulation and demodulation approach presented to the commitee in IEEE 802.4L/89-16 are destined to have serious operational difficulties.

What you will see in the attached is first a drawing showing three waveforms V(30),V(40),V(1). These represent the voltages within a SPICE simulation which are ultimately modulated and run through the channel model and demodulated. In other words, V(30) is the I-channel data stream, V(40) is the Q-channel data stream, and V(1) is the barker sequence which will be used to spread these data streams.

There are four sets of simulations. All of these have been processed identically. The first simulation is a single antennae with no multipath. The second simulation is a single antennae with multipath. The third and fourth are two different distributions systems. A relatively benign distribution system and a relatively harsh distribution system.

The SPICE source file which shows the actual channel simulation is attached to the two distribution system simulations. The same source file with parameters modified

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to eliminate the multiple antennae and multipath effects was used for the first two simulations. What I do in this file is take six voltage sources to act as six separate transmit oscillators for three separate antennae (note each antennae has two oscillators 90 degrees out of phase). The data streams described in the previous paragraph are chipped up in E10 and E11 and modulated with the three transmit oscillator pairs in E12,E13 and E14. Note antennae four is commented out as the version of SPICE I have was unable to handle the circuit with four antennaes in.

The signals which result from the modulation described above are then passed through three separate three ray multipath scenarios. These are the subcircuits MULTIPATH1, MULTIPATH2 and MULTIPATH3. Finally, these are combined at E25 with a set of weights into a received signal which is then downconverted using the oscillators from antennae one and low pass filtered to yield a baseband representation of the received signal.

The simulation is run for 18 microseconds with samples of the I and Q output taken every 5 nanoseconds. The attached hand sketch illustrates this SPICE simulation.

Next the I data and the Q data are each correlated against the barker sequences and coverted to MATHEMATICA format resulting in files named DISTxIC.data and DISTxQC.data. The MATHEMATICA printout which follows shows a plot of each of these correlated data streams. These correlated data streams have the DC term of 127 subtracted from them and then new set of data vectors is formed by taking I+iQ from the present and multiplying it by I-iQ from exactly one barker sequence time (2 microseconds) in the past. This yields the data vectors "real" and "imag" which are plotted next. This, unless I am missing something, is what a system based on the "Bruce Tuch" method has to work with in making a decision.

Finally, I combine the basic icorr and qcorr (the original correlated data reduced by the 127 DC value) data to show the arriving power profile and this is plotted for the nine individual data sections and combined into a three dimensional representation in the final diagram.

The harsh distribution system used oscillators at 20MHz, 20.001MHz, and 19.998 MHz. The initial phases of these were 0, 45, and 155 degrees and were chose at random. All the antennae were weighted equally at the combining point. The multipaths through which the signal traveled were:

Antennae One - one path of weight .3 at 338 ns
one path of weight .5 at 527 ns

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Antennae Two - one path of weight .2 at 104 ns
one path of weight .8 at 216 ns
Antennae Three - one path of weight 1 at 0 ns
one path of weight 1 at 75 ns
one path of weight 1 at 127 ns

These delays and weights were chosen at random with the only constraint being that I wanted to keep them away from delays that were specifically related to the carrier frequency.

In the benign distribution system, the signals arriving from the three antennae were not weighted equally at the receiver and instead had weights, .25 for antennae one, .5 for antennae two and z1 for antennae three and multipath profiles of:

Antennae One - one path of weight .5 at 338 ns
one path of weight .3 at 527 ns
Antennae Two - one path of weight .2 at 0 ns
one path of weight .8 at 104 ns
one path of weight .3 at 216 ns
Antennae Three - one path of weight 1 at 0 ns
one path of weight .6 at 75 ns
one path of weight .2 at 127 ns

Also in this benign set of data the transmit carrier frequencies were brought closer together so that antennae one was 20MHz, antennae two was 20.0001MHz, and antennae three was 19.9999MHz. The phases were randomly chosen and were the same as those used above.

My impression of what I am seeing here is an indication that the DQPSK scheme proposed will have serious difficulties operating in a distribution system oriented environment. The environment simulated in these drawings does not even include any disturbance associated with the fact that the radios will be moving and there are substantial variations in the detailed structure of the impulse response from symbol to symbol within the attached diagrams. In particular the complex demodulator seems to be developing false peaks. From this information it appears that any standard we may develop based on the DQPSK approach will be suitable only for single antennae systems.

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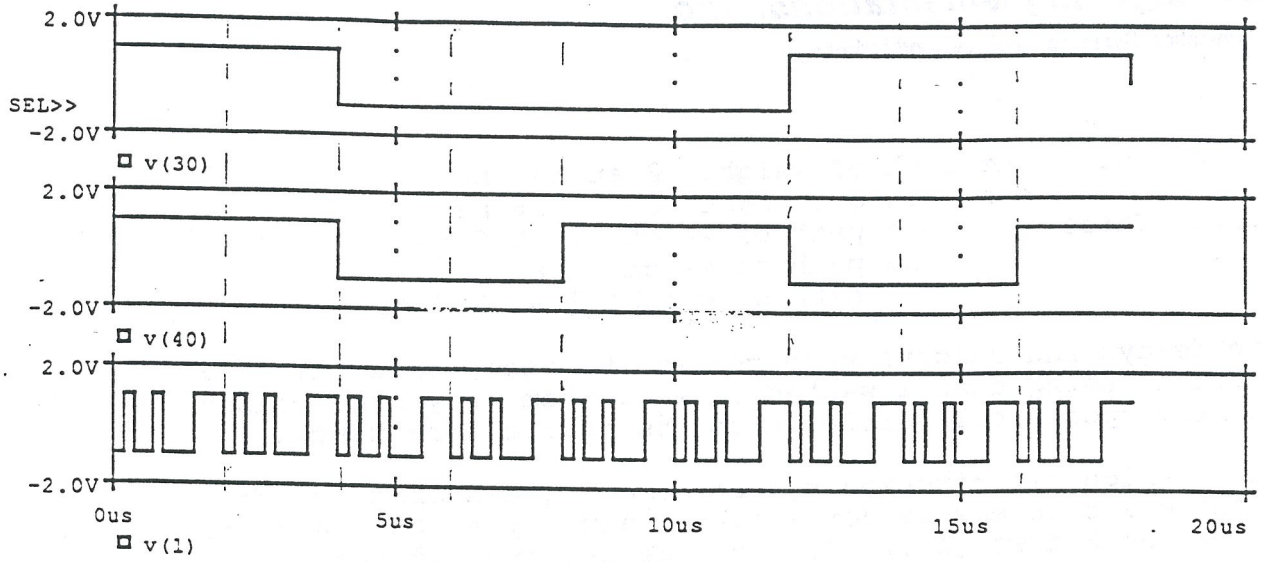
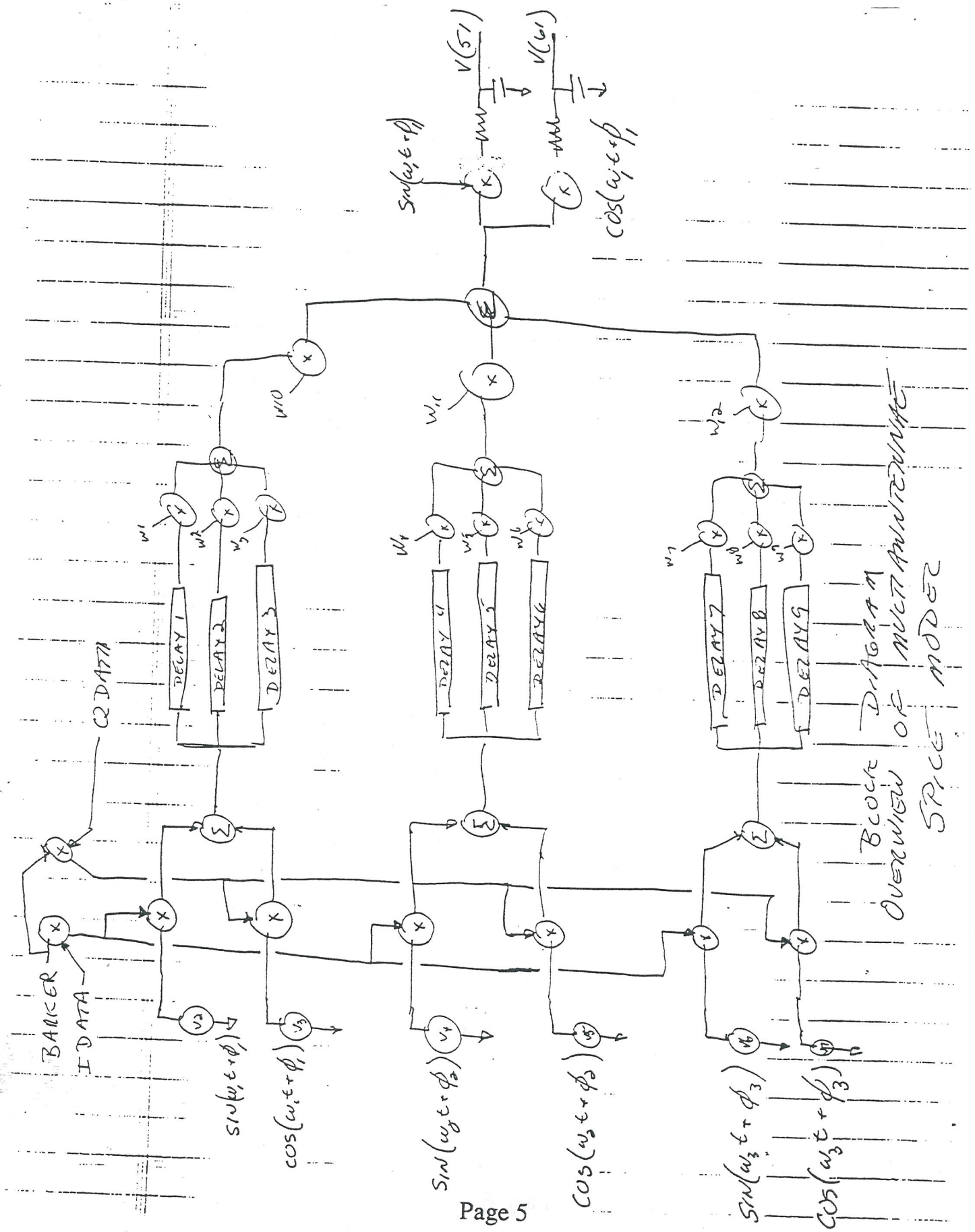
TRANSMIT DATA PATTERN



"*Distribution system simulation" 04/05/90 11:31:06 27.0°
PROBE 3.08a (Evaluation) from MicroSim Corp.


BARKER
I DATA
Q DATA
DELAY 1
DELAY 2
DELAY 3
DELAY 4
DELAY 5
DELAY 6
DELAY 7
DELAY 8
DELAY 9
V(sin)
V(cos)
Block Diagram of Multiaccess Spread Mode Overview

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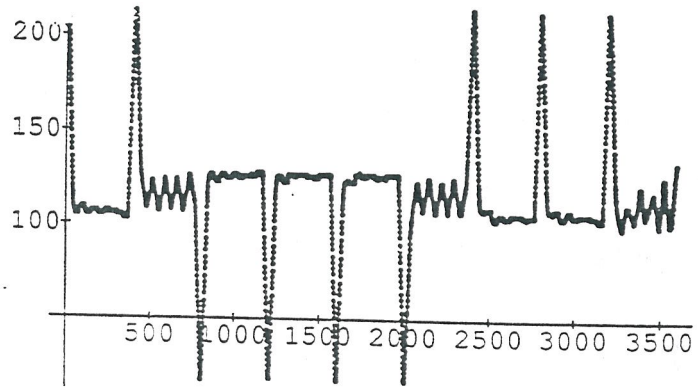
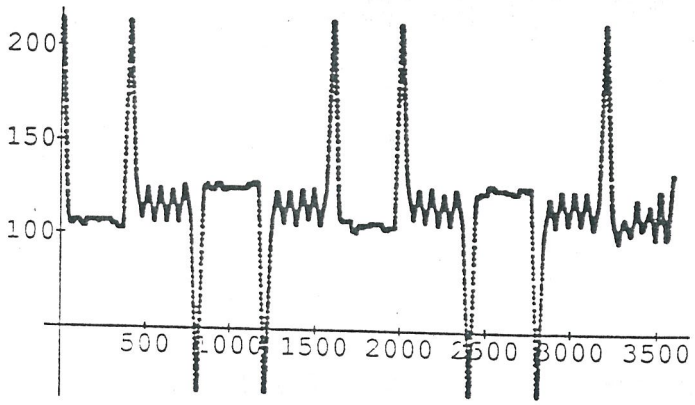
SINGLE ANTENNAE NO MULTIPATH

```
In[1]:=
  <<DISTPIC.data;

In[2]:=
  <<DISTPQC.data;

  ListPlot[Out[1],PlotRange ->All]
```




```
  -Graphics-

  ListPlot[Out[2],PlotRange ->All]
```




```
  -Graphics-

In[3]:=
  icorr=Out[1]-127;
  qcorr=Out[2]-127;

  real=Take[(icorr RotateRight[icorr,400])+(qcorr RotateRight[qcorr,400]

In[4]:=
  imag=Take[(icorr RotateRight[qcorr,400])-(qcorr RotateRight[icorr,400]

  ListPlot[real,PlotRange ->All]
```

Single Antenna No Multipath

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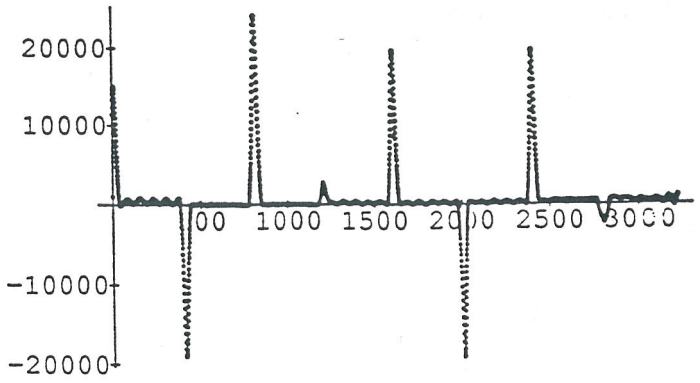
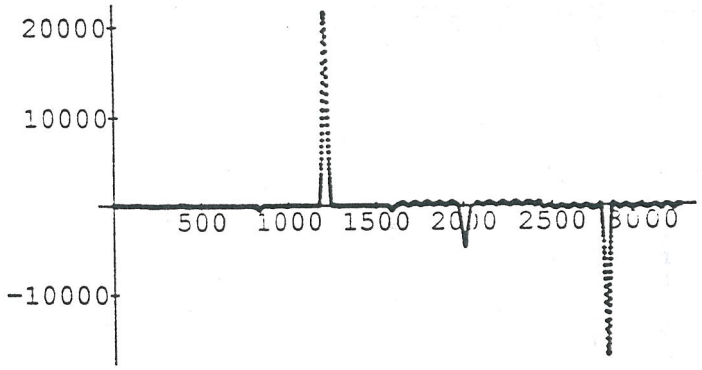


-Graphics-

In[5]:=

```
ListPlot[imag,PlotRange ->All]
```



Out[5]=

-Graphics-

In[6]:=

```
r={}
For[t=0,t<8,i=Take[icorr,{(t 400),((t 400)+399)}];
            q=Take[qcorr,{(t 400),((t 400)+399)}];
            p=(i + I q) (Conjugate[i + I q]);
            r=Append[r,p];
            ListPlot[p,PlotJoined -> True,PlotRange ->All];,t++]
```

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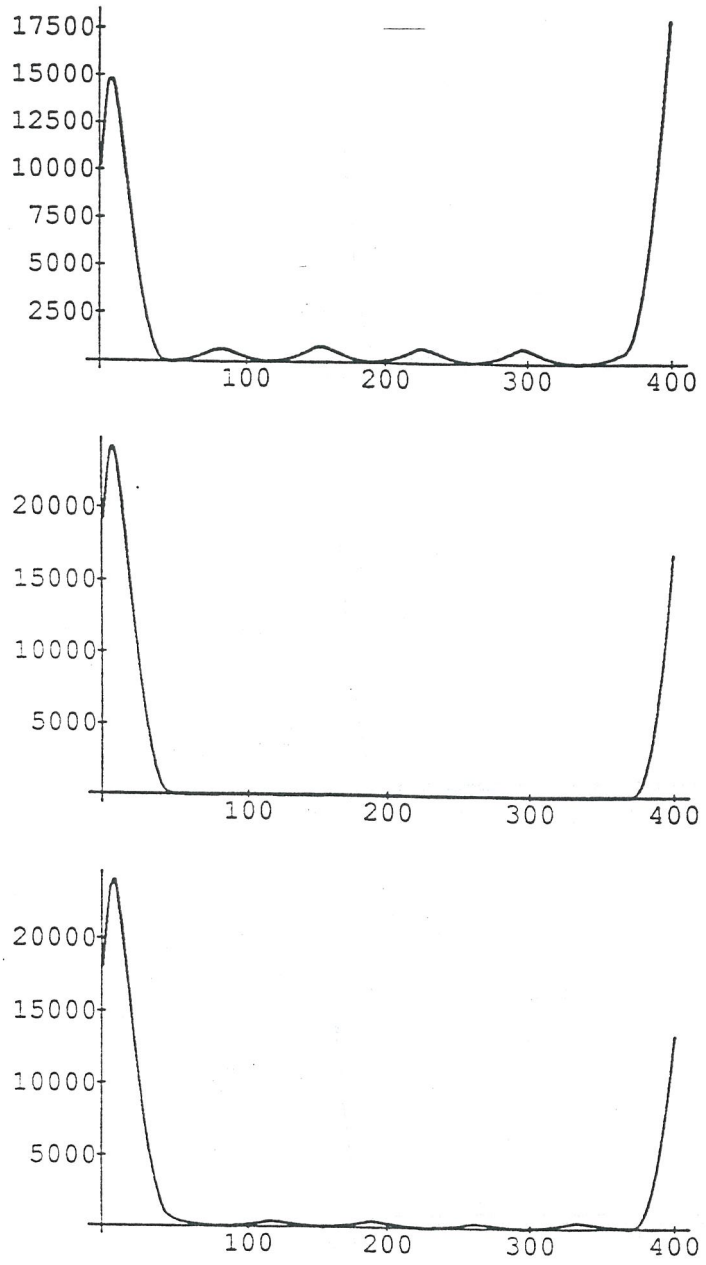

Single Antenna No Multipath

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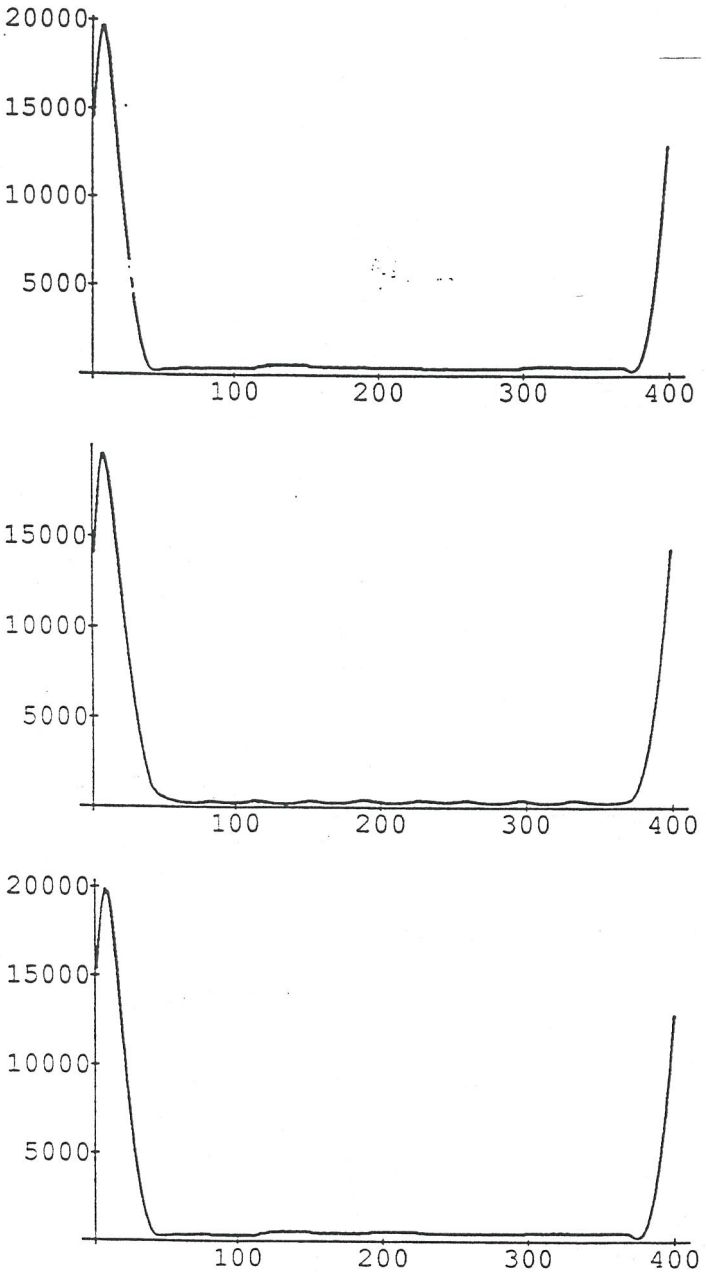

Single Antenna No Multipath

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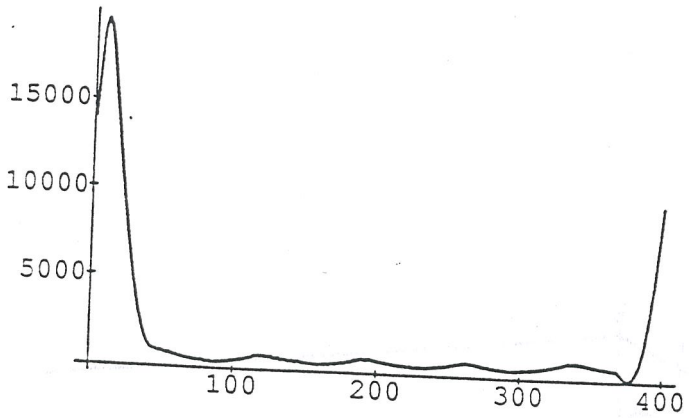
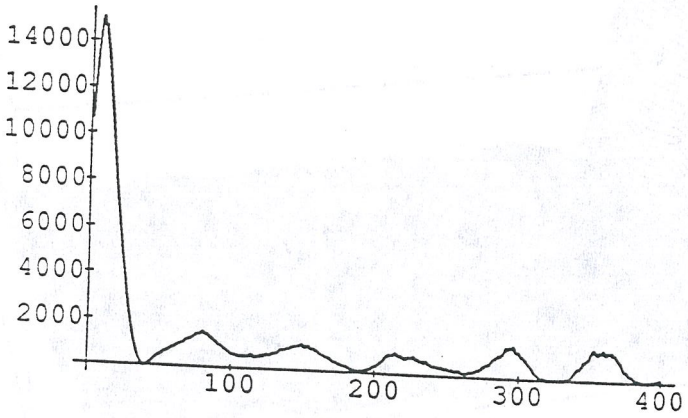
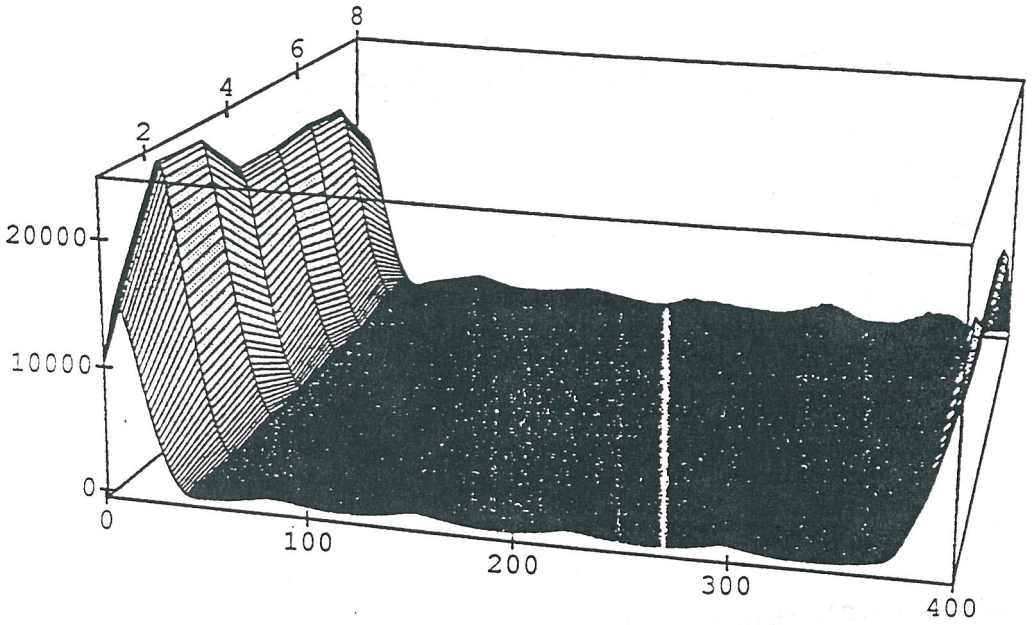




In[7]:=

```
ListPlot3D[r,PlotRange -> All,PlotColor ->True,ViewPoint->{0.662, -3.
```

Single Antenna No Multipath



Out[7]=

```
-SurfaceGraphics-
```

Single Antenna No Multipath

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SINGLE ANTENNAE WITH MULTIPATH

In[1]:=

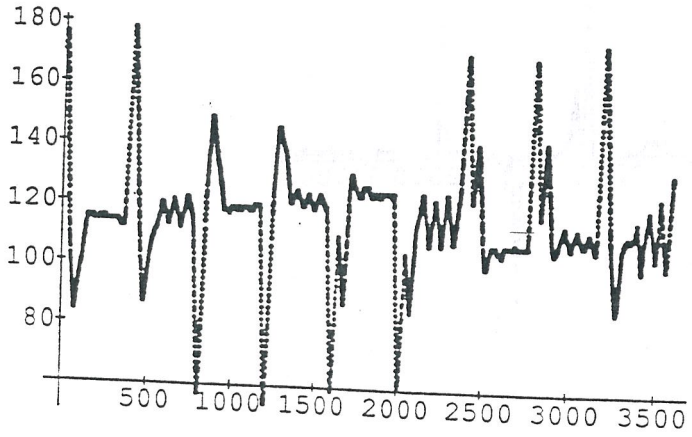
```
<<DISTMIC.data;
```

In[2]:=

```
<<DISTMQC.data;
```

In[3]:=

```
ListPlot[Out[1],PlotRange ->All]
```

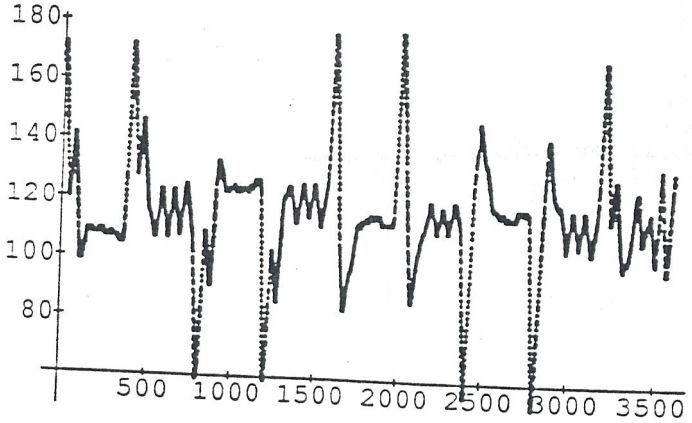


Out[3]=

```
-Graphics-
```

In[4]:=

```
ListPlot[Out[2],PlotRange ->All]
```



Out[4]=

```
-Graphics-
```

In[5]:=

```
icorr=Out[1]-127;
qcorr=Out[2]-127;
```

In[6]:=

```
real=Take[(icorr RotateRight[icorr,400])+(qcorr RotateRight[qcorr,400]
```

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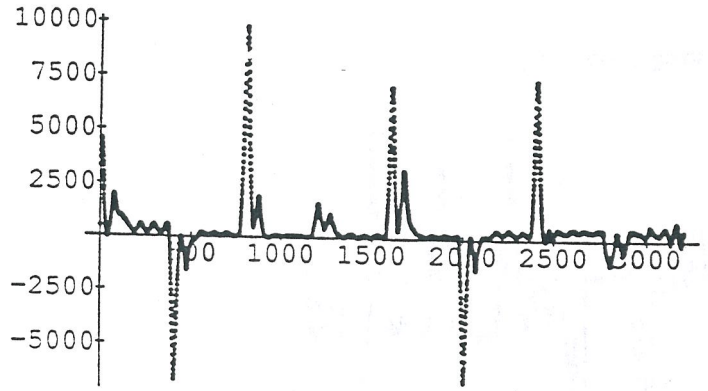
In[7]:=

```
imag=Take[(icorr RotateRight[qcorr,400])-(qcorr RotateRight[icorr,400]
```

In[8]:=

```
ListPlot[real,PlotRange ->All]
```

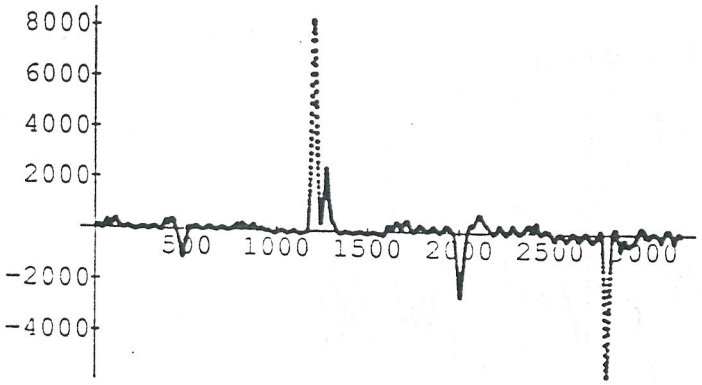


Out[8]=

```
-Graphics-
```

In[9]:=

```
ListPlot[imag,PlotRange ->All]
```



Out[9]=

```
-Graphics-
```

In[10]:=

```
r={}
For[t=0,t<8,i=Take[icorr,{(t 400),((t 400)+399)}];
            q=Take[qcorr,{(t 400),((t 400)+399)}];
            p=(i + I q) (Conjugate[i + I q]);
            r=Append[r,p];
            ListPlot[p,PlotJoined -> True,PlotRange ->All];,t++]
```

Single Antenna With Multipath

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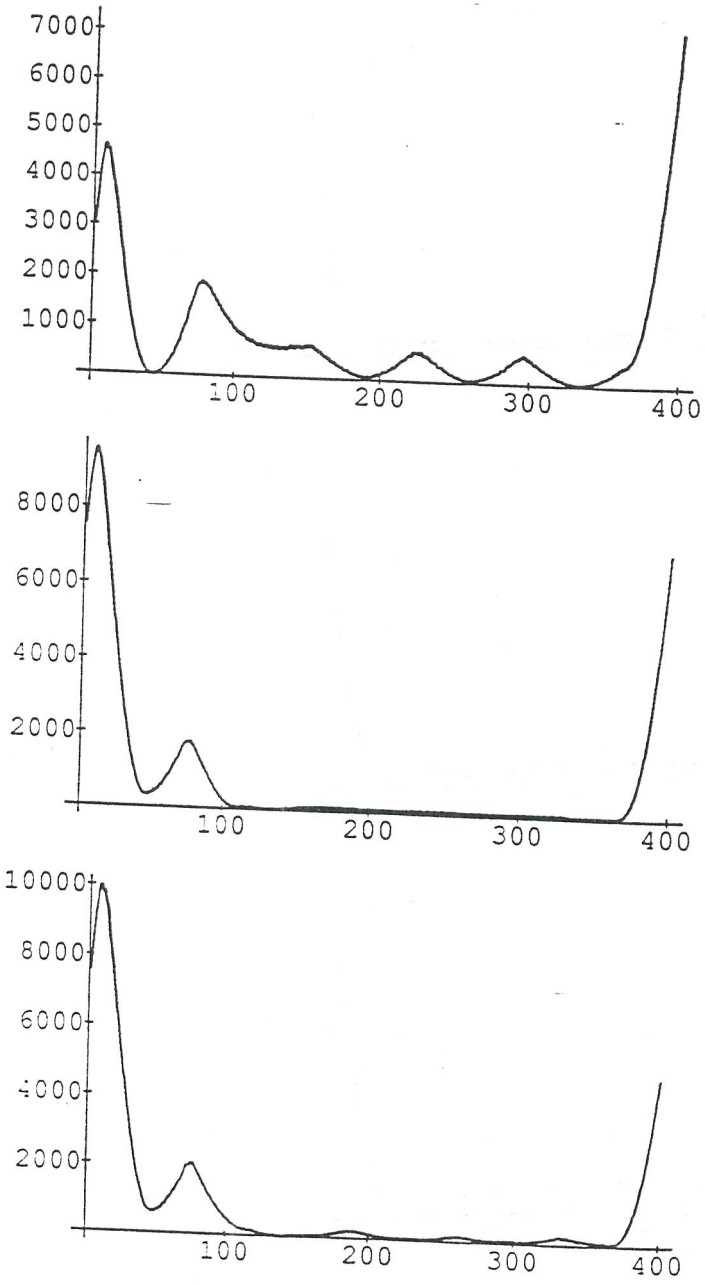
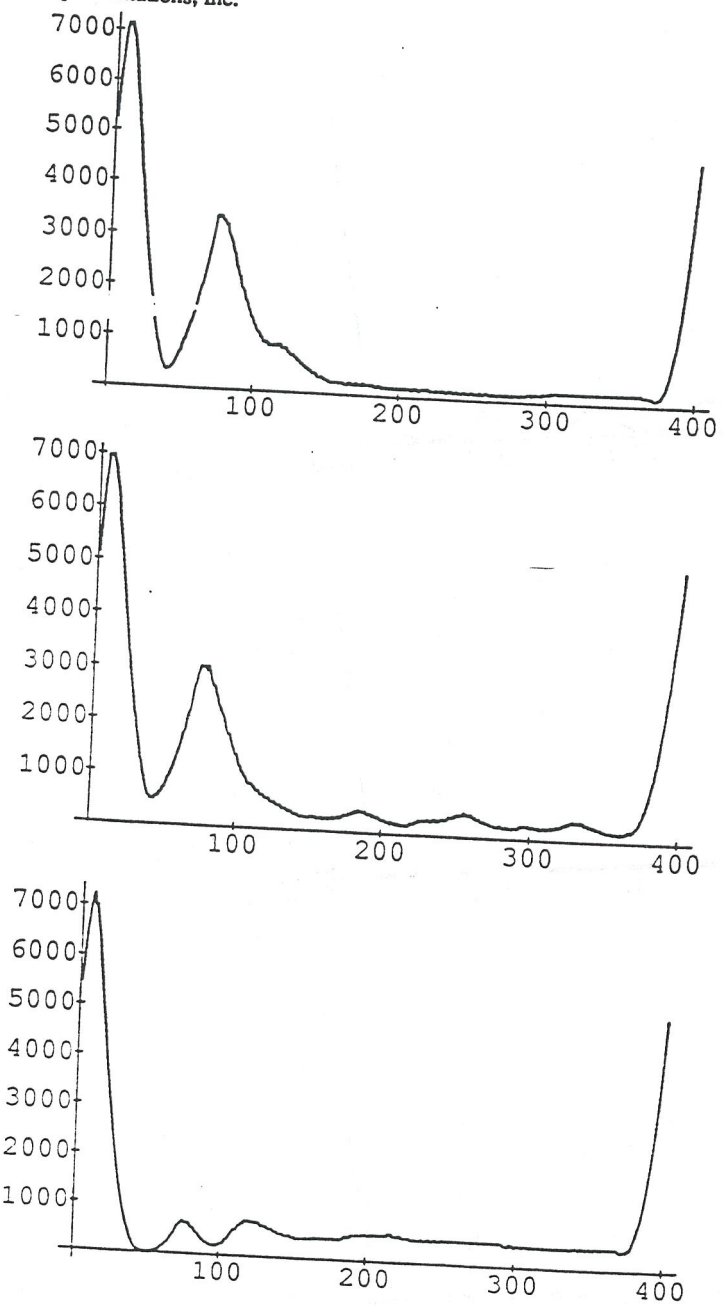


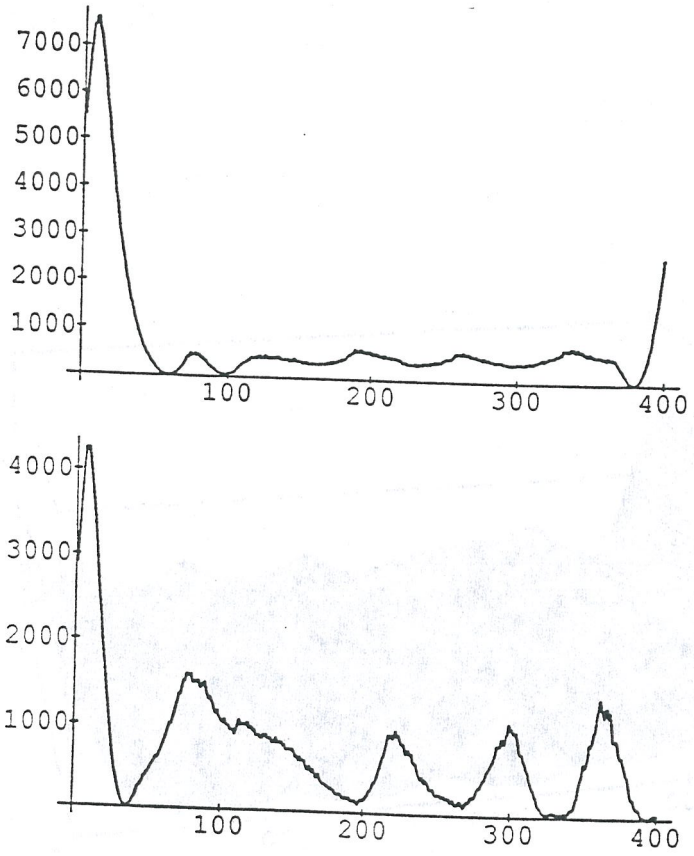
Single Antenna With Multipath

Knowledge Implementations, Inc.



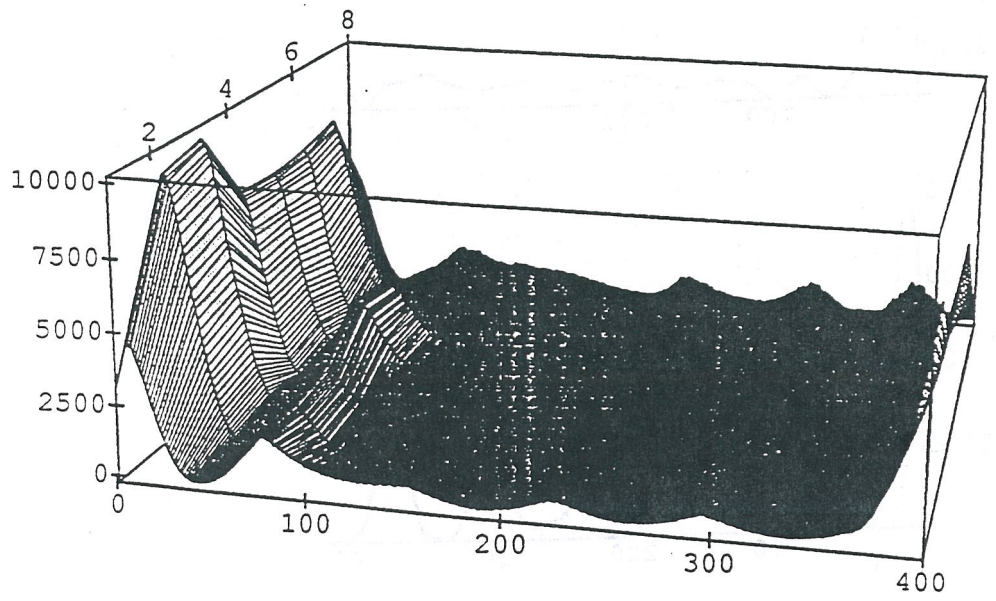
Single Antenna With Multipath

Knowledge Implementations, Inc.



In[11]:=

```
ListPlot3D[r,PlotRange -> All,PlotColor ->True,ViewPoint->{0.662, -3.
```



Out[11]=

-SurfaceGraphics-

Single Antenna With Multipath

DISTRIBUTION SYSTEM A (BANGN)

4/6/90 10:05 AM Hard Disk:Technical:CIRCUITS:Dist. System Page 1

```
*Distribution system simulation

*Antennae One
V2 2 0 SIN 0 1 20MEG 0 0 0
V3 3 0 SIN 0 1 20MEG 0 0 90

*Antennae Two
V4 4 0 SIN 0 1 20.0001MEG 0 0 165
V5 5 0 SIN 0 1 20.0001MEG 0 0 255

*Antennae Three
V6 6 0 SIN 0 1 19.9999MEG 0 0 45
V7 7 0 SIN 0 1 19.9999MEG 0 0 135

*Antennae Four
*V8 8 0 SIN 0 1 20MEG 0 0 45
*V9 9 0 SIN 0 1 20MEG 0 0 135

RX2 2 0 10MEG
RX3 3 0 10MEG
RX4 4 0 10MEG
RX5 5 0 10MEG
RX6 6 0 10MEG
RX7 7 0 10MEG
*RX8 8 0 10MEG
*RX9 9 0 10MEG

X1 1 BARKER

E10 10 0 POLY(2) 1 0 30 0  0  0 0   0 1
E11 11 0 POLY(2) 1 0 40 0  0  0 0   0 1

V40 40 0 PWL 0 0 .005U 1 1.995U 1 2.005U 1 3.995U 1 4.005U -1 5.995U -1
+6.005U -1 7.995U -1 8.005U 1 9.995U 1 10.005U 1 11.995U 1
+12.005U -1 13.995U -1 14.005U -1 15.995U -1 16.005U 1 17.995U 1
+18.005U 1 19.995U 1 20.005U 1 21.995U 1 22.005U -1 23.995U -1
+24.005U -1 25.995U -1 26.004U -1 27.995U -1 28.005U 1 29.995U 1
+30.005U -1 31.995U -1 32.005U 1 33.995U 1 34U 1
RX88 40 0 10MEG

V30 30 0 PWL 0 0 .005U 1 1.995U 1 2.005U 1 3.995U 1 4.005U -1 5.995U -1
+6.005U -1 7.995U -1 8.005U -1 9.995U -1 10.005U -1 11.995U -1
+12.005U 1 13.995U 1 14.005U 1 15.995U 1 16.005U 1 17.995U 1
+18.005U -1 19.995U -1 20.005U 1 21.995U 1 22.005U 1 23.995U 1
+24.005U -1 25.995U -1 26.004U 1 27.995U 1 28.005U -1 29.995U -1
+30.005U -1 31.995U -1 32.005U 1 33.995U 1 34U 1
RX89 30 0 10MEG

*Antennae One
E12 12 0 POLY(4) 10 0 2 0 11 0 3 0   0  0 0 0 0   0 1 0 0  0 0 0  0 1

*Antennae Two
E13 13 0 POLY(4) 10 0 4 0 11 0 5 0   0  0 0 0 0   0 1 0 0  0 0 0  0 1

*Antennae Three
E14 14 0 POLY(4) 10 0 6 0 11 0 7 0   0  0 0 0 0   0 1 0 0  0 0 0  0 1

*Antennae Four
*E15 15 0 POLY(4) 10 0 8 0 11 0 9 0   0  0 0 0 0   0 1 0 0  0 0 0  0 1

RX10 10 0 10MEG
RX11 11 0 10MEG
RX12 12 0 10MEG
```

```
RX13 13 0 10MEG
RX14 14 0 10MEG
*RX15 15 0 10MEG

*MEDIA DISTORTION

X12 12 20 MULTIPATH1
X13 13 21 MULTIPATH2
X14 14 22 MULTIPATH3
*X15 15 23 MULTIPATH4

*E25 25 0 POLY(4) 20 0 21 0 22 0 23 0   0     1      1      1      1
*                                            ANT1   ANT2   ANT3   ANT4
E25 25 0 POLY(3) 20 0 21 0 22 0   0     .25     .5     1
*                                           ANT1   ANT2   ANT3
RX25 25 0 10MEG

*RECEIVER

E50 50_0 POLY(2) 25 0 2 0    0   0 0  0 1
E60 60 0 POLY(2) 25 0 3 0    0   0 0  0 1
R11 50 51 636
R12 60 61 636
C1 51 0 40P
CX2 61 0 40P


.SUBCKT BARKER 3
V3 3 0 PWL 0 -1 5N -1 180.82N -1 182.82N 1 362.64N 1 364.64N -1 726.27N -1
+728.27N 1 908.09N 1 910.09N -1 1453.5N -1 1455.5N 1 1999.0N 1
+2001N -1 2180.82N -1 2182.82N 1 2362.64N 1 2364.64N -1 2726.27N -1
+2728.27N 1 2908.09N 1 2910.09N -1 3453.5N -1 3455.5N 1 3999.0N 1
+4001N -1 4180.82N -1 4182.82N 1 4362.64N 1 4364.64N -1 4726.27N -1
+4728.27N 1 4908.09N 1 4910.09N -1 5453.5N -1 5455.5N 1 5999.0N 1
+6001N -1 6180.82N -1 6182.82N 1 6362.64N 1 6364.64N -1 6726.27N -1
+6728.27N 1 6908.09N 1 6910.09N -1 7453.5N -1 7455.5N 1 7999.0N 1
+8001N -1 8180.82N -1 8182.82N 1 8362.64N 1 8364.64N -1 8726.27N -1
+8728.27N 1 8908.09N 1 8910.09N -1 9453.5N -1 9455.5N 1 9999.0N 1
+10001N -1 10180.82N -1 10182.82N 1 10362.64N 1 10364.64N -1 10726.27N -1
+10728.27N 1 10908.09N 1 10910.09N -1 11453.5N -1 11455.5N 1 11999.0N 1
+12001N -1 12180.82N -1 12182.82N 1 12362.64N 1 12364.64N -1 12726.27N -1
+12728.27N 1 12908.09N 1 12910.09N -1 13453.5N -1 13455.5N 1 13999.0N 1
+14001N -1 14180.82N -1 14182.82N 1 14362.64N 1 14364.64N -1 14726.27N -1
+14728.27N 1 14908.09N 1 14910.09N -1 15453.5N -1 15455.5N 1 15999.0N 1
+16001N -1 16180.82N -1 16182.82N 1 16362.64N 1 16364.64N -1 16726.27N -1
+16728.27N 1 16908.09N 1 16910.09N -1 17453.5N -1 17455.5N 1 17999.0N 1
+18U 1
RX1 3 0 10MEG
.ENDS

.SUBCKT MULTIPATH1 1 2
R1 1 10 50
T1 10 0 11 0 ZO=50 TD=338N
R2 11 0 50
R3 1 12 50
T2 12 0 13 0 ZO=50 TD=527N
R4 13 0 50
E1 2 0 POLY(3) 10 0 11 0 13 0   0  0 .5 .3
RX2 2 0 10MEG
.ENDS

.SUBCKT MULTIPATH2 1 2
```

```
R1 1 10 50
T1 10 0 11 0 ZO=50 TD=104N
R2 11 0 50
R3 1 12 50
T2 12 0 13 0 ZO=50 TD=216N
R4 13 0 50
E1 2 0 POLY(3) 10 0 11 0 13 0   0  .2 .8 .3
RX2 2 0 10MEG
.ENDS

.SUBCKT MULTIPATH3 1 2
R1 1 10 50
T1 10 0 11 0 ZO=50 TD=73N
R2 11 0 50
R3 1 12 50
T2 12 0 13 0 ZO=50 TD=127N
R4 13 0 50
E1 2 0 POLY(3) 10 0 11 0 13 0   0  1 .6 .2
RX2 2 0 10MEG
.ENDS

*.SUBCKT MULTIPATH4 1 2
*R1 1 10 50
*T1 10 0 11 0 ZO=50 TD=200N
*R2 11 0 50
*R3 1 12 50
*T2 12 0 13 0 ZO=50 TD=225N
*R4 13 0 50
*E1 2 0 POLY(3) 10 0 11 0 13 0   0  1 1 1
*RX2 2 0 10MEG
*.ENDS

.PROBE
.PRINT TRAN V(51) V(61)
.OPTION ITL5=0
.TRAN 5N 18U
.END
```

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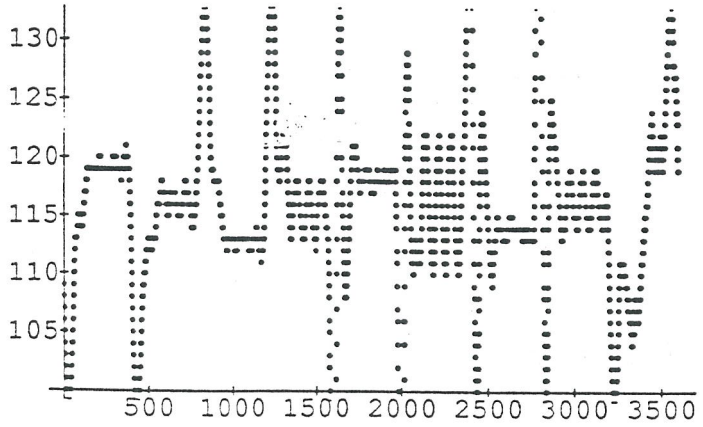
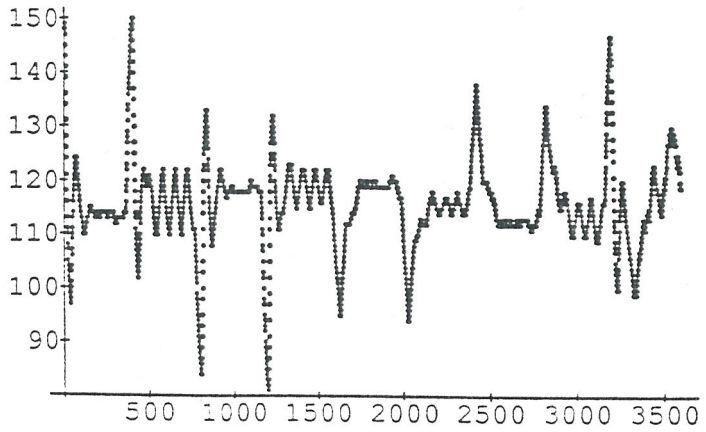
```
<<DISTAIC.data;

<<DISTAQC.data;

ListPlot[Out[1]]
```




```
-Graphics-

ListPlot[Out[2],PlotRange ->All]
```




```
-Graphics-

icorr=Out[1]-127;
qcorr=Out[2]-127;

real=Take[(icorr RotateRight[icorr,400])+(qcorr RotateRight[qcorr,400]

imag=Take[(icorr RotateRight[qcorr,400])-(qcorr RotateRight[icorr,400]

ListPlot[real,PlotRange ->All]
```

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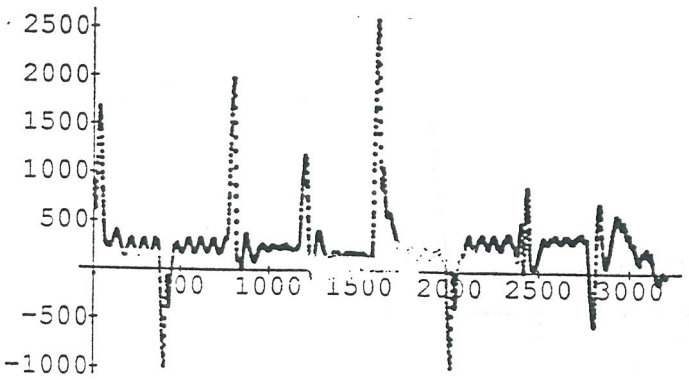
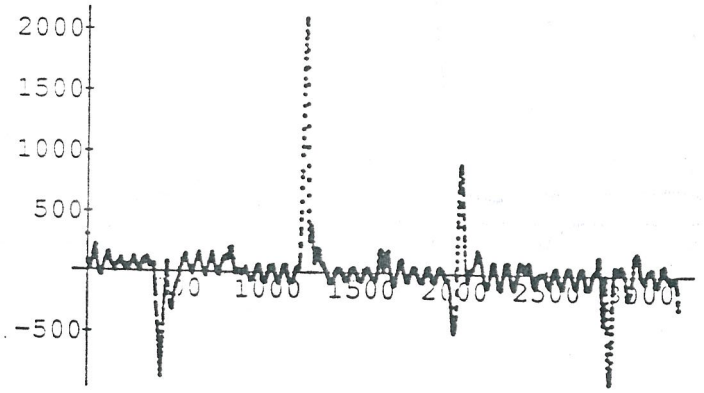
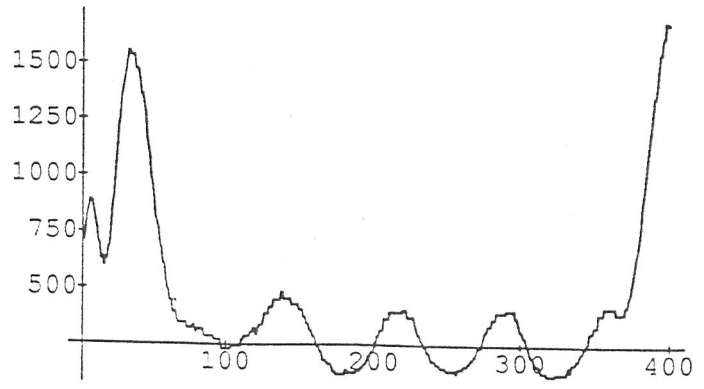



```
-Graphics-

ListPlot[imag,PlotRange ->All]
```

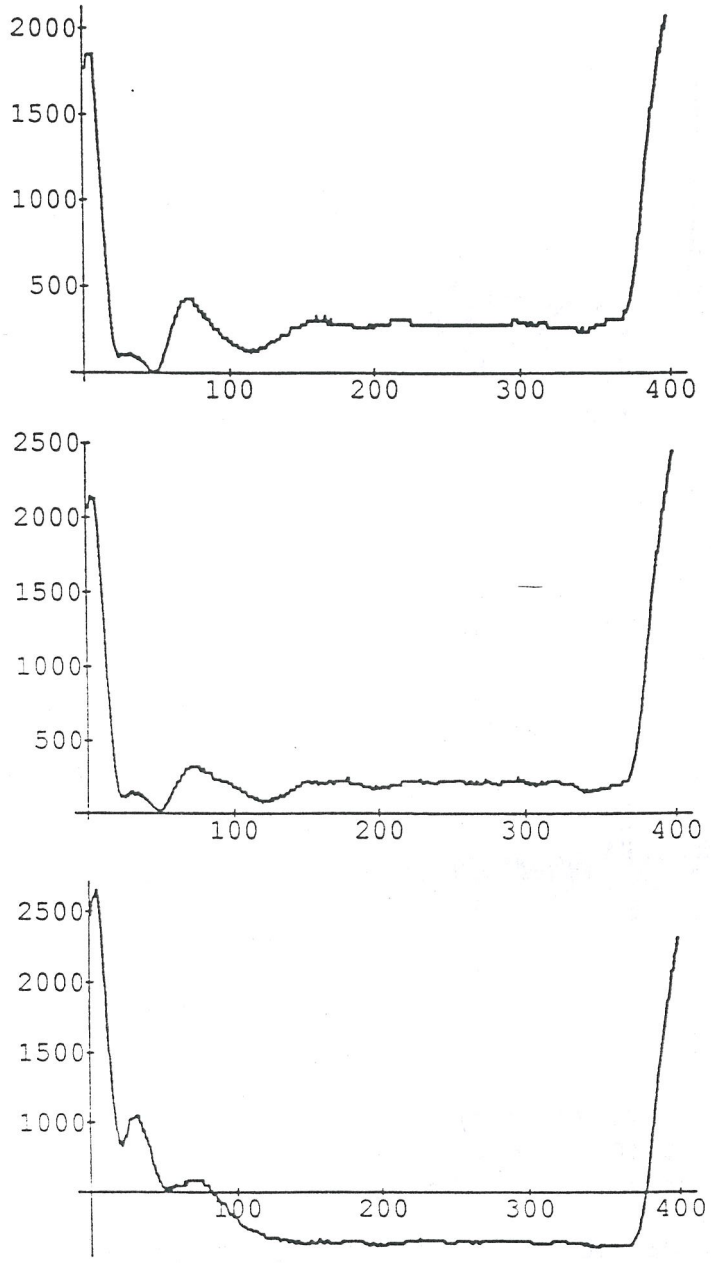



```
-Graphics-

r={}
For[t=0,t<8,i=Take[icorr,{(t 400),((t 400)+399)}];
              q=Take[qcorr,{(t 400),((t 400)+399)}];
              p=(i + I q) (Conjugate[i + I q]);
              r=Append[r,p];
              ListPlot[p,PlotJoined -> True,PlotRange ->All];,t++]
```



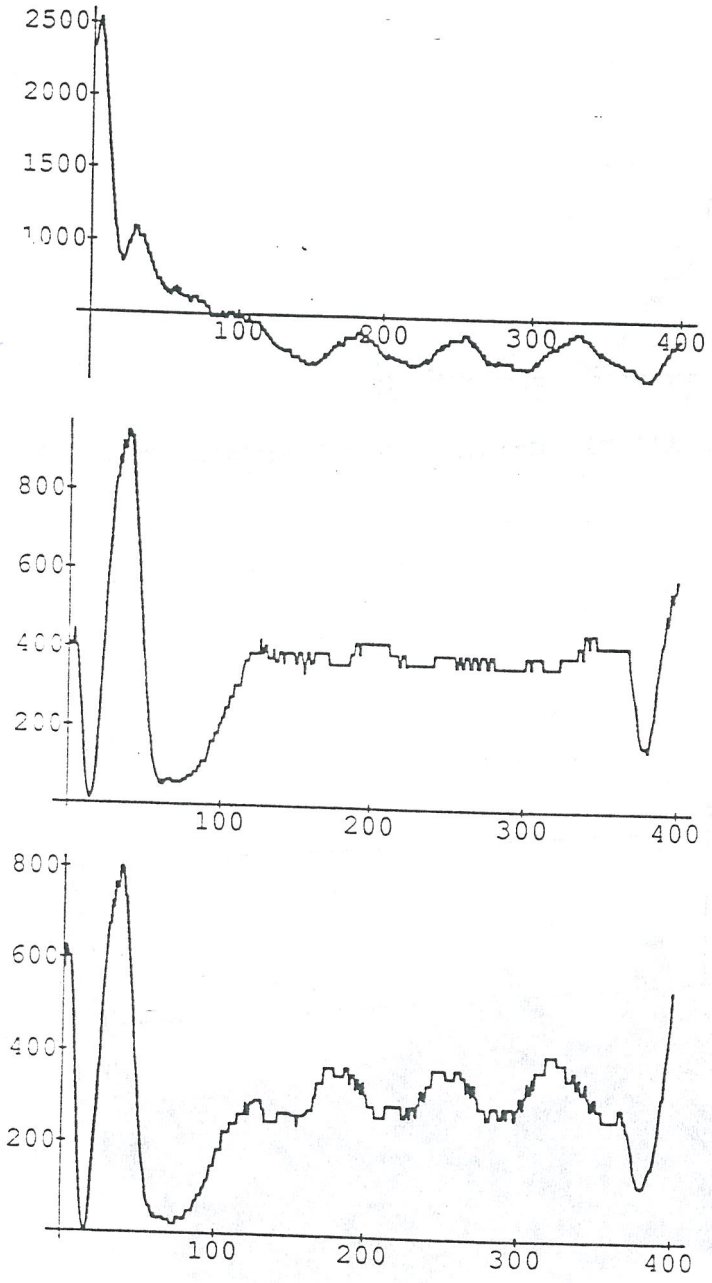
Multiantennae A Impulse Response

Knowledge Implementations, Inc.



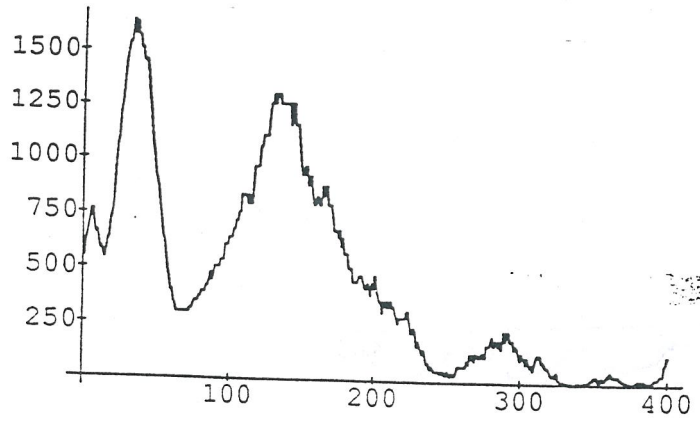
Multiantennae A Impulse Response

Knowledge Implementations, Inc.

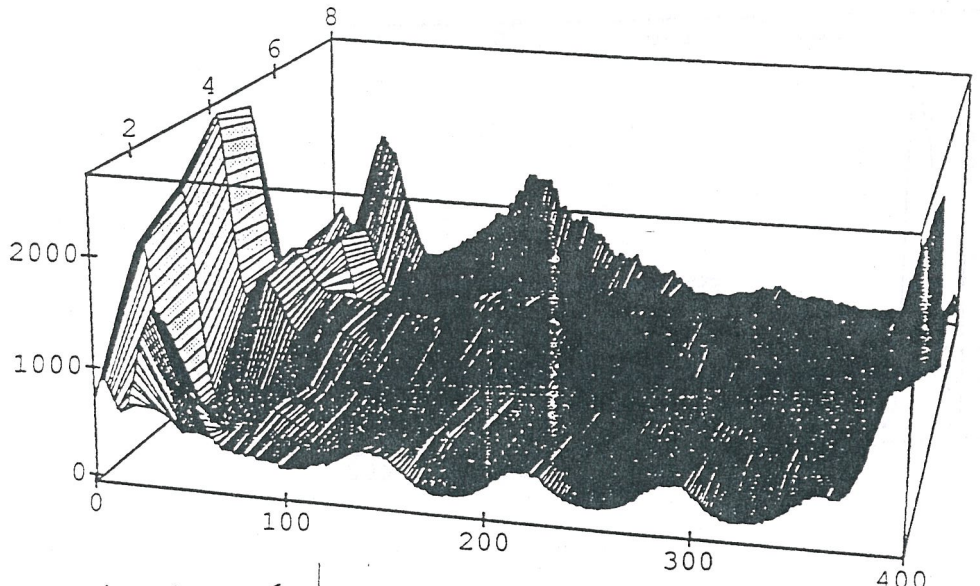


Multiantennae A Impulse Response

Knowledge Implementations, Inc.




```
ListPlot3D[r,PlotRange -> All,PlotColor ->True,ViewPoint->{0.662, -3.
```



ANT 1	.25	MULTIPATH .5 AT 338 NS .3 A 527 NS
ANT 2	.5	MULTIPATH .2 AT 0 NS .8 AT 104 NS .3 AT 216 NS
ANT 3	1	MULTIPATH 1 AT 0 NS .6 AT 73 NS .2 AT 127 NS

```
-SurfaceGraphics-
```

Multiantennae A Impulse Response

ORIGINAL (HARSH)
DISTRIBUTION SYSTEM

4/6/90 8:17 AM Hard Disk:Technical:CIRCUITS:Dist. System Page 1

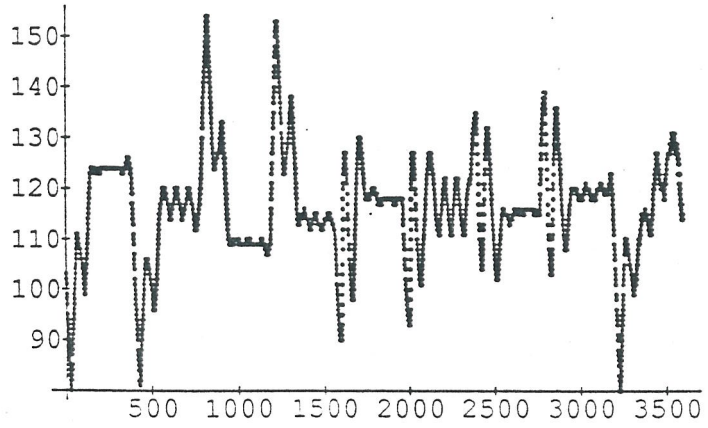
```
*Distribution system simulation

*Antennae One
V2 2 0 SIN 0 1 20MEG 0 0 0
V3 3 0 SIN 0 1 20MEG 0 0 90

*Antennae Two
V4 4 0 SIN 0 1 20.001MEG 0 0 165
V5 5 0 SIN 0 1 20.001MEG 0 0 255

*Antennae Three
V6 6 0 SIN 0 1 19.998MEG 0 0 45
V7 7 0 SIN 0 1 19.998MEG 0 0 135

*Antennae Four
*V8 8 0 SIN 0 1 20MEG 0 0 45
*V9 9 0 SIN 0 1 20MEG 0 0 135

RX2 2 0 10MEG
RX3 3 0 10MEG
RX4 4 0 10MEG
RX5 5 0 10MEG
RX6 6 0 10MEG
RX7 7 0 10MEG
*RX8 8 0 10MEG
*RX9 9 0 10MEG

X1 1 BARKER

E10 10 0 POLY(2) 1 0 30 0  0  0 0   0 1
E11 11 0 POLY(2) 1 0 40 0  0  0 0   0 1

V40 40 0 PWL 0 0 .005U 1 1.995U 1 2.005U 1 3.995U 1 4.005U -1 5.995U -1
+6.005U -1 7.995U -1 8.005U 1 9.995U 1 10.005U 1 11.995U 1
+12.005U -1 13.995U -1 14.005U -1 15.995U -1 16.005U 1 17.995U 1
+18.005U 1 19.995U 1 20.005U 1 21.995U 1 22.005U -1 23.995U -1
+24.005U -1 25.995U -1 26.004U -1 27.995U -1 28.005U 1 29.995U 1
+30.005U -1 31.995U -1 32.005U 1 33.995U 1 34U 1
RX88 40 0 10MEG

V30 30 0 PWL 0 0 .005U 1 1.995U 1 2.005U 1 3.995U 1 4.005U -1 5.995U -1
+6.005U -1 7.995U -1 8.005U -1 9.995U -1 10.005U -1 11.995U -1
+12.005U 1 13.995U 1 14.005U 1 15.995U 1 16.005U 1 17.995U 1
+18.005U -1 19.995U -1 20.005U 1 21.995U 1 22.005U 1 23.995U 1
+24.005U -1 25.995U -1 26.004U 1 27.995U 1 28.005U -1 29.995U -1
+30.005U -1 31.995U -1 32.005U 1 33.995U 1 34U 1
RX89 30 0 10MEG

*Antennae One
E12 12 0 POLY(4) 10 0 2 0 11 0 3 0   0  0 0 0 0   0 1 0 0  0 0 0  0 1

*Antennae Two
E13 13 0 POLY(4) 10 0 4 0 11 0 5 0   0  0 0 0 0   0 1 0 0  0 0 0  0 1

*Antennae Three
E14 14 0 POLY(4) 10 0 6 0 11 0 7 0   0  0 0 0 0   0 1 0 0  0 0 0  0 1

*Antennae Four
*E15 15 0 POLY(4) 10 0 8 0 11 0 9 0   0  0 0 0 0   0 1 0 0  0 0 0  0 1

RX10 10 0 10MEG
RX11 11 0 10MEG
RX12 12 0 10MEG
```

```
RX13 13 0 10MEG
RX14 14 0 10MEG
*RX15 15 0 10MEG

*MEDIA DISTORTION

X12 12 20 MULTIPATH1
X13 13 21 MULTIPATH2
X14 14 22 MULTIPATH3
*X15 15 23 MULTIPATH4

*E25 25 0 POLY(4) 20 0 21 0 22 0 23 0   0     1     1     1     1
*                                          ANT1  ANT2  ANT3  ANT4
E25 25 0 POLY(3) 20 0 21 0 22 0   0     1     1     1
*                                          ANT1  ANT2  ANT3
RX25 25 0 10MEG

*RECEIVER

E50 50 0 POLY(2) 25 0 2 0    0   0 0  0 1
E60 60 0 POLY(2) 25 0 3 0    0   0 0  0 1
R11 50 51 636
R12 60 61 636
C1 51 0 40P
CX2 61 0 40P


.SUBCKT BARKER 3
V3 3 0 PWL 0 -1 5N -1 180.82N -1 182.82N 1 362.64N 1 364.64N -1 726.27N -1
+728.27N 1 908.09N 1 910.09N -1 1453.5N -1 1455.5N 1 1999.0N 1
+2001N -1 2180.82N -1 2182.82N 1 2362.64N 1 2364.64N -1 2726.27N -1
+2728.27N 1 2908.09N 1 2910.09N -1 3453.5N -1 3455.5N 1 3999.0N 1
+4001N -1 4180.82N -1 4182.82N 1 4362.64N 1 4364.64N -1 4726.27N -1
+4728.27N 1 4908.09N 1 4910.09N -1 5453.5N -1 5455.5N 1 5999.0N 1
+6001N -1 6180.82N -1 6182.82N 1 6362.64N 1 6364.64N -1 6726.27N -1
+6728.27N 1 6908.09N 1 6910.09N -1 7453.5N -1 7455.5N 1 7999.0N 1
+8001N -1 8180.82N -1 8182.82N 1 8362.64N 1 8364.64N -1 8726.27N -1
+8728.27N 1 8908.09N 1 8910.09N -1 9453.5N -1 9455.5N 1 9999.0N 1
+10001N -1 10180.82N -1 10182.82N 1 10362.64N 1 10364.64N -1 10726.27N -1
+10728.27N 1 10908.09N 1 10910.09N -1 11453.5N -1 11455.5N 1 11999.0N 1
+12001N -1 12180.82N -1 12182.82N 1 12362.64N 1 12364.64N -1 12726.27N -1
+12728.27N 1 12908.09N 1 12910.09N -1 13453.5N -1 13455.5N 1 13999.0N 1
+14001N -1 14180.82N -1 14182.82N 1 14362.64N 1 14364.64N -1 14726.27N -1
+14728.27N 1 14908.09N 1 14910.09N -1 15453.5N -1 15455.5N 1 15999.0N 1
+16001N -1 16180.82N -1 16182.82N 1 16362.64N 1 16364.64N -1 16726.27N -1
+16728.27N 1 16908.09N 1 16910.09N -1 17453.5N -1 17455.5N 1 17999.0N 1
+18U 1
RX1 3 0 10MEG
.ENDS

.SUBCKT MULTIPATH1 1 2
R1 1 10 50
T1 10 0 11 0 ZO=50 TD=338N
R2 11 0 50
R3 1 12 50
T2 12 0 13 0 ZO=50 TD=527N
R4 13 0 50
E1 2 0 POLY(3) 10 0 11 0 13 0   0  0 .3 .5
RX2 2 0 10MEG
.ENDS

.SUBCKT MULTIPATH2 1 2
```

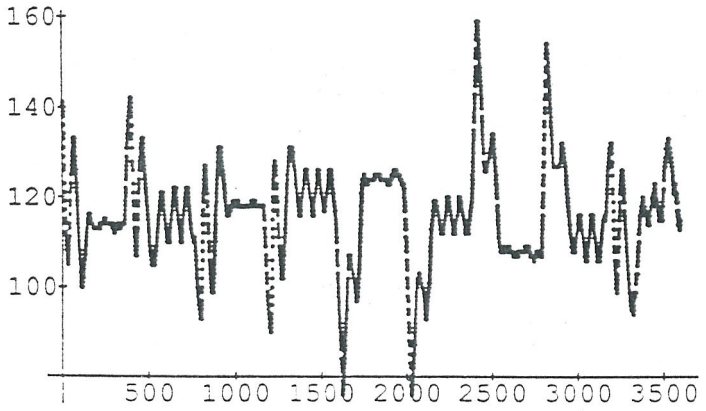
```
R1 1 10 50
T1 10 0 11 0 ZO=50 TD=104N
R2 11 0 50
R3 1 12 50
T2 12 0 13 0 ZO=50 TD=216N
R4 13 0 50
E1 2 0 POLY(3) 10 0 11 0 13 0   0  .2 .8 .3
RX2 2 0 10MEG
.ENDS

.SUBCKT MULTIPATH3 1 2
R1 1 10 50
T1 10 0 11 0 ZO=50 TD=73N
R2 11 0 50
R3 1 12 50
T2 12 0 13 0 ZO=50 TD=127N
R4 13 0 50
E1 2 0 POLY(3) 10 0 11 0 13 0   0  1 .6 .2
RX2 2 0 10MEG
.ENDS

*.SUBCKT MULTIPATH4 1 2
*R1 1 10 50
*T1 10 0 11 0 ZO=50 TD=200N
*R2 11 0 50
*R3 1 12 50
*T2 12 0 13 0 ZO=50 TD=225N
*R4 13 0 50
*E1 2 0 POLY(3) 10 0 11 0 13 0   0  1 1 1
*RX2 2 0 10MEG
*.ENDS

.PROBE
.PRINT TRAN V(51) V(61)
.OPTION ITL5=0
.TRAN 5N 18U
.END
```

Knowledge Implementations, Inc.

```
In[1]:=
  <<DISTIIC.data;

In[2]:=
  <<DISTIQC.data;

  ListPlot[Out[1]]
```



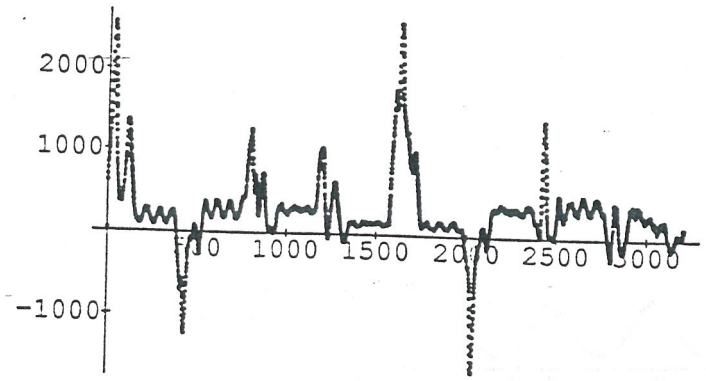

```
  -Graphics-

  ListPlot[Out[2],PlotRange ->All]
```




```
  -Graphics-

In[3]:=
  icorr=Out[1]-127;
  qcorr=Out[2]-127;

In[4]:=
  real=Take[(icorr RotateRight[icorr,400])+(qcorr RotateRight[qcorr,400]

In[5]:=
  imag=Take[(icorr RotateRight[qcorr,400])-(qcorr RotateRight[icorr,400]

In[6]:=
  ListPlot[real,PlotRange ->All]
```

Multiantennae Impulse Response

Knowledge Implementations, Inc.

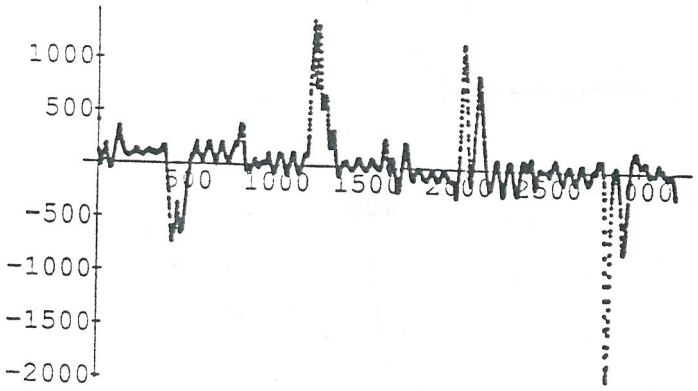


Out[6]=

-Graphics-

In[7]:=

```
ListPlot[imag,PlotRange ->All]
```



Out[7]=

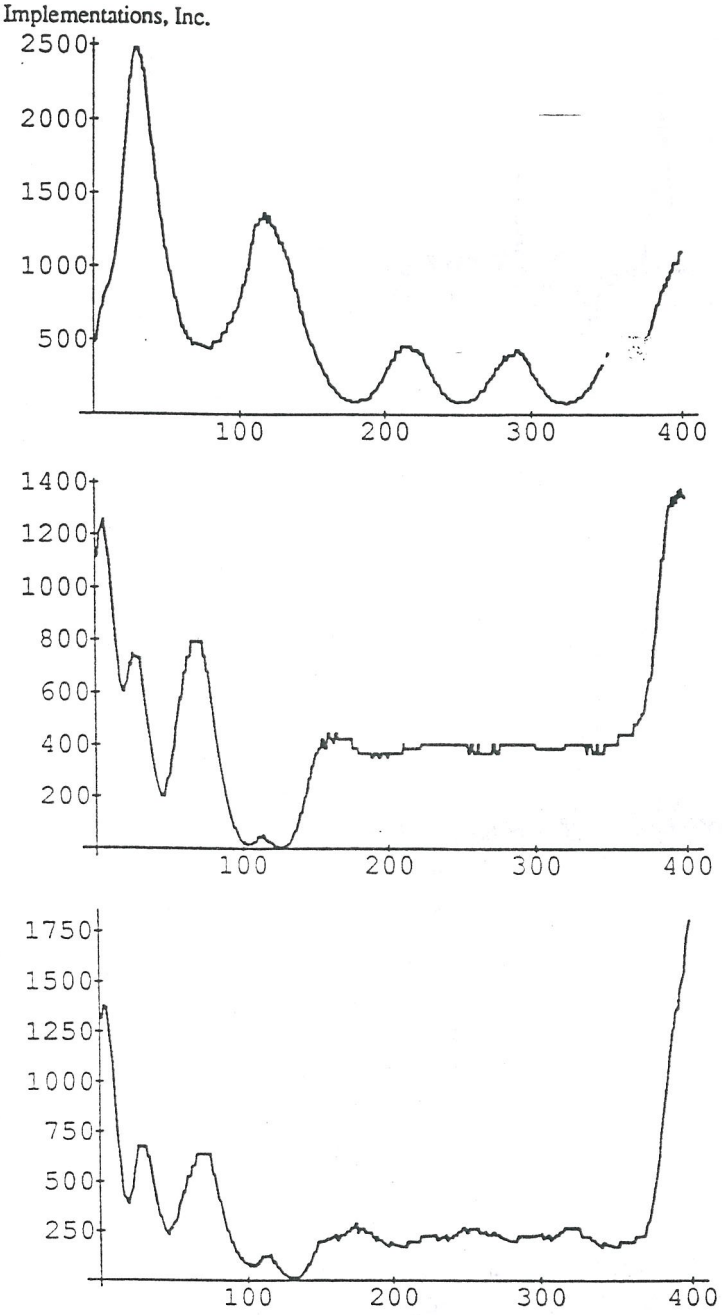
-Graphics-

In[8]:=

```
r={}
For[t=0,t<8,i=Take[icorr,{(t 400),((t 400)+399)}];
            q=Take[qcorr,{(t 400),((t 400)+399)}];
            p=(i + I q) (Conjugate[i + I q]);
            r=Append[r,p];
            ListPlot[p,PlotJoined -> True,PlotRange ->All];,t++]
```

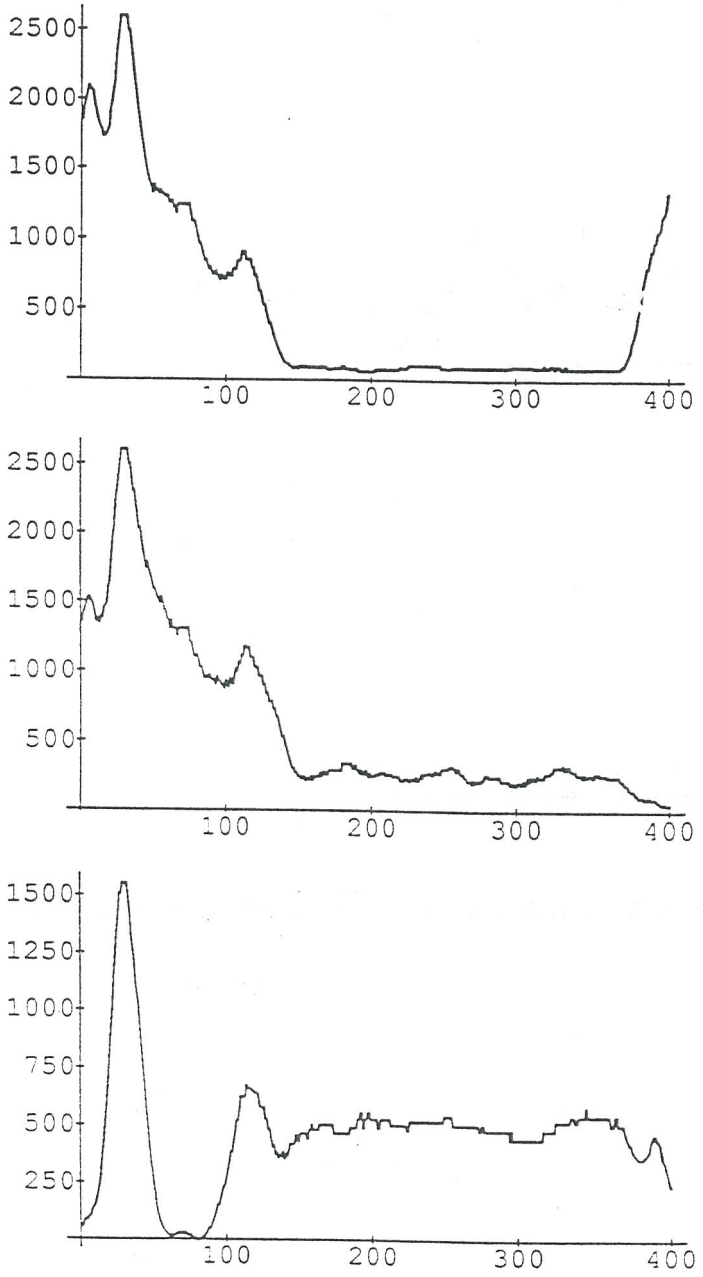
Multiantennae Impulse Response

Knowledge Implementations, Inc.



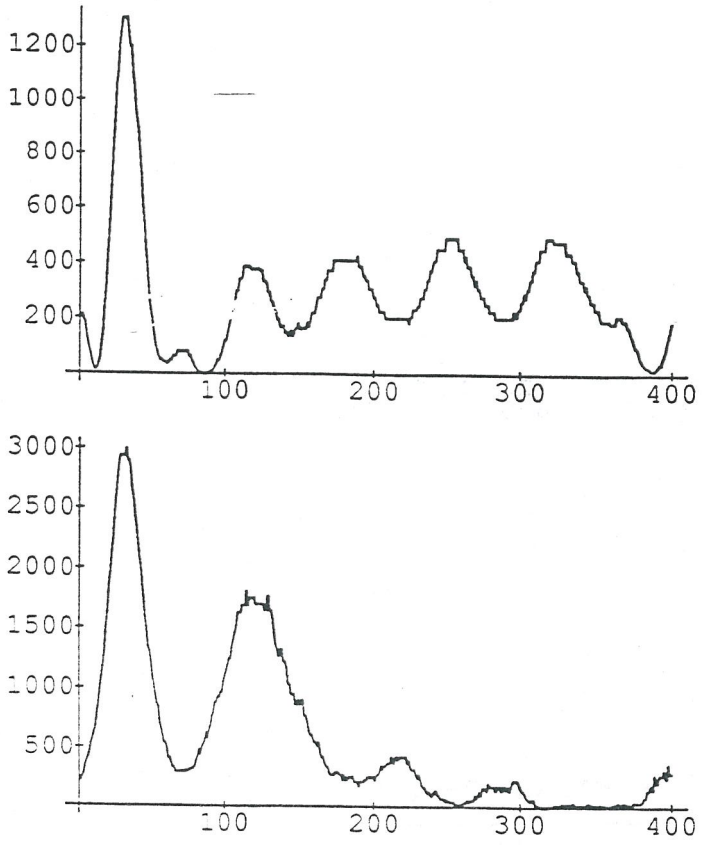
Multiantennae Impulse Response

Knowledge Implementations, Inc.



Multiantennae Impulse Response

Knowledge Implementations, Inc.

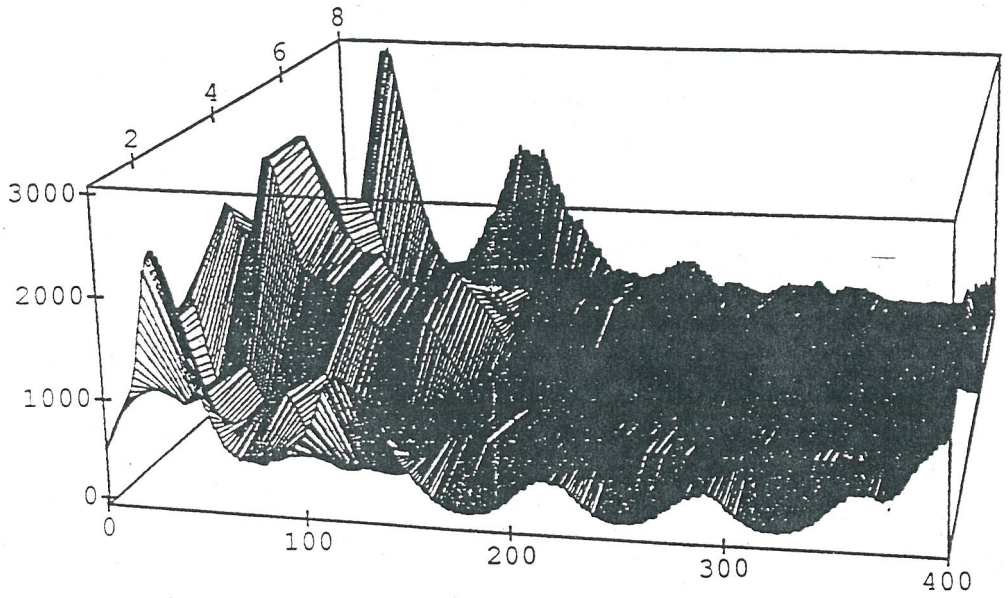


In[9]:=

```
ListPlot3D[r,PlotRange -> All,PlotColor ->True,ViewPoint->{0.662, -3.
```

Multiantennae Impulse Response

Knowledge Implementations, Inc.



THREE ANTENNAE EQUALLY WEIGHTED

FREQUENCY AND PHASE	MULTIPATH DELAYS AND WEIGHTS
1) 20 MEG 0, 70°	338 NS (.3) 527 NS (.5)
2) 20.001 MEG 165, 255°	104 NS (.2) 216 NS (.8)
3) 19.998 MEG 45, 135°	0 NS (1) 73 NS (1) 127 NS (1)

Multiantennae Impulse Response