DECISION-FEEDBACK EQUALIZER SIMULATION (DFES) - DESCRIPTION OF \( \text{ETC(U)} \)
Technical Document 469

DECISION-FEEDBACK EQUALIZER SIMULATION (DFES)
- DESCRIPTION OF VARIABLES

KL Payne
RF & Acoustic Communications Technology Branch
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San Diego, California 92152
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- High frequency
- Equalizer
- Decision-feedback

**ABSTRACT** (Continue on reverse side if necessary and identify by block number)

This document lists and describes the usage of the variables in the Decision-Feedback Equalizer Simulation (DFES) program which was written for the Naval Ocean Systems Center by Signatron, Inc.

The DFES program can transmit QPSK or BPSK through an hf channel. The channel can have fading, doppler and multipath. The transmission can be received and demodulated by a Decision-Feedback Equalizer with one of four weight update algorithms: Kalman, LMS, fixed, and Rake.
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INTRODUCTION

The Decision-Feedback Equalizer Simulation (DFES) program is written in FORTRAN. It simulates LMS (Least Means Squares), Kalman, Rake, and fixed tap versions of high frequency radio channel equalizers. Considerable interest in this program has been shown by other Government laboratories, industry, and universities. It was felt necessary to preserve the following information on DFES in this publication in order to ease the use and/or modification of this complex program by future users.

The material herein includes basic information on every variable in DFES including:

1. Alphabetically arranged descriptions of all variables.
2. Page numbers from the "Program Performance Specification" where more information on each variable may be found.
3. A tabular listing of all variables indicating which subprograms and routines set, use, or output each variable.
4. A listing of subroutines and functions and where they are used in the program.

This document is useful for identifying and locating variables when modifying and/or debugging the program.

In the following sections, DFES refers to the main program which precedes the initialize parameters subprogram.
DFES SUBPROGRAMS

DFES
Initialize Parameters
Update Input
Channel
Interpolator
Noise Filter
Forward Filter
Compressor
Detector
Differential Decoder
FUNCTIONS

ABS
AIMAG
ALOG
ALOG10
AMOD
CABS
CEXP
CMPLX
CONJG
COS
DEXP
ERFC
EXIT
EXP
FLOAT
JABS
MOD
RAN
REAL
SIGN
SIN
SINC
SQRT
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<td>detector</td>
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<td>DPGEN</td>
<td>detector, Sync, Key</td>
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<td>FWATE</td>
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<tr>
<td>GAURAN</td>
<td>channel, Noise</td>
</tr>
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<td>KEY</td>
<td>compressor, Sync</td>
</tr>
<tr>
<td>MAX</td>
<td>Sync</td>
</tr>
<tr>
<td>NOISE</td>
<td>channel</td>
</tr>
<tr>
<td>PIN1</td>
<td>initialize parameters</td>
</tr>
<tr>
<td>SEMUL</td>
<td>initialize parameters</td>
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<tr>
<td>SINC</td>
<td>update input</td>
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<tr>
<td>SYNC</td>
<td>noise filter</td>
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<td>TAPER</td>
<td>channel</td>
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<td>Function</td>
<td>Where Used</td>
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<td>ABS</td>
<td>differential decoder, function sinc</td>
</tr>
<tr>
<td>AIMAG</td>
<td>detector, differential decoder, Fwate, Bfilt, Taper (Rgen)</td>
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<td>ALOG</td>
<td>Gauran</td>
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<td>ALOG10</td>
<td>detector, differential decoder, Semul</td>
</tr>
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<td>AMOD</td>
<td>update input, detector, differential decoder, Parin, Fwate</td>
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<tr>
<td>CABS</td>
<td>channel, differential decoder, noise filter, forward filter, detector, Bfilt, Fwate, Sync, Max</td>
</tr>
<tr>
<td>CEXP</td>
<td>channel, noise filter</td>
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<td>CMPLX</td>
<td>channel, noise filter, detector, Sync, Fwate, Bfilt, Dpgen, Noise</td>
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<td>CONJG</td>
<td>noise filter, detector, differential decoder, Sync, Fwate, Bfilt, Key</td>
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<td>COS</td>
<td>Gauran</td>
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<td>IABS</td>
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<td>MOD</td>
<td>Sync, Pinl, Parin</td>
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<td>RAN</td>
<td>Gauran</td>
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<td>REAL</td>
<td>detector, differential decoder, Fwate, Bfilt</td>
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<td>SIGN</td>
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<td>SIN</td>
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<td>SINC</td>
<td>function Sinc</td>
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<tr>
<td>SQRT</td>
<td>initialize parameters, channel, detector, Noise, Sync, Gauran</td>
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DECISION FEEDBACK EQUALIZER SIMULATION (DFES) PROGRAM (FORTRAN)

1. A

local variable Set DFES
set & used detector output differential decoder Set & used Gauran
Set & used Sync Set & used Taper (Rgen)

A = Transmitted PSK digit (Complex, ARG)

A = (1., 1.) set in DFES

The transmitted PSK digit is then formed by the detector as

A = D

A = D*EJ*AI if LTAPE = 1

Gauran sets A to

A = RAND (NRAN1, NRAN2)

Taper (Rgen) sets

A = D

2. A

array Set & used ERFC
set & used Max

A = Complex array of N elements
3. Al

local variable set DFES
used noise filter set & used Sinc
set & used detector set & used Taper (Rgen)

Previous PSK Digit at Transmitter

Al is the complex previous transmitted PSK digit after encoding used by SNYC to differentially encode its present PSK digit A obtained from DPGEN when IDEC=1.

\[ A = A \cdot A_1 \cdot E_J \]

where \[ E_J = (1+j)/2 \]

The encoded A is then stored in Al for the next iteration. When the acquisition decision is made, the latest value of Al is stored in AHAT1 as the previous detected PSK digit for the first iteration (NUM=1) pass through the Detector and Differential Decoder. Al is updated by SYNC for NA bit symbol iterations.

Al is set in DFES to

\[ A_1 = (1,0, 1,0) \]

Sinc sets Al to The detector sets Al to \[ A_1 = \text{ABS}(\text{PIX}) \]

4. A2

local variable set & used Sinc

A2 is set in Sinc as

\[ A_2 = \text{ABS} (\text{SIN} (\text{PIX})) \]

5. AC

local variable set & used channel

\[ AC = 2(1-EC)EDC \]
6. ADATA
   
   local variable set & used Sync
   
   ADATA is the modulation PSK symbol
   
   Sync sets ADATA to
   
   \[ ADATA = \text{CONJG}(A) \]

7. ADR

   local variable set & used Max

   ADR is set in MAX as

   \[ ADR = \text{CABS}(A(\text{MSET}(I)))/\text{CABS}(A(\text{MSET}(1))) \]

8. AERR

   local variable set DFES used differential decoder

   AERR = .97723

9. AGCLB

   Common block used Pim1

   AGCLB is the AGC bandwidth in Hz, real default = 10.

10. AGCLG

    local variable set, used, & output Parin

    AGCLG = 0.01
11. **AHAT**

local variable

set DFES

set & used detector

used & output differential decoder

used Bfilt

**Detected PSK Digit**

AHAT is the complex detected PSK digit developed by the Detector each bit symbol interaction after the acquisition decision. In the Detector it is used to compute the error E. The DFES main program sets AHAT = 1+j. It is a calling sequence argument of the subroutine BFILT where it is used to form ALPHA(I), I=1,2,...NCB. AHAT has the values ±1±j.

AHAT is set by DFES to

\[
AHAT = (1, \emptyset, 1, \emptyset)
\]

12. **AHAT1**

Local variable

set DFES

set noise filter

set & used differential decoder

AHAT1 is the previous AHAT value

The noise filter sets AHAT1 to

\[
AHAT1 = A1
\]

DFES sets AHAT1 = (1., 1.)

The differential decoder sets AHAT1 to

\[
AHAT1 = AHAT
\]

13. **AIX**

local variable

set & used noise filter

AIX is a constant for the 2 pole Butterworth filter

\[
AIX = AN*CJ
\]

where CJ = CEXP (CMPLX (0., -CX))


14. AKC

local variable
set & used Fwate

Fwate sets AKC to

\[ AKC = \frac{1}{1. - (6.28 \times KFLB / BSR)} \]

15. AL

local variable
set & used Semul

\[ AL = 3. \]

16. ALGOR

local variable
set & used initialize parameters
used channel
used forward filter
used detector

ALGOR = Algorithm type used in Forward Filter weight adaptation
(Integer word for alphanumeric input). ALGOR is either LMS
(Least Mean Square), KAL (Kalman algorithm), or FIX (fixed
weight input). Default = LMS.

Initialize parameters sets ALGOR = NALG
Parin sets ALGOR = LMS, default

<table>
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<th>NALG</th>
<th>Weight Adaptation Method</th>
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<td>1</td>
<td>Least Mean Squares algorithm</td>
</tr>
<tr>
<td>KAL</td>
<td>2</td>
<td>Kalman algorithm</td>
</tr>
<tr>
<td>FIX</td>
<td>3</td>
<td>Weights remain fixed to initialization values</td>
</tr>
<tr>
<td>RAKE</td>
<td>4</td>
<td>Rake equalizer</td>
</tr>
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17. ALPHA
   a) local variable pages (3-37)
      set & used & output noise filter
      \[
      \text{ALPHA} = \frac{\pi}{\sqrt{2}} \frac{\text{BRF}}{\text{RSR}} = \text{normalized filter parameter}
      \]
   b) virtual array Previous chip values
      set & used Sync pages (3-82, 3-96, 3-97)
      Sync sets ALPHA as
      \[
      \text{ALPHA} (I) = (\emptyset, \emptyset),
      \]
      \[
      \text{ALPHA} (I) = \text{ALPHA} (I-\text{NRB})
      \]
      \[
      \text{ALPHA} (I) = \text{PN} (I) \ast \text{ADATA}
      \]
   c) array ALPHA (I) = \text{AHAT} \ast \text{ALPHA} (I),
      I=1,2,\ldots,\text{NCB}.
      set & used Bfilt
      Bfilt sets ALPHA to
      \[
      \text{ALPHA} (I) = \text{CONJG} (\text{PN} (I \ast \text{NRC})
      \]
      \[
      \text{ALPHA} (I) = (0.,0.)
      \]
18. AMAX
   local variable
   set & used Max
   \[
   \text{AMAX} = -1.0
   \]
   \[
   \text{AMAX} = \text{CABS} (A(J))
   \]
19. AN
   local variable pages (3-37)
   set & used noise filter
   \[
   \text{AN} = 2(1-\text{ALPHA})
   \]
20. ARG
   local variable
   set & used Semul
   \[
   \text{ARG} = \text{FLOAT} \left( \frac{I-1}{100} \right)
   \]
   \[
   \text{ARG} = \emptyset / 3 - \text{ALOG} \emptyset (\text{ARG})
   \]
21. ASTEP

   local variable
   used channel
   set PinI

   PinI sets ASTEP to
   ASTEP = 2. * PI * AGCLG/BSR
   and if NA>0 then ASTEP = 2. * PI/NA

22. B

   local variable
   set & used Gauran

   B = RAN (NRAN1, NRAN2)

23. BC

   local variable
   set & used channel

   BC = (1-2EC + 2EC^2) EDC^2

24. BDEL

   local variable
   set & used PinI

   BDEL as set in PinI
   BDEL = RSR / (3. * BRF) + 0.5
25. **BETA**

array  
set DFES  
output update input  
output differential decoder  

DFES sets $\beta(I) = (0, 0, 0)$

**Backward Filter Tap Array**

BETA is a complex array dimensioned BETA (40). For $\text{NALG}=1$ or 2 it is updated each bit symbol iteration following the acquisition decision by the subroutine BFILT in order to form the backward filter output C. For $\text{ALGOR}=\text{FIX}$, the BETA remains fixed at its initial values. Within PARIN the array is indexed as $\beta(I)$, $I=1, 2 \ldots \text{LTAP}$.

BETA is a calling sequence argument of both PARIN and BFILT.

Bfilt sets BETA to

$\beta(I) = \text{CMPLX}(\text{RW}, \text{QW})$

26. **BFLB**

common block  
used Bfilt  
set, used & output Parin  

**Backward Filter Loop Bandwidth in Hz**

BFLB is an input parameter to PARIN with a default of 5. It is used by the subroutine BFILT to compute BSTEP.

27. **BIX**

local variable  
set & used noise filter  

BIX is a constant for the 2 pole Butterworth filter

$\text{BIX} = \text{BN} * \text{CJ}$

where $\text{CJ} = \text{CEXP}(\text{CMPLX}(0, -\text{CX}))$
28. BKC

local variable
set & used Fwate

Fwate sets BKC to

\[ BKC = AKC \times (1 - 1/\text{AKC}) \]

29. BN

local variable
set & used noise filter

\[ BN = 2 \, \text{ALPHA}^2 \]

30. BRF

common block
used noise filter
used Pini
set, used, & output Parin

RF Bandwidth in Hz of 2 Pole Butterworth Filter

BRF is a real input constant to PARIN with a default of 3840. It is used by the Noise Filter subprogram to compute the constants ALPHA and FSPACE.

31. BRMS

array
set DFES
used channel
set, used, & output Parin

Channel Tap Gain Doppler Spectrum Standard Deviation

BRMS is a real array, dimensioned BRMS(4) used by the Channel subprogram in updating the Channel Tap Gain array H(I). Indexing is BRMS(I), I=1,2,...CTAP. Its values remain fixed to the initial values input by the subroutine PARIN. The default is BRMS(I)=0, I=1,2,...CTAP.
BSR

common block
used Initialize parameters
used channel
used noise filter
used differential decoder
used Bfilt
used Fwate
used Noise
used Pini Set, used, & output Parin

Bit Symbol Rate in Hz

BSR is a real input constant to the subroutine Parin with a default of 2400. It is used in Parin to compute

\[ NTB = \frac{TSR}{BSR} \]
\[ NRB = \frac{RSR}{BSR} \]
\[ NCB = \frac{CSR}{BSR} \]

Initialize parameters uses it to set

\[ \Sigma = \sqrt{\frac{TSR}{(BSR \times 2 \times SNR)}} \]

The channel uses BSR to compute

\[ DC = 2 \times PI \times \frac{DOP(J)}{BSR} \]
\[ EC = 2 \times PI \times \frac{BRMS(J)}{(BSR \times SQ2)} \]

The noise filter uses it to set

\[ VS = 2 \times PI \times NFLB \times RSR / (BSR \times BRF \times NRB) \]

The differential decoder computes

\[ DR = 2 \times BSR \times (1 - FLOAT(KADAPT) / KRST) \]

Bfilt uses it to set

\[ BSTEP = 2 \times PI \times BFLB / BSR \]

Fwate uses BSR to set

\[ AKC = 1 / (1 - (6.28 \times KFLB / BSR)) \]

Noise uses it to compute

\[ SVAR = TSR / (2 \times BSR \times SNR) \]

Pini uses BSR to compute

\[ DELTA = 2.0 \times PI \times FFLB / BSR \]
\[ ASTEP = 2 \times PI \times AGCLB / BSR \]
\[ ESTEP = 2 \times PI \times MSELB / BSR \]
\[ KDEL = 2 \times PI \times RGLB / BSR \]
33. BSTEP

local variable set, used, & output Bfilt

\[ \text{BSTEP} = \frac{2n \cdot \text{BFILT}}{\text{BSR}}. \]

34. C

local variable set & used detector output differential decoder

Backward Filter Output

C is the complex backward filter output argument returned by BFILT. It is used by the Detector to form the predecision sample

\[ Z_C = Z + C \]

The detector sets \( C = (0., 0.) \)

Bfilt sets \( C \) as

\[ C = (0., 0.) \]

\[ C = C + \text{BETA}(I) \cdot \text{CONJG}(\text{GBACK}(\text{JSET}(I))) \]

35. CAS

Noise filter mode indicator

local variable set DFES used forward filter
used noise filter set & output Parin

CAS is set \( CAS = \emptyset \) in DFES and Parin

36. CC

local variable set & used channel

\[ CC = 2EC / 2EC(1-EC)EDC \]
37. CIX

   local variable set & used noise filter
   pages (?-38)

   constant for 2 pole Butterworth filter

   CIX = CN * CJ * CJ

   where CJ = CEXP (CMPLX (0.,-CX))

38. CJ

   local variable set & used noise filter

   CJ is set in the noise filter as

   CJ = CEXP (CMPLX (0.,-CX)),
   CJ = (0.,0.),
   and CJ = CJ + PN(K) * XFREQ

39. CLEAR

   local variable set & used filter

   CLEAR = 0.
   CLEAR = 1.

   if CABS (W(I)) > 0.2 then CLEAR = 0.

40. CMAG

   local variable set & used filter

   CMAG is set in the noise filter as

   CMAG = CABS (V(I))

41. CN

   local variable set & used noise filter
   pages (3-37)

   CN = 1-2 ALPHA + 2 ALPHA^2
42. CON

**Local variable**

**Set & used by Fwate**

\[
\begin{align*}
\text{CON} & = \left( \sum_{i=1}^{\text{NTAP}} \text{SBAR}(i) \sum_{i=\text{NTAP}+1}^{\text{NLATAP}} \text{GBACK} \left( \text{JSET}(i-\text{NTAP}) \right) \right) \times \text{VKAL}(i) \times \text{BKC} \\
\text{Fwate sets CON to} & \quad \text{CON} = (0, 0)
\end{align*}
\]

if \( I \leq \text{NTAP} \) then

\[
\text{CON} = \text{CON} + \text{CONJG} \left( \text{SBAR}(I) \right) \times \text{VKAL}(I) \times \text{BKC}
\]

IF \( I > \text{NTAP} \) then

\[
\text{CON} = \text{CON} + \text{CONJG} \left( \text{GBACK} \left( \text{JSET}(I-\text{NTAP}) \right) \right) \times \text{VKAL}(I) \times \text{BKC}
\]

43. CSR

**Common block**

**Pages (3-6 back, 3-12, 3-55, 3-57, 3-58, 3-66)**

**Set, used, & output by Parin**

**Chip Symbol Rate in Hz**

CSR is a real input constant to the subroutine PARIN. It has a default of 96K and must be an integer multiple of BSR.

44. CTAP

**Common block**

**Pages (3-17 back, 3-12, 3-15, 3-17, 3-21, 3-23, 3-28, 3-54, 3-55, 3-58, 3-59, 3-60)**

**Set, used, & output by Parin**

**Number of Discrete Channel Paths**

CTAP is a fixed integer input to the PARIN subroutine with a default of 1. It has the range \( 1 \leq \text{CTAP} \leq 4 \). If the input value of CTAP is greater than 4, PARIN forces CTAP=4. The channel subprogram uses CTAP as the size of the channel arrays H, DELAY, BRMS, POW, DOP, and KSET. The Initialize Parameters subprogram uses it to set the size NQ of the receiver input array Q as

\[
\text{NQ} = \text{NTB} + \text{INT} - \text{NTR} + \text{KSET(CTAP)}
\]
45. CVAR

local variable
set channel

Channel Variance

CVAR is the variance used by the Channel subprogram as an argument to the random number generator subroutine GAURAN. It is set to the real value

CVAR = \text{POW}(J)/2

46. CX

local variable
set & used noise filter

CX is set as

CX = 2. * PI * I*FSPACE / RSR
Transmitted PSK Digit

D is the complex transmitted PSK digit, before encoding, returned to the Detector by DPGEN. It has the values \( \pm 1 \pm j \). The Detector uses it to set the transmitted PSK symbol \( A = D \). The Differential Decoder uses it in a comparison with DHAT to update the error counter ERROR.

The following process is performed twice to generate the real \( D(1) \) and imaginary \( D(2) \) parts of the complex output.

(a) The high order bit I is extracted from MWORD.

(b) MWORD is shifted one place to the left by extracting the low order 31 bits and multiplying the result by 2.

(c) If the extracted bit I is a 1, MWORD is replaced by an exclusive OR of MWORD and JWORD.

(d) For I = 1, \( D(J) = +1 \)

For I = 0, \( D(J) = -1 \).

The detector sets D to

\( D = A \) if IDEC = 0

Dpgen sets D to

\( D(J) = MSIGN \)

48. DC

local variable
set & used channel

DC is set in the channel as

\[ DC = 2 \times \pi \times DOP(J) / BSR \]
49. DELAY

array pages (3-21 back, 3-13, 3-17, 3-21, 3-23, 3-28, 3-54, 3-59)
set, used, & output Parin

Channel Tap Delays in Seconds

DELAY is a real array of size DELAY (4) used by the channel subprogram in updating H(I), I=1,2,--CTAP.

Indexing is DELAY (I), I=1,2,--CTAP. Its values remain fixed to those input by the subroutine PARIN. The default is

\[ \text{DELAY (I)} = \frac{I-1}{2400}, \]

\[ I = 1, 2, \ldots \text{ CTAP} \]

50. DELTA

local variable output update input
set Pin1 used Fwate

LMS Algorithm Step Size

Pin1 sets DELTA to

\[ \text{DELTA} = 2^n \frac{\text{FFLB}}{\text{BSR}}. \]

It is the calling sequence argument for the LMS algorithm step size used by FWATE to compute the weight vector W.

51. DERR

local variable set & used differential decoder

\[ \text{DERR} = \text{ERROR} \]
52. DHAT

Detected source digit

local variable set detector
set, used, & output differential decoder

The differentially decoded PSK digit is given by

\[ DHAT = \text{AHAT} \times \text{CONJG(EJ)} \times \text{CONJG(AHAT1)} \]

The detector defines DHAT as

\[ DHAT = \text{AHAT} \]

53. DOP

array set DFES
used channel
set, used, & output Parin

Doppler Shift in Hz

DOP is a real array dimensioned DOP(4) used by the channel sub-
program in updating the array H. Indexing is DOP(I), I=1,2,--CTAP. DOP
is a fixed real parameter input to PARIN, with a default of

\[ DOP(I)=0, I=1,2,--CTAP. \]

54. DR

local variable set & used differential decoder
used Max

DR is the Dynamic Range Threshold.

The differential decoder sets DR as

\[ DR = \emptyset \]

if \( ERROR \neq \text{DERR} \) then \( DR = \text{DERR} - \text{ERROR} \)
55. DRATE

local variable pages (3-51, 3-52)
set & output differential decoder

DRATE is the transmitted data rate calculated as

\[ DRATE = 2 \times BSR \times (1. - \text{FLOAT(KADAPT)} / \text{KRST}) \]

by the differential decoder.

56. E

local variable pages (4-2 back, 3-13, 3-46 to 3-48, 3-58, 3-95)
set DFES
set & used detector
used Bfilt

DFES sets E to

\[ E = (0.0, 0.0) \]

Adaption Error Sample

E is the complex error sample computed each bit symbol iteration by
the Detector according to the values of PSK and REF. The Detector also
uses E to update the mean square error MSE.

The detector sets E to

\[ E = A-ZC \]
\[ \hat{e} = \text{AHAT-AC} \]
\[ E = \text{CMPLX(RE,QE)} \]
\[ E = E/2 \]
\[ E = E \times \text{EMUL (IERR)} \]

57. EBER

local variable pages (3-47, 3-48)
set, used & output detector

EBER = Estimated bit error rate

\[ EBER = 0.5 \times \text{ERFC}(\rho) \]

58. EC

local variable
set & used channel

\[ EC = 2\pi(\text{BRMS}(J)) / \sqrt{2BSR} \]
59. EDC

    local variable
    set & used channel

    EDC = CEXP (CMPLX (Ø.,-DC))

60. EDEL

    local variable
    set Sync

    EDEL is set by Sync to

    EDEL = FLOAT (INEXT - IMAX) / RSR

61. EJ

    local variable
    set initialize parameters
    used detector
    used differential decoder
    set & used Sync
    set & used Key
    set & used Taper (Rgen)

    EJ = (1.,1.)/2 in initialize parameters, Sync, Key, and Taper (Rgen)

    EJ = (1+j)/2

62. EMSE

    local variable
    set & used Fwate

    EMSE is set in Fwate to

    EMSE = 1. or EMSE = Ø.1

63. EMUL

    array
    set DFES
    set & output Semul

    EMUL(1) = 1.Ø Set in DFES

    In Semul, EMUL is set to

    EMUL(1) = 1.
    EMUL(1) = 1.-SUM * EXP(-AL * ARG)
64. ERFC

local variable

set Erfc

Erfc sets ERFC = SUM

The function computes

$$\text{ERFC}(x) = \frac{2}{\sqrt{\pi}} \int_{x}^{\infty} e^{-y^2} dy, \quad x \geq 0$$

Using the series approximation

$$\text{ERFC}(x) \approx \sum_{i=1}^{5} A(i) * T^i * e^{-X^2}$$

65. ERROR

local variable

set DFES

pages (3-13, 3-50, 3-51)

set, used & output differential decoder

Error is the total number of errors.

ERROR = 0. Bit error counter set in DFES

The differential decoder sets ERROR to

ERROR = ERROR + 1 in certain cases

66. ESNR

local variable

set, used & output detector

pages (4-3 back, 3-47, 3-48)

Estimated Signal to Noise Ratio

ESNR is the real variable for the estimated SNR computed each bit symbol iteration by the Detector as

$$\text{ESNR} = \frac{1-MSE}{\sqrt{2} \times \text{MSE}}$$

The detector sets ESNR to

ESNR = -9.99E + 32

ESNR = 20. * ALOG10 (ESNR)
67. ESTEP

local variable
used detector
set Pin1

The step size for averaging the mean square error is computed

\[ \text{ESTEP} = \frac{2\pi(MSELB)}{\text{BSR}}. \]

68. F

local variable
used noise filter
set & used detector
output differential decoder

Modified Adaptation Error Sample

The Detector computes the complex error \( F = \frac{E}{\text{NCB}} \) to be used as a calling sequence argument for FWATE and BFILT where it is used in updating \( W \) and \( \text{BETA} \) respectively.

The detector sets \( F \) to

\[ F = E \]

69. FFLB

common block
set, used, & output Parin
used Pin1

Forward Filter Loop Bandwidth in Hz

FFLB is an input parameter to the subroutine PARIN with a default value of 5.

70. FIX

fixed weight input

local variable
used Parin
algorithm

no numerical value, determines algorithm
71. FSPACE

local variable pages (3-37)
set, used, & output noise filter

\[ FSPACE = \frac{BRF}{2} = \text{Spacing between filter center frequencies} \]

72. GBACK

array pages (3-22 back, 3-88, 3-89, 3-96)
used Fwate to 3-98
set Bfilt

**Backward Filter Signal Array**

GBACK is a complex array dimensioned GBACK(40). It is updated each bit symbol iteration with the latest PSK decision and chip values by the subroutine BFILT which uses it to compute the backward filter output C. The subroutine FWATE uses the updated GBACK in computing the variable CON and array VKAL in the Kalman algorithm adaptation. GBACK is a calling sequence argument of the subroutines BFILT and FWATE. It is indexed as GBACK(JSET(I)). \( I = 1, 2, \ldots, \text{LTAP} \).

Bfilt sets GBACK to

\[
\begin{align*}
\text{GBACK(JSET(I))} & = (0, 0), \\
\text{GBACK(JSET(I))} & = \text{GBACK(JSET(I))} + \text{CONJG(PN(J*NRC))} \\
& \quad \times \text{CONJG(ALPHA(J + JSET(I)-1))/NCB}
\end{align*}
\]
73. GCON

common block
set DFES
output update input
set & used channel
used interpolator
output detector
set, used, & output Sync
set & used Parin

Gain Control Constant

When the bit synchronization subroutine SYNC is required for
acquisition (NA > 0 and SMODE = 0), GCON is computed recursively for
IBS = NA iterations. The initial value of GCON is 1 set in DFES. If
NA = 0, which forces SMODE = 1, GCON is an input parameter to the sub-
routine PARIN. Whenever SMODE = 1, the value of GCON remains fixed.

The channel sets GCON to
GCON = (.-.-ASTEP)*GCON+ASTEP/SQRT(SPOW)

Sync sets
GCON = GCON/SQRT(SUM*2.)

Parin sets
GCON = 1 if GCON = Ø

74. H

array
set DFES
set, used, & output channel
set, used, & output Parin

Channel Tap Gain

H is a complex array dimensioned H(4) for the channel subprogram
and redefined as a real array H(8) in the parameter input subroutine
PARIN. Initial values are input by PARIN with the default H(1)=1, all
other H(I)=0. Indexing is H(I), I-1,2,---CTAP. The array H is updated
each bit symbol iteration for ICHAN≠0.
75. HD

Previous channel value
array pages (3-27)
set DFES
set & used channel
set Parin

The channel subprogram sets HD as

\[ HD(J) = YC \]

and the initial values of the channel are stored, i.e.,

\[ HD(I) = H(I), I=1,2,...NCTAP2 \]

as set in Parin DFES initially sets HD to

\[ HD(I) = (0.0, 0.0) \]
\[ HD(1) = (1.0, 0.0) \]

76. HP

Preset channel value
array
set DFES
set & used channel
set Parin

Parin sets HP to

\[ HP(I) = H(I) \quad \text{where} \quad I = 1,NCTAP2 \]

DFES initially sets HP to

\[ HP(I) = (0.0,0.0) \]
\[ HP(1) = (1.0,0.0) \]

The channel sets

\[ HP(J) = H(J) \]
77. I

local variable
used DFES
set & used initialize parameters
set & used differential decoder
set & used update input
set & used interpolator
set & used noise filter
set, used, & output forward filter
set, used, & output compressor
set & used Taper (Read)
set & used Noise
set & used Erfc
set & used Parin
set & used Fwate
set & used Sync
set & used Bfilt
set & used Max
set, used, & output Semul
set & used Dpgen
set & used Pini

example

I = 1, 2, ..., MTAP.

78. IBDEL

local variable
used & output update input
used forward filter
used Fwate
set Pini

IBDEL is set in Pini to

IBDEL = BDEL

79. IBETA

algorithm
local variable
set & used Parin

IBETA = Initial BEAT (I) value flag (Integer).

IBETA = 0, BETA (I) = default values.

IBETA = 1, BETA (I) from hand input.
80. IBLOCK

local variable
set, used, & output Taper (Read)

Taper (Read) sets IBLOCK to

IBLOCK = 0 and IBLOCK = IBLOCK + 1

81. IBRMS

local variable
set & used channel

Channel sets IBRMS to

IBRMS = 0 and IBRMS = 1

82. ICH

array pages (4-3 back, 3-16, 3-65)
set Pin1
used Taper (Rgen)

Tape Simulator Chip Shift Register

ICH is the integer shift register for the signal tape simulator subroutine TAPER (file name RGEN). It is set to its starter value by the Initialize Parameters subprogram

ICH = ICHIP

TAPER-RGEN uses it in the call to DPGEN to generate the chip values.

Pin1 sets ICH to

ICH(I) = ICHIP(I)
ICH(I+16) = ICHIP(I+16)

83. ICHAN

local variable pages (3-14, 3-16)
set DFES
used channel
used Parin

If ICHAN = 1 indicating a non ideal channel situation.

If the default condition for the CHANNEL subprogram (3.4.3) is detected ICHAN = 0.
84. ICHIP

array
set, used & output Pin1
used Key

Receiver Chip Shift Register

ICHIP is the integer shift register for the receiver chip data
generation of the PN sequence.

Pin1 sets ICHIP to

ICHIP(I) = MOD(IL,2)
ICHIP(I+16) = MOD(IH,2)

85. ICHP

local variable
used Taper (Rgen)

86. IDATA

array
used & output Taper (Read)

87. IDEC

common block
used detector
used differential decoder
used Sync
used Taper (Rgen)
set Parin

Differential Decoder Indicator

Parin sets IDEC = 1 for REF=0, and IDEC=0 (no decoding required)
for REF ≥ 1. When IDEC=1, the error rate is recalculated as

RATE=RATE/2

If IDEC=1, the Differential Decoder must decode to obtain DHAT and
the SYNC subroutine must encode the bit symbol returned by DPGEN.
88. IDEL1

Local variable pages (3-16)
set DFES
Tape Simulator Previous PSK Symbol

DFES sets IDEL1 to

\[ IDEL1 = (1.0, 1.0) \]

89. IDOP

Local variable
set & used channel

IDOP is set in channel as

\[ IDOP = \emptyset \text{ and } IDOP = 1 \]

90. IEOF

Local variable pages (3-63, 3-64)
set & used Taper (Read)

IEOF = 0 End of file indicator returned by TREAD.

Taper (Read) sets IEOF = \emptyset

91. IEOT

Local variable
set DFES
used channel
set Noise

IEOT is set

IEOT = \emptyset in DFES and NOISE

= 1 for end of NOISE(Tape)
92. **IERR**

   local variable  
   set DFES  
   used detector  
   set & used differential decoder  
   set, used, & output Taper (Read)  

   \[
   \text{IERR} = 1 \text{ in DFES}  
   \text{IERR} = 0 \text{ in Taper (Read)}  
   \text{IERR} = \text{XERR} + 1 \text{ in differential detector}  
   \text{and if IERR > 50, IERR = 50}  
   \]

93. **IFIX**

   local variable  
   used Parin  
   integer 'FIX'  

   no numerical value, determines algorithm

94. **IH**

   local variable  
   set & used Pin1  

   \[
   \text{IH} = 24329 \text{ in Pin1}  
   \text{and}  
   \text{IH} = \text{IH}/2  
   \]

95. **II**

   LOCAL VARIABLE  
   SET & used noise filter  

   IT is set in the noise filter as  

   \[
   \text{IT} = I-NV  
   \]

96. **IK**

   local variable  
   set & used Fwate  

   IK is set in Fwate as  

   \[
   \text{IK} = \text{ISET}(I) + K + \text{IBDEL}  
   \]

35
97. **IL**

local variable set & used Pin1

IL is set in Pin1 to

\[ IL = 1432 \]

and

\[ IL = IL/2 \]

98. **IMAX**

local variable set, used, & output Sync

IMAX is set to \( IMAX = 1 \)

and

\[ IMAX = MSYNC(1) \] in Sync

99. **IMIN**

local variable set & used Sync

IMIN is set in Sync to

\[ IMIN = 9999 \]

100. **INC**

local variable set & used Sync

Sync sets INC to

\[ INC = 0, \]

\[ INC = INC + 1, \]

and

\[ INC = LM \]

101. **INCH**

local variable set & used Parin

\begin{align*}
\text{INCH} & = \text{Input Channel Flag (Integer).} \\
0 & = \text{Channel default parameter values used.} \\
1 & = \text{Channel parameter values from hand input.}
\end{align*}
102. **INEXT**

Local variable, set, used, & output Sync

INEXT is set by Sync to

\[ \text{INEXT} = 1 \]

and

\[ \text{INEXT} = \text{MSync}(2) \]

103. **INT**

Common block, used initialize parameters, used update input, set, used, & output Parin

Number of Interpolator Samples

INT is an input parameter to the subroutine PARIN. It is an odd integer of range \(1 \leq \text{INT} \leq 11\) with a default of 5. The Initialize Parameter subprogram uses it to set the Interpolator half span interval INT1, the length NQ of the input array Q and the length NR of the receiver sample array R as follows:

\[
\begin{align*}
\text{INT1} &= (\text{INT} - 1)/2 \\
\text{NQ} &= \text{NTB} + \text{INT} - \text{NTR} + \text{KSET (CTAP)} \\
\text{NR} &= \text{NTB} + \text{INT} - \text{NTR}
\end{align*}
\]

In the bit symbol iteration processing it is used to set the number of additional input samples NRQ to be provided by the subroutine TAPER for \(\text{IBS} = 1\) to

\[
\text{NRQ} = \text{INT} - \text{NTR}
\]

The Initialize Parameters subprogram will reset INT for \(\text{INT} < \text{NTR}\) to \(\text{NTR} + 1\) for \(\text{NTR}\) even or \(\text{NTR} + 2\) for \(\text{NTR}\) odd. From that point on the value of INT remains fixed.

Parin sets INT to

\[ \text{INT} = ((\text{NTR}+1)/2) \times 2 + 1 \]

104. **INT1**

Common block, set initialize parameters, used update input, used interpolator

\[ \text{INT1} = (\text{INT}-1)/2 \text{ Interpolator half span} \]
105. INV

local variable set & used Parin

INV = Input V(I) value flag (Integer).
INV = 0, V(I) = default values.
INV = 1, V(I) from hand input.

*Line 22: INV

0 = default V(I) values
1 = hand input of V(I) values

This line is input only for MTAP > 1

106. IP

local variable set & used Taper (Rgen)

IP is set

IP = ICHP * EJ by Taper(Rgen)

107. IPLUS

local variable set & used Sync

Sync sets IPLUS = 0 and IPLUS = 1

108. IPOS

local variable set & used Taper (Read)

IPOS is set to IPOS = 0 and IPOS = 3 by Taper(Read)

109. IPRIN

local variable set update input used channel used interpolator used compressor used noise filter

IPRIN = Print parameter from UPDATE INPUT (3.4.2). (Integer).
IPRIN = 0 Output print flag
110. IQ

local variable
set & used interpolator

The interpolator sets IQ as

\[ IQ = 1 + \text{INT1} + 1 \]

111. IQSET

local variable
set initialize parameters
set & used update input
set noise filter

IQSET is set IQSET = 0 by Update Input.

The flag IQSET is set to IQSET = 1 in the initialize parameters.

IQSET=SMODE as set in the noise filter.

112. IRAKE

algorithm

local variable
used Parin

IRAKE indicates the 'RAKE' algorithm—RAKE equalizer
113. ISET

array used initialize parameters
used & output update input
used & output forward filter
used Fwate
set, used, & output Sync
set & used Parin

Transversal Filter Delay

ISET is an integer array of non-negative values dimensioned
ISET(100). It may be input by PARIN or computed by the subroutine SYNC,
after which its values remain fixed. ISET(1) defines the main tap of
the forward filter and is used by the Initialize Parameters subprogram
to compute the parameter

$$NSHIFT = NTR*ISET(1)$$

Indexing is ISET(I), I=1,2,--NTAP. In the Forward Filter subprogram
ISET(I) is used in the index value of X for computing the forward filter
output Y. The subroutine FWATE also uses ISET(I) in index value of X
for updating the array SBAR. ISET is a calling sequence argument of the
subroutines SYNC, FWATE, and PARIN.

ISET(1) defines main tap of forward filter.

114. ISMAX

local variable set & used update input

The span of the forward filter is computed as

$$ISMAX = \max_I ISET(I)$$

Update input sets ISMAX to

$$ISMAX = \emptyset$$

$$ISMAX = ISET(I)$$ if $$ISNR(I) > ISMAX$$

115. ISNR

local variable set DFES
used Parin

ISNR is set in DFES to the values SNR is to be set at.
116. **IT**

   local variable
   set initialize parameters
   used Semul

   Initialize Parameters sets IT as
   
   IT = KFLB

117. **ITRY**

   local variable
   set & used Taper (Read)
   set & used Parin

   ITRY is set by Taper (Read) as
   
   ITRY = 0 and ITRY = ITRY + 1
   
   Parin sets ITRY to
   
   ITRY = 0 and ITRY = 1

118. **IW**

   local variable
   set & used Parin

   IW = Initial Weight Value flag (Integer)
   
   IW = 0, W(I) = default values.
   IW = 1, W(I) initial values from hand input
119. IX

local variable          pages (3-18, 3-36, 3-37)
set and output initialize parameters
used noise filter

The number of bit symbol iterations to be executed with no signal
present is computed.

If NOSIG = 0 (Signal Present), IX = 0
If NOSIG = 1 (Signal Absent), IX = \frac{3(BSR)}{2n(NFLB)}

The simulation automatically cycles through

IX = \left\lfloor \frac{3*RSR}{2n*NFLB*NRB} \right\rfloor
\times x \leq [x] < x + 1, [x] integer

The NOISE Filter also has the number of adaptation cycles input from
UPDATE INPUT (3.4.2);
IX = \frac{3*RSR}{2.*P!*NFLB*NRB}

120. IXF

local variable
set noise filter

The noise filter sets IXF as

IXF = 1
IXF = (NRB + K-1) \times NRB + 1  \text{ IFX = J + 1}
IXF = (K-1) \times NRB + 1  \text{ IFX = J}

121. J

local variable          set & used Fwate
set & used update input  set & used Bfilt
set & used channel       set & used Max
set & used noise filter   set & used Semul
set, used, & output forward filter set & used Dpgen
set & used Taper (Read)   set & used Parn
set & used Sync

example: J = 1, CTAP
122. JBLOCK

local variable
set, used, & output Taper (Read)

JBLOCK is set by Taper (Read) as

\[ \text{JBLOCK} = 0 \text{ and JBLOCK} = \text{JBLOCK} + 1 \]

123. JBS

local variable
set & used channel

Channel sets JBS to

\[ \text{JBS} = \text{RJBS} \]

124. JFACT

local variable
set & used Semul

JFACT is set by Semul as

\[ \text{JFACT} = 1 \text{ and JFACT} = JFACT * (J) \]

125. JH

local variable
set & used Pin1

Pin 1 sets JH as

\[ \text{JH} = "7702 \text{ and JH} = \text{JH}/2 \]

126. JL

local variable
set & used Pin1

Pin 1 sets JL as

\[ \text{JL} = "27607 \text{ and JL} = \text{JL}/2 \]
127. JMAX

local variable
set & used Bfilt

Bfilt sets JMAX as

\[ JMAX = 0 \]
\[ JMAX = JSET(1) \]
\[ JMAX = JMAX + NCB - 1 \]
\[ JMAX = \left(\frac{JMAX}{NCB}\right) \times NCB + NCB \]

128. JP

local variable
set & used Semul

JP is set by Semul as

\[ JP = 1, M+1 \]

129. JRAN1

Integer starter for Gauran used by noise

local variable
set DFES

DFES sets JRAN1 = 0

130. JRAN2

Integer starter for Gauran used by noise

local variable
set DFES

DFES sets JRAN2 = 0
131. JSET

array
set DFES
set, used, & output Sync
used Fwate
used & output Bfilt
set Parin

Backward Filter Delay

JSET is an integer array of non-negative values dimensioned JSET(120). It may be input by PARIN or computed by SYNC. Indexing is JSET(I), I=1,2,...LTAP. JSET is a calling sequence argument to the subroutines SYNC, BFILT, FWATE, and PARIN. FWATE uses JSET as an index for the array GBACK and BFILT uses it in the index for the GBACK and ALPHA arrays.

132. JTIME

local variable
set DFES
used differential decoder
used Parin
used update input

JTIME is set in DFES to values desired; such as, JTIME = 1,3
133. JWORD

a) array
used Dpgen
set & output Pin1

Pin1 sets JWORD as

\[ JWORD(I) \mod(JL,2) \]
\[ JWORD(I+16) = \mod(JH,2) \]

b) common block
set & output Pin1
used Dpgen

Polynomial for the Receiver Message and Chip Random Number Generator

\[ JWORD=I*(2^{16})+J \]
Pin1 sets JWORD to

where

\[ JWORD(I) = \mod(JL,2) \]
\[ I = 77028_8 \]
\[ JWORD(I+16) = \mod(JH,2) \]
\[ J = 276078_8 \]

JWORD has the actual representation of 1760427607

The message and chip random number generator DPGEN uses JWORD in an exclusive OR with the message in chip shift register MWORD to produce a new shift register value when the last shift resulted in a carry of "1."

The integer JWORD is the COMMON block 32 bit polynomial used for both message and chip data generations.

\[ JWORD = 1760427607 \text{ (base 8)} \]

134. K

local variable
set & used channel
set & used interpolator
set, used, & output noise filter
set, used, & output forward filter
set & used Taper (Read)
set & used Sync
set & used Fwate
set & used Dpgen

examples \( K = \text{NRB, NRB-1, ..., 2,1} \)

the last \( K \) unused data samples \( K=\text{HIGH-NVIN} \)
135. KADAPT

common block pages (3-20 back, 3-11, 3-15, 3-49, 3-56)
used forward filter
used detector
used differential decoder
used Pin1
set, used, & output Parin

Number of Adaptation Cycles for Kalman Algorithm

KADAPT is a fixed integer parameter input to PARIN when ALGOR=KAL.
It has a default of 1000. KADAPT is used to compute RATE and DRATE.

Parin uses it to set KEND=KADAPT+KVAR.

136. KAL algorithm

local variable pages (3-55)
used Parin

KAL (Kalman algorithm)

No numerical value, determines algorithm.

137. KALA

local variable pages (3-16)
set DFES
set & used initialize parameters
used channel

DFES sets KALA = 0

Initialize parameters sets KALA = 2 * NTAP
if NALG = 2 and SMODE = 1

This is accomplished with the flag KALA which is used to fix the weights (NALG=3) for this period of time.
138. KEND

common block used Fwate set & used Parin
Kalman Adaptation Cycle Limit
Subroutine PARIN sets the integer constant

\[ KEND = KADAPT + KVAR \]

It is used by FWATE in a decision making comparison with KNUM.

139. KFLB

Kalman filter loop bandwidth. Default = 0

common block set DFES used initialize parameters used Fwate used update input set & output Parin used detector

DFES sets KFLB = 0.0
Parin also sets KFLB = 0

140. KKN

common block sets DFES set & used Fwate

KKN is set by DFES as
\[ KKN = 1 \]

KKN is set by Fwate as
\[ KKN = 2 \]
141. KLMS

Kalman/LMS Adaptation Indicator

KLMS is an integer variable with a value of 0 or 1. Initially when NUM=1, FWATE sets KLMS=1 for NALG=1 and KLMS=0 for NALG=2. When KLMS=1, FWATE updates the weight vector W using the least mean squares algorithm. For KLMS=0, the Kalman algorithm is used. For NALG=2 FWATE leaves KLMS=0 until KNUM > KEND or KNUM=KRST when it sets KLMS=1. For each KVAR < KNUM ≤ KEND, KLMS=0.

In the subroutine BFILT the method used to compute the array BETA depends on the value of KLMS.

142. KNUM

Kalman Adaptation Bit Symbol Iteration Counter

The integer variable KNUM is set to 0 by the DFES main program. When NALG=2, the subroutine FWATE increments KNUM by 1 each bit symbol iteration until KNUM=KRST. At this point, it is reset

KNUM=0

FWATE sets

REF=3 for KNUM=KVAR
REF=0 for KNUM=KEND
KLMS=0 for KNUM < KEND
or KNUM > KRST
KLMS=0 for KNUM > KVAR

KNUM is used computing the FWATE variables

AKC=FLOAT(KNUM+1)/KNUM
BKC=1./KNUM
143. KRST

common block
used detector
used differential decoder
used Pin1
set, used, & output Parin
used Fwate

Number of Cycles for Kalman Algorithm to Restart

KRST is a fixed integer input to PARIN when ALGOR=KAL. It has a
default value of 100. KRST is used in computing the error rate RATE and
actual data rate DRATE when NALG=2. FWATE uses KRST in a comparison
with KNUM in order to set KLMS.

144. KSET

array
set DFES
used initialize parameters
used channel
set & output Parin

DFES sets KSET to

KSET(I)=Ø

If ICHAN≠0, the channel transversal filter delays are computed as

KSET(I) = TSR*DELAY(I)+0.5  I=1,2,...CTAP

KSET(I) = Transversal filter delay of Ith channel tap expressed in units
of 1/TSR. (Integer)

KSET(I)>0=1,2,...CTAP.

If a nontrivial channel is selected ICHAN=1 and the subprogram
computes the set of integers corresponding to the number of tape
sampling intervals for each path delay, i.e.,

KSET(I) = TSR*DELAY(I) + 0.5  = XKSET

as in Parin
145. KSTEP

Local variable set & used FWATE used BFILT

**Kalman Step Variable**

KSTEP is a real variable computed by FWATE for use in its Kalman algorithm adaptation of the weight vector W and in the Kalman algorithm update of the BETA array in BFILT. KSTEP is a calling sequence argument of FWATE and BFILT.

FWATE sets KSTEP to

\[
KSTEP = \frac{BKC}{(EMSE + REAL(CON))}
\]

146. KSYNC

Local variable set initialize parameters used update input set noise filter

Synchronization flag is

\[
KSYNC = 1.
\]

147. KVAR

Common block set, used, & output PARIN used FWATE

**Number of Iterations for Adaptation of Kalman Inverse**

KVAR is a fixed integer parameter input to PARIN.

Parin sets KVAR = 0

PARIN uses it to set

\[
KEND = KADAPT + KVAR
\]

The subroutine FWATE uses it to set

- REF = 3 for KNUM = KVAR
- KLMS = 0 for KNUM > KVAR
148. LIMIT

local variable pages (3-82)
set & used Sync

LIMIT = NPN + NRB-1

149. LM

local variable
set & used Sync

Sync sets LM=0 and in special cases to LM=LM+1

150. LMS
algorithm

local variable pages (3-55)
used Parin
no numerical value
determines algorithm

LMS (Least Mean Square)

Default = LMS

151. LOUT
common block
set DFES

LOUT is set in DFES as LOUT = 5

152. LP

local variable
set & used Sync

Sync sets LP = 0 and in certain cases to LP = LP+1

153. LPD

local variable pages (3-66, 3-67)
set & used Taper(Rgen)

LPD = 0, Chip counter.
154. **LRC**

Local variable set & used key

KEY sets LRC

\[ LRC = LRC + 1 \]

if \( LRC = NRC \) then \( LRC = 0 \)

\[ LRC = 1,2,\ldots,NRC \]

155. **LRP**

Local variable set & used Taper (Rgen)

\[ LRP = 0, \text{Tape samples per chip symbol counter.} \]

156. **LTAP**

Common block used detector, used differential decoder, used detector, used & output Sync, used Bfilt, used, & output Parin, used Fwate

Number of Backward Filter Taps

LTAP is a fixed integer parameter input to the subroutine PARIN. It indicates the presence (LTAP\(\geq 1\)) or absence (LTAP = 0) of backward filter taps.

In the backward filter subroutine, BFILT, LTAP is the size of the arrays JSET and BETA and is used to define the number of chip values stored in the array ALPHA as LTAP\(\times\)NCB.

The forward filter subroutine, FWATE, uses LTAP to define the size of the Kalman algorithm arrays PVAR and KVAL as

\[ NLTAP = NTAP + LTAP \]

157. **LTAP1**

Local variable set & used Sync

\[ LTAP1 = LTAP/2. \]
158. LTAPE

local variable pages (6-1 back, 3-35)
used channel
used detector
set & used Taper(Read)
set Taper(Rgen)
used Sync

End of Input Tape

LTAPE is the integer flag for the end of file reached on the input tape. It is initially set to 0 by TAPER-READ and set to 2 when an end of file is read on the input tape. If TAPER returns LTAPE=2 bit iteration processing ends.

TAPER(RGEN) sets LTAPE = 0

159. M

local variable pages (3-99, 3-100)
set Max
set & used Semul

M = Dimension of MSET (integer, M ≤ N) where 1 ≤ M ≤ N. The final value of M depends on when the ratio of the next largest magnitude to the largest drops below the dynamic range threshold.

160. MA

array pages (3-99)
set & used Max

The integer array MA(I), I=1,2,...,N, is the Max-A-Index Stored indicator array; MA is used as follows in processing:

MA(I)=0, A(I) index I not stored in MSET
MA(I)=1, A(I) index I stored in MSET.

Initially, MA(I)=0 for all I.
161. MES
    Transmitter Shift Register
    array
    set PinI
    MES is set by PinI as
    MES(I) = MESS(I)
    MES(I+16) = MESS(I+16)

162. MESS
    array
    set, used, & output PinI
    MESS is set in PinI to
    MESS(I) = MOD(ML,2)
    MESS(I+16) = MOD(MH,2)

163. MH
    local variable
    set & used PinI
    MH is set by PinI as
    MH = 27945
    MH = MH12

164. MI
    local variable
    set & used Sync
    pages (3-85)
    Sync sets MI (delay) to
    MI = |INEXT-IMAX|/NRC chip values and
    MI = IMAX-(MSYNC(I)-IMAX)
165. **MODE**

local variable used Parin

MODE = Input mode indicator (Integer).

Mode = 0, Interactive mode
Mode = 1, Batch mode.

166. **MR**

local variable used Sync

167. **MSE**

local variable set DFES
set, used, & output detector
set & used Fwate
used Bfilt

Mean Square Error

DFES sets MSE = 0.0

MSE is the mean square area real value computed each bit symbol iteration for SMODE=1 by the Detector as

\[ MSE = 1 \text{ if } MSE > 1 \]

\[ MSE = (1. - ESTEP) \times MSE + ESTEP \times TEMPF \times TEMPF \]

Each iteration that the counter NUM is an integer multiple of ISKIP it is used by the Detector to compute ESNR. It is included as a calling sequence argument to the subroutine BFILT where it is used in the decision skip the update of the ALPHA and BETA arrays if NALG=2, KLMS=1, and MSE>0.10.

168. **MSELB**

common block used Pin1
set, used, & output Parin

Mean Square Error Loop Bandwidth in Hz

MSELB is a real input parameter to PARIN with a default of 1.

Parin sets MSELB = 1 if MSELB = 0
169. **MSET**

output integer array

array pages (3-99, 3-100)

set & used Max

MSET(I) = Index pointer array to A in decreasing magnitude order,

I=1,2,...M (Integer)

A(MSET(1)) = largest |A|

A(MSET(2)) = 2nd largest |A|

...

A(MSET(M)) = Mth largest |A|

integer array MSET(I), I=1,2,...M

Max sets MSET to

MSET(I) = J

where

J = 1,N

170. **MSIGN**

local variable

set & used Dpgen

Dpgen sets MSIGN as

MSIGN MWORD(32)

171. **MSYNC**

array pages (3-24 back)

used & output Sync

**Synchronization Index Array**

MSYNC is an integer array of maximum dimension MSYNC(180). It is returned to the subroutine SYNC by MAX containing the index values to the synchronization array RSYNC in order of the decreasing magnitude values of RSYNC. SYNC uses MSYNC(1) and MSYNC(2) to set IMAX and INEXT for the computation of TI and NNI.
172. MTAP

common block
used update input
used noise filter
used Pin1
set, used, & output Parin

Number of Noise Filter Taps

MTAP is an input parameter to the PARIN subroutine with a default of 1. MTAP must be an integer in the range 1<MTAP<25. If the MTAP input is even PARIN forces it to be odd by setting

MTAP=MTAP+1

The value of MTAP then remains fixed. PARIN also sets NFLB=0 for MTAP=1.

Subroutine Pin1 uses it to set the constant NV used in the Noise Filter subprogram as

NV=(MTAP+1)/2

MTAP defines the size of the noise filter arrays V(I) and XFREQ(K,I), I=1,2,...MTAP. When MTAP=1 the Noise Filter subprogram is bypassed.

173. MULT

local variable
set & used channel

MULT is set in channel to

MULT = (JBS-1)/NTB
174. MWORD

array set & used Dpgen

Message/Clip Shift Register

MWORD is the shift register input to the random number generator for the message and chip data subroutine DPGEN.

Dpgen sets MWORD

\[
MWORD(K) = MWORD(K-1)
\]

\[
MWORD(1) = 0
\]

\[
MWORD(K) = MWORD(K) + JWORD(K)
\]

if \( MWORD(K) = 2 \) then \( MWORD(K) = 0 \)

175. N

a) local variable used Max

set & used key set Taper(Read)

\[ N = \text{Dimension of A (positive integer)} \]

b) array used channel

set & used Noise

Discrete Noise Sequence

\( N \) is the complex noise sequence array returned by the subroutine NOISE dimensioned \( N(90) \). Indexing is \( N(I), I-1,2,---NR \). It is used in the Channel subprogram in forming the receiver sample array \( R \).

Noise sets \( N \) to

\[
N(I) = N(I-NTB)
\]

\[
N(I) = NDATA(NOP)*SF
\]

\[
N(I) = SUM1* CMPLX(S(1),S(2))
\]
local variable used initialize parameters set, used & output Sync used Pini
set Parin

**Number of Bits Averaged before Acquisition Decision**

NA is the integer input parameter to initialize parameters for the number of bit symbol iterations used by SYNC to reach an acquisition decision. For NA=0 the Initialize Parameters subprogram sets SMODE=1, indicating that SYNC is not to be used. When NA>0, SYNC decrements NA by 1 each time it is called until NA=0 when SYNC computes NNI, TI, GCON, and sets SMODE=1. Whenever SMODE=1 NA remains an unused constant.

Parin sets NA

\[ NA = 0 \]

if JTIME = 1 then NA = 20 or some chosen number

NA = Number of bit symbols to be averaged in the correlation (Integer).
NALG

Algorithm Indicator (NALG)

NALG is the integer indicator for the adaptation algorithm used by FWATE in updating the forward filter weight vector w. The subroutine PARIN sets NALG to the following values according to the input value of ALGOR:

<table>
<thead>
<tr>
<th>ALGOR</th>
<th>NALG</th>
<th>Weight Adaptation Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>LMS</td>
<td>1</td>
<td>Least Mean Squares algorithm</td>
</tr>
<tr>
<td>KAL</td>
<td>2</td>
<td>Kalman algorithm</td>
</tr>
<tr>
<td>FIX</td>
<td>3</td>
<td>Weights remain fixed to initialization values</td>
</tr>
<tr>
<td>RAKE</td>
<td>4</td>
<td>Rake equalizer</td>
</tr>
</tbody>
</table>

NALG remains constant unless the Kalman algorithm is specified (NALG = 2) and the synchronization subroutine is not used (SMODE = 1). When this occurs, the Initialize Parameters subprogram temporarily sets NALG = 3 to force a delay in the adaptation. When 2*NTAP iterations have been completed, NALG is reset to its original input value of 2.

The Detector sets AHAT = A when NALG = 2 and REF = 3. The Detector also calls the BFILT subroutine to update BETA for NALG = 1 or 2 and LTAP > 1.

Initialize parameters sets NALG = 3 if KALA > 0.

The channel sets NALG = ALGOR if KALA > 0 and RNUM > KALA.

The detector sets NALG = ALGOR.

NBLOCK

local variable
set Taper(Read)

NBLOCK is set by Taper(Read) as NBLOCK = 5000
179. NBYTE

    local variable
    set Taper (Read)

    NBYTE = 3840  Number of bytes per block on the signal input tape.

180. NCB

    common block
    set & used Parin

    Parin sets NCTAP2 to
    NCTAP2 = 2*CTAP

181. NCTAP2

    local variable
    set & used Parin

    Parin sets NCTAP2 to
    NCTAP2 = 2*CTAP

182. NFLB

    common block
    set & used noise filter
    used detector
    used initialize parameters

    Noise Filter Loop Bandwidth in Hz

    NFLB is a real input parameter to the subroutine PARIN. The Initialize Parameters subprogram uses it in computing the number of iterations for NOISE FILTER adaptation IX and the Noise Filter subprogram uses it in computing VSTEP.

    When NFLB=0, the noise filter weights, V(I), I=1,2,...,MTAP, are fixed. If NFLB>0, NFLB is reset to 0 when IBS reaches IX. The subroutine PARIN sets NFLB=0 when MTAP=1.
183. NGEN

local variable
set & used update input
used Taper (Read)
used Taper (Rgen)

Number of Input Samples Accessed by TAPER

NGEN is the integer number of new input samples for TAPER-RGEN to generate or the number of tape samples for TAPER-READ to generate. It is a calling sequence argument for both versions of TAPER. NGEN=NTB+NRQ for each bit symbol iteration unless it is the first iteration where SMODE=1. (KSYNC=1 and SMODE=1). Then it is increased by NSHIFT.

184. NI

local variable
set & used Sync

NI = 1-1 as set by Sync

185. NIN

Noise input indicator

local variable
set DFES
set & used initialize parameters
used differential decoder
used Noise
set & used Parin

NIN = 0 as set by DFES, Initialize Parameters, and Parin
Parin also sets NIN = 1

186. NLTAP

local variable
set & used Fwate

is NLTAP = NTAP + LTAP where NTAP is the number of forward filter taps and LTAP is the number of backward filter taps.
187. NN

local variable
set & used Noise

NN is set by Noise to

\[ \text{NN} = \text{NTB} \]

\[ \text{NN} = \text{NR} \text{ if RIBS} = 1 \]

188. NNI

common block pages (3-9 back, 3-11, 3-17, 3-19, 3-56, 3-58, 3-63, 65, 3-66, 3-83, 3-85)
set DFES
output update input
set channel
used Taper (Rgen)
set & output Sync
set Parin

Number of Input Samples to Be Skipped in Order to Produce Bit Synchronization

When the SYNC subroutine is required for acquisition (NA > 0 and SMODE = 0), NNI is determined by SYNC. The initial value of NNI is 0. If SYNC is not required (NA = 0), NNI is an input parameter to PARIN. The value of NNI set by SYNC or input by PARIN is used for only one bit symbol iteration call (NUM = 1) to the Tape Read subroutine TAPER (Rgen). After each call to TAPER, NNI is reset to 0.

TAPER (Rgen) uses NNI in computing the number of input samples to read as

\[ \text{NK} = \text{NGEN} + \text{NNI} \]

NNI is set to \( \text{NNI} = 0 \) by Sync, DFES, and channel Sync sets

\[ \text{NNI} = \text{IMAX}-1 \]
189. NOSIG

common block pages (3-18 back, 3-17, 3-22, 3-26, used and output initialize parameters 3-55, 3-57)
used channel
set & used noise filter
used differential decoder
Set & output Parin

Input Signal Control Indicator

NOSIG is an input integer parameter of 0 or 1 to PARIN. NOSIG=0 is the normal operation mode. When NOSIG = 1, there is no signal input, R(K) = N(K). If NFLB = 0, PARIN sets NOSIG = 0.

The NOSIG-1 option is no longer used in the program.

190. NOZDC

common block pages (3-21 back, 3-22, 3-26, 3-55, 3-57)
used channel
set & output Parin

DC Noise Indicator

NOZDC is a fixed integer parameter input to PARIN. NOZDC=0 is the normal default case. NOZDC=1 implies a test case of DC NOISE.

191. NPD

local variable pages (3-66)
set & used Taper (Rgen)

NPD = CSR/BSR, Number of chip symbols per bit symbol

NPD = NCB

192. NPN

local variable pages (3-81, 3-82)
set, used, & output Sync

NPN = RANGE*6000*RSR*1.E-9 = QN

NPN = NPN+1 IF QN > NPN

The program exits if NPN is greater than 180
193. NPOW
   local variable
   set & used channel
   used & output detector

   \[ NPOW = JBS - \text{MULT} \times NTB \]

194. NQ
   local variable
   set initialize parameters
   output update input
   used channel

   \[ NQ = NTB + \text{INT} - \text{NTR} + \text{KSET(CTAP)} \]

195. NR
   common block
   output update input
   used Taper (Both)
   used Noise
   set, used, & output Parin
   used channel

   Number of Receiver Input Samples - Integer

   NR is the size of the Receiver input array R.
   Parin sets the fixed value as

   \[ NR = NTB + \text{INT} - \text{NTR} \]

196. NRAN1
   local variable
   set DFES
   output channel
   used Gauran
   set Parin

   NRAN1 is set by DFES and Parin as

   \[ NRAN1 = \emptyset \]
NRAN2

local variable
set DFES
output channel
used Gauran
set Parin

NRAN2 is set by DFES and Parin as

NRAN2 = 0

NRB

common block
used initialize parameters
used & output update input
used interpolator
used noise filter
used key
used sync
used Fwate
set & used Parin

Number of Receiver Samples per Bit Symbol

NRB is set to the fixed integer value

NRB = RSR/BSR

It is used by the Initialize Parameters Subprogram to compute the size NY of the forward filter output array Y and by the Update Input subprogram to compute the size NS of the interpolator input array S

NY = NRB

NS = NRB = NSPAN

In the noise filter subprogram it is the number of XFREQ (K,I), K = 1,2,...-NRB, values generated.

The SYNC subroutine uses NRB to set the size of the ALPHA array

LIMIT = NPN + NRB - 1

where NRB is the number of new ALPHA values generated.

The number of PN sequence values to be generated by KEY is I = NRB and the number of interpolator output x values used in computing RSYNC.
199. NRC

Number of Receiver Samples per Chip Symbol

The constant NRC is defined in Parin as NRC=RSR/CSR. It is used by the KEY subroutine as the number of PN sequence duplications.

The BFILT subroutine uses NRC as part of the PN index in computing the ALPHA and GBACK arrays.

200. NRD

For IBS=1 only, the number of forced delay samples is set (NRD=5).

Later set to NRD=NRD-1

201. NREC

used DFES

202. NRP

NRP = NTR*RSR/CSR, Number of tape samples per chip symbol.

203. NRQ

Update input sets NRQ as

NRQ = Ø

and

NRQ = INT - NTR
204. NS

common block set DFES set, used, & output update input used interpolator used Fwate

Interpolator Array Size

NS is the fixed integer dimension of the Interpolator arrays S and X. The Update Input subprogram sets

\[ NS = \text{NRB} + \text{NSPAN} \]

\[ NX = NS \]

NS has the range \( 1 < NS < 500 \) as set in DFES

205. NSHIFT

local variable set DFES set, used, & output update input

The NSHIFT parameter is computed. The purpose of this parameter is to maintain synchronization for the nondispersive channel for any forward filter tap specification.

\[ \text{NSHIFT} = \text{NTR} \times \text{ISET}(1). \]

NSHIFT is set to 0 by DFES.

206. NSPAN

common block set DFES set, used, & output update input

Forward Filter Span

In receiver sample widths DFES sets NSPAN = 0

NSPAN is an integer set to the fixed value

\[ \text{NSPAN} = \max \sum_{I} \text{ISET}(I) = \text{ISMAX} \]

by the update Input subprogram where it is used to compute the size NS of the Interpolator arrays S and X

\[ NS = \text{NRB} + \text{NSPAN} \]
Number of Forward Filter Taps

NTAP is a fixed integer parameter to the subroutine PARIN with a default of 1. It defines the size of the forward filter arrays ISET and W. The subroutine FWATE uses NTAP to set the size of the Kalman algorithm arrays VKAL and PVAR.

\[ NLTAP = NTAP + LTAP \]

FWATE also uses NTAP as an index indicator in computing the variable CON for NALG=2.

The Backward Filter subroutine uses NTAP in the index for the VKAL array when KLMS=0.

The Initialize Parameters subprogram uses NTAP when NALG=2 and SMODE=1 to set the adaptation delay to KALA=2*NTAP iterations.

Sync sets NTAP = NTAP + 1 if MOD(NTAP, 2) ≠ 0.

208. NTAP1

local variable
set & used Sync

Sync sets NTAP1 to be

\[ NTAP1 = NTAP / 2 \]

209. NTAP2

local variable
set & used Parin

Parin sets NTAP2 to be

\[ NTAP2 = 2 \times NTAP \]
210. NTB

Number of channel samples per bit symbol

common block pages (3-10, 3-11 back, 3-13, 3-15, 3-19, 3-23, 3-24, 3-80)
used initialize parameters used & output update input
used Noise set & used Parin
used channel

Number of Channel Samples per Bit Symbol

NTB is a fixed integer value set by Parin to

\[ NTB = \frac{TSR}{BSR} \]

where it is used to set

\[ NR = NTB + INT - NTR \]

and

\[ NQ = NTB + INT - NTR + KSET(CTAP) \]

Each bit symbol iteration is used to set the number of receiver samples NGEN to be input by TAPER. The Channel subprogram uses NTB in computing the index NPOW and the NOISE subroutine uses it to set the number of noise samples generated in N array.

211. NTR

common block pages (3-13, 3-15, 3-18, 3-42, 3-80)
used initialize parameters used Taper (Rgen)
used & output update input used interpolator
set & used Parin

\[ NTR = \frac{TSR}{RSR} \text{ as set by Parin} \]
212. NV

local variable

used noise filter

set & used Taper (Read)

set Pin 1

Taper (Read) sets NV to

\[ NV = NGEN + NNI \]

The number of data samples to transfer to the output array, VR, plus the number of data samples to be skipped for bit synchronization and \( NV = NV - 1 \).

An integer half-width of the Noise Filter is computed

\[ NV = (MTAP + 1)/2 \]

as set in Pin 1.

213. NVIN

common block

set & used Taper (Read)

Receiver Sample Pointer

NVIN is an integer variable used by the Tape Read subroutine TAPER (file name READ) as the pointer to the consecutive receiver samples in the input data block array VIN. When IBS=1, NVIN is initialized to 0 in Taper (Read).

The data sample pointer is set (NVIN=0).

Later updated NVIN = NVIN + 1

214. NX

common block

set DFES

set update input

used interpolator

used noise filter

used forward filter

Noise Filter Output Size

NX is the fixed integer size of the noise filter output array x.

The Update Input subprogram sets

\[ NX = NS \]

DFES sets NX initially.
215. NY

local variable
set initialize parameters
used forward filter
used Key
used compressor

Forward Filter Output Size

The integer size NY of the forward filter output array Y is set by the Initialize Parameters subprogram

NY=NRB.

It is used by the Compressor as a calling sequence argument for KEY to generate NY PN sequence values.

216. ONE

local variable
set & used ERFC

ONE is set by ERFC as

1.0D0 in a Data Statement

217. P

local variable
set & used ERFC
set & used key
set & used Taper (Rgen)

The receiver sample P (Complex) is

\[ P = P^*E^J. \]

ERFC sets the value of P in a Data Statement.
218. PI

common block
used initialize parameters
set DFES
used channel
used noise filter
used Bfilt

\[ \pi \]

The real constant \( \pi \) is set by the DFES main program to

\[ \pi = 3.14159265. \]

219. PIX

local variable
set & used Sinc

PIX is set by Sinc as

\[ \text{PIX} = \pi \times X \]

220. PN

array
used noise filter
used Sync
used Fwate
used Bfilt
set Key

Pseudo-Noise Sequence Array

The complex array \( \text{PN}(K), K=1,2,--NY \) generated each bit symbol iteration by the subroutine KEY. It is a calling sequence argument of the subroutines KEY, SYNC, BFILT, and FWATE.

The Noise Filter subprogram uses \( \text{PN} \) in computing the array \( V \). The Compressor subprogram uses it to compute the compressor output \( Z \). SYNC uses \( \text{PN} \) to compute the array \( \text{ALPHA} \) and FWATE to compute the \( S \) BAR array. \( \text{PN} \) is used in BFILT for setting the \( \text{ALPHA} \) and \( \text{GBACK} \) arrays.

Key sets \( \text{PN}(N) = \text{CONJG}(P) \)
221. **POW**

Array pages (3-25 back, 3-13, 3-17, 3-22, 3-54, 3-60)

Set, used, channel, set & output Parin

**Channel Relative Power Array**

POW is a real array of the subroutine PARIN dimensioned POW(4). Its default is POW(I)=1, POW(I)=0, I=2,3,CTAP. It is the relative power of path I with respect to the first path. It is used by the Channel subprogram for the variance CVAR used in the channel random number generation by GAURAN

$$CVAR = \frac{POW(J)}{2}$$

222. **PSK**

Common block pages (3-2 back, 3-45, 3-46, 3-48, 3-54, 3-57)

Set, used, & output Parin

**Number of Transmitted Phases**

PSK is an integer of fixed value 2 or 4. It is used by the Detector as an indicator to determine the value of AHAT. PSK is an input parameter to the subroutine PARIN with the default PSK = 2.

223. **PVAR**

Virtual array pages (3-89 to 3-91)

Set, used, & output Fwate

The inverse matrix estimate PVAR

The Kalman matrix PVAR is updated.

PVAR is set by Fwate to

$$PVAR(I,J) = (4.,0.)$$

if I = J  $$PVAR(I,J) = (1.,0.)$$

$$PVAR(I,I) = PVAR(I,I)*AKC-RCON*(CABS(VKAL(I))^2)$$

$$PVAR(I,J) = PVAR(I,J)*AKC-RCON*VKAL(I)*CONJG(VKAL(J))$$

$$PVAR(J,I) = CONJG(PVAR(I,J))$$
224. Q

virtual array set & used channel

Every bit symbol iteration, the subprogram receives a transmit signal array

\[ Q(K) = \text{Input array to the subprogram } \text{(Complex)} \]
\[ K = 1, 2, \ldots \text{ NQ. } \text{NQ} \leq 330. \]
\[ \text{NQ} = \text{NTB} + \text{INT} - \text{NTR} + \text{KSET}(\text{CTAP}). \]

the most recent input values (Q array)

\[ Q(K) = Q(K-\text{NTB}) \quad K = \text{NTB} + 1, \ldots \text{ NQ} \]
\[ Q(K) = \text{CMPLX}(V_R(1,K),V_R(2,K)) \]

225. QE

local variable set & used detector

QE is set by the detector as

\[ QE = \text{AIMAG}(E) \]
\[ QE = \text{SIGN}(1., QE) \]

226. QN

local variable set & used Sync set Parin

QN is set by Sync as

\[ QN = 6000. \times \text{RANGE} \times (1.E-9) \times RSR \]

QN is set by Parin as

\[ QN = 6000. \times (1.0 \times E-9) \times RSR \]
227. QS
local variable
set & used interpolator

The interpolator sets QS as

\[
QS = (0.0, 0.0)
\]

\[
QS = QS + GCON \times R (NTR \times K + I + INT1 + (1-NTR)) \times SINK(IQ)
\]

228. QW
local variable
set & used Fwate
set & used Bfilt

QW is set by Fwate as

\[
QW = \text{AIMAG}(W(I))
\]

\[
QW = 100. \times \text{SIGN}(1. QW)
\]

QW is set by Bfilt as

\[
QW = \text{AIMAG}(\text{BETA}(I))
\]

\[
QW = 100. \times \text{SIGN}(1., QW)
\]

229. R
array pages (3-14, 3-23 to 3-27, 3-29, 3-30 to 3-33)
set DFES
set, used, & output channel
used interpolator
output detector

R is the receiver input array
DFES sets \((R(I) = (0.0, 0.0))\)

\(\text{\textbackslash Channel sets } R \text{ to}
\)

\[
R(K) = (0.0, .)
\]

\[
R(K) = R(K) + H(I) \times Q (K\#SET(I))
\]

\[
R(K) = R(K) + N(K)
\]

where \(K = 1, NTB + NRQ\)
230. RANGE

Range in Nautical Miles

RANGE is an input parameter to PARIN only if the bit synchronization routine SYNC is to be used (NA > 0). It is used by SYNC to compute the number of PN sequence values range used in synchronization NPN. The default is RANGE = 300. DFES initially sets RANGE = 0.0.

231. RATE

The error rate (RATE) is computed as the number of bit errors divided by the total number of received bits.

The differential decoder sets

\[ RATE = \frac{ERROR}{RNUM \times 2} \]

and if REF = 1 then

\[ RATE = RATE \times 2 \]

232. RCON

RCON = KSTEP * AKC.

233. RDEL

\[ RDEL = 2. \times PI \times RGLB/BSR \]
234. RE

local variable
set & used detector

RE is set in the detector to

\[ RE = \text{REAL}(E) \]
\[ RE = \text{SIGN}(1., RE) \]

235. REF

common block pages (3-2 back, 3-11, 3-15, 3-45 to 3-50, 3-54, 3-57, 3-92)
set update input
used detector
used differential decoder
set, used, & output Parin
set Fwate

Presence or Absence of Reference Signal Indicator

REF is an integer input parameter to PARIN of value 0, 1, 2, or 3.

PARIN uses the input value of REF to set the differential decoder indicator IDEC. The value of REF remains constant for NALG = 1 or NALG = 3. When NALG = 2, the subroutine FWATE modifies REF in the Kalman algorithm adaptation to the following:

\[ REF = 3 \text{ for } \text{KNUM = KVAR} \]
\[ REF = 0 \text{ for } \text{KNUM = KEND} \]

When REF = 3 and NALG = 2, the Detector sets \( \text{AHAT} = A \). The Detector also uses the current value of REF as an indicator for setting the adaptation error sample E.

236. RGAIN

local variable
set DFES
set, used, & output detector

RGAIN is set by DFES as

\[ RGAIN = (1.0, 0.0) \]

RGAIN is set in the detector to

\[ RGAIN = RGAIN + RDEL * E * \text{CONJG}(Z) \]
237. RGLB
Rake gain loop bandwidth in Hz, default = 5

common block
set, used, & output Parin
used Pin1

Parin sets RGLB to
RBLB = 5.0 or some other number
if RGLB = 0 then RGLB = 5.0

238. RIBS
Number of bit Symbol iterations including Sync

common block
set DFES
set, used, & output update channel
used interpolator
used detector
used noise filter
used Noise
used Key
set, used, & output Sync
set Taper (Read)
used Taper (Rgen)

RIBS is set as
RIBS = 0.0 in DFES
Update input sets RIBS to
RIBS = RIBS + 1

239. RJBS
local variable
set & used channel

Channel sets RJBS to
RJBS = RIBS

If RJBS > 1.E+4 then RJBS = 1
240. RKAL

local variable
used update input
set Pin

RKAL is set by Pin 1 as

\[ RKAL = \text{FLOAT} \left( \frac{KRST}{KADAPT} \right) \]

241. RKBS

local variable
set & used noise filter

The noise filter sets RKBS as

\[ RKBS = RIBS \]
\[ RKBS = \text{RNUM} \text{ if } SMODE = 1 \]

242. RKIBS

local variable
used forward filter
set & used detector

243. RKIPS

local variable
set DFES

RKIPS is set by DFES to

\[ RKIPS = 0.0 \]

244. RMAX

local variable
set, used, & output Sync

Sync sets RMAX to

\[ RMAX = 0.0 \]
\[ RMAX = RS(IMAX) \]
245. RNBS
Real number of bit symbol iterations to do after Sync
common block
used differential decoder
set & output Parin
RNBS is set by Parin to a number desired for the number of bits,
example:
1,000, 10,000, etc.

246. RNEXT
local variable
set & output Sync
Sync sets RNEXT to
RNEXT = 0
RNEXT = RS(INEXT)

247. RNUM
Number of bit symbol iterations after Sync
common block
set DFES
set update input
set & used channel
used noise filter
used detector
used & output differential decoder
used Bfilt
RNUM is set  RNUM = 0.0 in DFES
and
Update Input Channel sets RNUM to
RNUM = RNUM + 1

248. RS
array  
set, used, & output Sync
Comparison is made on the magnitude of the correlator output
RS(I) = CABS(RSYNC(I))
RSR is a real input constant to the PARIN subroutine. It has a default value of 96K and must be an integer multiple of BSR.

RSR is used by the Initialize Parameters subprogram in computing NRB, NRC, NrR, and the noise filter adaptation delay IX.

In the Noise Filter subprogram it is used in computing the constant

$$\alpha = \frac{n}{\sqrt{2}} \left( \frac{B_{RF}}{R_{SR}} \right)$$

and the variable

$$C_x = 2\pi (1 - \left( \frac{MTAP+1}{2} \right) \left( \frac{F_{SPACE}}{R_{SR}} \right) ), \; I = 1, 2, \ldots MTAP$$

When all bit symbol iterations have been completed, RSR is used in computing the measured SNR

$$SNRM = 10 \log_{10} \left( \frac{SP^2}{TSR/(B_{SR}(SIGMA^2))} \right)$$

The SYNC subroutine uses RSR in computing the number of PN sequence range values used in bit synchronization

$$NPN = 6000*RANGE*R_{SR}*10^{-9}$$
250. **RSYNC**

array set & used Sync

**Bit Synchronization Array**

RSYNC is a complex array computed by SYNC of size

\[ \text{NPN} = 6000 \times \text{RANGE} \times 10^{-9} \times \text{RSR} \]

where \( \text{NPN} \leq 180 \).

SYNC uses it as the calling sequence input array for the subroutine MAX.

SYNC sets \( \text{RSYNC}(I) = (0,0) \)

\[ \text{RSYNC}(I) = \text{RSYNC}(I) + X(J) \times \text{ALPHA}(J+N) \]

251. **RTHOLD**

common block used forward filter set, used, & output Parin

Rate threshold in dB down from maximum weight, default = 12

Parin sets RTHOLD as

\[ \text{RTHOLD} = 10 \times (-\text{RTHOLD}/20) \]

and

if \( \text{RTHOLD} = 0 \) then \( \text{RTHOLD} = 12 \)

252. **RW**

local variable set & used Fwate set & used Bfilt

RWIS set by Fwate as

\[ \text{RW} = \text{REAL}(W(I)) \]

\[ \text{RW} = 100 \times \text{SIGN}(1,\text{RW}) \]

RW is set by Bfilt as

\[ \text{RW} = \text{REAL}(\text{BETA}(I)) \]

\[ \text{RW} = 100 \times \text{SIGN}(1,\text{RW}) \]
Interpolator output array

a) Virtual array set, used, & output interpolator
set noise filter

The interpolator sets $S$ as

$$S(K) = S(K-NRB) \text{ where } K = NS, NRB+1, -1$$

$$S(K) = QS \text{ where } K = 1, NRB$$

b) array set Gauran used Noise

The real and imaginary parts of the complex number are then formed

$$S(1) = (-2 V \log_e A)^{1/2} \cos(2nB)$$

$$S(2) = (-2 V \log_e A)^{1/2} \sin(2nB)$$

$S(1)$ = Real part of the complex number

$S(1)$ = Imaginary part of the complex number

Gauran sets $S$ to

$S(I) = X*COS(Y)$

$S(2) = X*SIN(Y)$

254. SBAR

array set & used Fwate

weight input voltage after compression

$$SBAR(I) = \sum_{K=1}^{NRB} \overline{PN(K)} \overline{X}(ISET(I)+K)$$
255. SCALE
   
   local variable
   set & used Taper (Read)
   
   Taper (Read) sets SCALE as
   SCALE = 1.0E-4

256. SDC
   
   local variable
   set noise filter
   
   SDC is set in the noise filter as
   SDC = 0.

257. SI
   
   local variable
   set & used detector
   
   The detector sets SI as
   SI = SIGN(1.0, AIMAG(ZC))
258. SIGMA

local variable pages (5-3, 5-4 back, 3-18, 3-25, 3-49, 3-51, 3-77, 3-79, 3-80)
set initialize parameters
used channel
set Noise

Standard Deviation $\sigma$ of a Quadrature Component of the Complex Noise Sample $N$

SIGMA is a real constant set to

$$SIGMA = \sqrt{\frac{TSR}{BSR \cdot 2 \cdot SNR}}$$

by the Initialize Parameters subprogram and NOISE subroutine

In Noise it is set to

$$SIGMA = \sqrt{SVAR}$$

The Channel subprogram uses it to form the noise array $N$

$$N(K) = O + j\sigma$$

when NOZDC = 1.

259. SINC

local variable pages (3-109)
used Sinc
set update input

The function $SINC(X)$ is defined as

$$SINC(X) = \frac{\sin nx}{\pi x}, \text{ for } x \neq 0$$

$$= 1, \text{ for } X = 0.$$  

For $X = 0$ or $|\sin nx| - |\pi x| < 10^{-6}$ the routine returns

$$SINC = 1$$

otherwise

$$SINC = (\sin(PIX))/(PIX)$$

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260. SINK

array pages (3-19, 3-29, 3-33)
set & output update input
used interpolator

\[
\text{SINK}(I) \quad \text{Array of sin } x/x \text{ interpolation values (Real).} \\
I = 1, 2, \ldots \text{INT.}
\]

\[
\text{SINK}(J) = \text{SINC}\left(\frac{J-\text{INT}1-1}{\text{NTR}} - \text{TI}\right)
\]

where the SINC(X) function is defined in (3.4.22.).

To speed up the computation, the SINC (·) function is precomputed as an array SINC in the subprogram UPDATE INPUT (3.4.2) as follows

\[
\text{SINC}(J) = \text{SINC}(I/\text{NTR}-\text{TI}), \quad I = -\text{INT}1, \ldots \text{INT}1 \\
J = I+\text{INT}1+1.
\]

\[
\text{SINK}(J) = \text{SINC}(XX)
\]

261. SIX

local variable
set & used initialize parameters

SIX is set in initialize parameters to

\[
\text{SIX} = 3.\text{RSR}/(2.\text{PI}\text{NFLB}\times\text{NRB})
\]

262. SKIP

common block
used detector
used differential decoder
used channel
used noise filter
used & output Fwate
set & used Parin

SKIP is set in Parin to the number of bits to be skipped during printout according to desired number, example:

\[
\text{SKIP} = 100, 1,000, \text{or } 5,000
\]

If \(\text{SKIP} = 0\), \(\text{SKIP} = 100\)
Bit Synchronization Mode

SMODE is the integer synchronization mode indicator. Its values are 0 or 1. When SMODE = 0 bit synchronization is performed by SYNC for IBS=NA iterations until the acquisition decision is obtained. When SMODE=1, the acquisition decision has been made and SYNC is not used. The Initialize Parameters subprogram sets SMODE=0 for NA>0 and SMODE=1 for NA=0. The subroutine sets SMODE=1 after NA iterations when it makes the acquisition decision. SMODE is a calling sequence argument of the subroutine SYNC.

Signal to Noise Ratio

SNR is the real variable input parameter of the signal to noise ratio in dB for the subroutine PARIN. The Initialize Parameters subprogram converts it to

\[ \text{SNR} = 10^{\frac{\text{SNR}}{10}}. \]

SNR is a calling sequence argument for the NOISE subroutine where it is used to compute the variance \( \text{SVAR} \) for the random number generator GAURAN.

Measured signal-to-noise ratio in dB (Real).

It is also printed. The measured signal-to-noise ratio expressed in dB is calculated as

\[ \text{SNRM} = 10^{\frac{\text{SPAW}\times\text{TSR}}{2\times\text{BSR}\times(\text{SIGMA}\times2)}} \]
266. SPAW

local variable
set DFES
set & used channel
used differential decoder

DFES sets SPAW to
SPAW = 1.0

The channel sets SPAW to

SPAW = (1 - 1/RNUM) * SPAW + (CABS(R(NPOW))) ** 2 / (2 * RNUM)

267. SPOW

local variable pages (3-14, 3-24, 3-25, 3-49, 3-51)
set DFES
set & used channel
output detector
used differential decoder

DFES sets SPOW as
SPOW = 1.

Receiver input power per quadrature channel and recursively computing every IBS iteration in channel is

SPOW = (1 - ASTEP) * SPOW + ASTEP * CABS(R(NPOW))) ** 2 / 2

The measured signal power is recursively computed as

SPOW = ((NUM - 1) * SPOW + CABS(R(NPOW))) ** 2 / NUM

which is mathematically equivalent to

SPOW = \frac{1}{NUM} \sum_{1=1}^{NUM} |R_i|^2

where the R_i are independent samples of the signal.
268. SQ2

local variable  
set initialize parameters  
used channel  
used noise filter  

\[ SQ2 = \sqrt{2}. \]

269. SR

local variable  
set & used detector  

The detector sets SR to be

\[ SR = \text{SIGN}(1.0, \text{REAL}(ZC)) \]

270. SUM

local variable  
set & used ERFC  
set & used Sync  
set & used Semul  

Sync sets SUM as

\[ \text{SUM} = \text{SUM} + \text{CABS}(W(I))^2 \]

ERFC sets SUM to be

\[ \text{SUM} = 0 \]

\[ \text{SUM} = \text{SUM} + A(I)^*(T^I) \text{DEXP}(-X^2) \]

Semul sets SUM as

\[ \text{SUM} = 0. \]

\[ \text{SUM} = \text{SUM} + ((AL*ARG)^J)/JFACT \]

271. SUM1

local variable  
set & used Noise  

SUM1 is set by Noise to

\[ SUM1 = 1 \]
DECISION-FEEDBACK EQUALIZER SIMULATION (DFES) - DESCRIPTION OF (ETC(U))

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272. SVAR

local variable pages (5-4 back, 3-105)
used Gauran
set & used Noise

Gaussian Random Number Generator Variance

SVAR is the real variance computed by NOISE and used in the call to Gaussian random number generator GAURAN

$$\text{SVAR} = \frac{\text{TSR}}{\text{BSR} \times \text{SNR}}$$

273. T

local variable set & used ERFC

$$T = \frac{1}{1 + 0.3275911 \times X}$$

$$T = \frac{1}{1 + P \times X}$$

274. TEMPF

local variable set & used detector

The detector sets TEMPF as

$$\text{TEMPF} = \text{AIMAG}(F)$$
275. TI

Timing Interval

When bit synchronization is required (NA > 0 and SMODE=0), the initial value of TI is 0 and the final TI value is computed by the subroutine SYNC. If bit synchronization is not used, TI is an input parameter to the subroutine PARIN. TI is a real variable with the range

\[-1 \leq TI \leq 1\]

Once computed by SYNC or input by PARIN, TI remains constant.

Sync sets TI as

\[ TI = \frac{TOP}{(RMAX * 2.)} \] and \[ TI = 0 \]

TI is used to compute the SINK array for the Interpolator subprogram.

DFES sets TI = 0.0

276. TOP

local variable

set & used Sync

Sync sets TOP as

\[ TOP = RS(IMAX+1) \] if \[ IMAX = 1 \]
\[ TOP = RS(IMAX-1) \] if \[ IMAX = NPN \]
\[ TOP = RS(IMAX+1)-RS(IMAX-1) \] if \[ IMAX > 1 \] and \[ IMAX < NPN \]
277. TSR

common block pages (3-4 back, 3-12, 3-18, 3-23, 3-25, 3-29, 3-49, 3-55, 3-57, 3-58, 3-66)
used initialize parameters set, used, & output Parin
used differential decoder
set, used, & output noise
used Noise

Tape Sample Rate in Hz

TSR is a real input constant to the PARIN subroutine. It has a default value of 192K and must be an integer multiple of BSR.

TSR is used by the Initialize Parameters subroutine in computing NTB, SIGMA, the number of tape samples per receiver sample NTR = TSR/RSR, and the channel tap integer array KSET(I) = TSR*DELAY(I)+0.5. The NOISE subroutine uses it to compute the variance

\[ SVAR = \frac{TSR}{2*BSR*SNR} \]

and

\[ SIGMA = \sqrt{\frac{TSR}{2*BSR*SNR}} \]

278. V

array pages (3-25 back, 3-12, 3-17, 3-37, 3-39, 3-40, 3-54, 3-59)
set DFES set, used, & output noise filter set & output Parin

Noise Filter Array

V(I), I=1,2,...,MTAP is a complex array used by the Noise Filter subprogram in computing the noise filter output array X when MTAP>1. It has a maximum size V(25). V is initialized by PARIN where it is re-defined as a real array (V(50). When MTAP>1, V may be optionally initialized as an input parameter array to PARIN. The Default values are V(I)=0, I=1,2,...,MTAP.

DFES sets V as

\[ V(I) = (0,0,0,0) \]

The Noise filter sets V as

\[ V(I) = V(I) - VSTEP*F*CONJG(CJ) \]
279. VIN

virtual array
set & used Taper (Read)
Complex data samples array

\[ \text{VIN}(1,J) = \text{FLOAT(IDATA}(I)) \times \text{SCALE} \]
\[ \text{VIN}(2,J) = \text{FLOAT(IDATA}(I+1)) \times \text{SCALE} \]

280. VKAL

array pages (3-25 back, 3-89, 3-91, 3-92, 3-96, 3-98)
set, used, & output FWATE used Bfilt

Kalman Update Vector

VKAL(I), I=1,2,...-NLTA is a complex array computed by FWATE for use in updating the weight vector W and array PVAR when NALG=2. BFILT also uses VKAL to update BETA when NALG=2. VKAL is a calling sequence argument of FWATE and BFILT and has a maximum size VKAL(50).

FWATE sets VKAL to

\[ \text{VKAL}(I) = (0.0,0.) \]

if J>NTAP then

\[ \text{VKAL}(I) = \text{VKAL}(I)+\text{PVAR}(I,J) \times \text{GBACK}(J \text{-SET}(J-NTAP)) \]

if J<NTAP then

\[ \text{VKAL}(I) = \text{VKAL}(I)+\text{PVAR}(I,J) \times \text{SBAR}(J) \]

281. VMAX

local variable
set DFES
set & used noise filter

DFES sets VMAX to

\[ \text{VMAX} = 0.0 \]

The noise filter sets VMAX to

\[ \text{VMAX} = 0 \]

\[ \text{VMAX} = \text{CMAG} \text{ if CMAG > VMAX} \]
282. VR

array
used channel
set Taper (Read)

Receiver Sample Input Array

VR is the receiver sample array returned by TAPER each bit iteration. VR is defined as a real array dimensioned CV(2,100) where (VR1,1) = real sample part and VR(2,1) = imaginary sample part. It is used to set the transmit signal array for the Channel subprogram

\[ Q(K) = \text{CMPLX}(VR(1,K), VR(2,K)), \]
\[ k = 1,2,\ldots,\text{NTB+NRQ} \]

When IBS=1, TAPER (READ) returns NR samples in VR. For IBS > 1 NTB samples are returned.

\[ VR(1,NV) = 0 \]
\[ VR(2,NV) = 0 \]
\[ VR(1,I) = \text{VIN}(1,NVIN) \]
\[ VR(2,I) = \text{VIN}(2,NVIN) \]
\[ VR(1,NV) = \text{VIN}(1,NVIN) \]
\[ VR(2,NV) = \text{VIN}(2,NVIN) \]

283. VSTEP

local variable
set, used, & output noise filter

Adaptation algorithm step size

\[ \text{VSTEP} = 2. \pi \text{NFLB*RSR}/(\text{BSR*BRF*NRB}) \]
Forward Filter Weight Vector

W(I), I=1,2,---,NTAP is an input parameter array to the subroutine PARIN, with the default W(1)=1, W(I)=0, I=2,3,---,NTAP2. W has a maximum dimension of 25. The array W is updated each bit symbol iteration by FWATE using either the Kalman or LMS algorithm. W is used in computing the forward filter output array Y.

Sync sets W to

\[ W(I) = \text{CONJG}(RSYNC(2\times I - ISET(I))/RSYNC(IMAX)) \]

FWATE sets W to

\[ W(I) = \text{CMPLX}(RW,QW) \]

WMAX

local variable

set & used forward filter

The forward filter sets WMAX to

\[ WMAX = 0. \]

\[ WMAX = \text{CABS}(W(I)) \text{ if } \text{CABS}(W(I)) > WMAX \]

\[ WMAX = WMAX \times \text{RTHOLD} \]

WMULT

local variable

set & used Fwate

WMULT is set by Fwate to

\[ WMULT = 1. \]

\[ WMULT = 1.-\text{DELTA} \text{ if } \text{ALGOR} = 4 \]
287. \( X \)

a) virtual array

set & used interpolator
set, used, & output noise filter
used forward filter
set & used ERFC
used Sync
used Fwate

Noise Filter Output

\( X \) is a complex array of size \( NX=NS \) with a maximum dimension \( X(500) \). For \( MTAP=1 \) it is formed directly from the Interpolator array \( S \). When \( MTAP > 1 \), \( X \) is computed by the Noise filter sub-program each bit symbol iteration. It is used in forming the forward filter output array \( Y \).

\( X \) is a calling sequence argument of the subroutines SYNC and FWATE. In SYNC it is used in forming the synchronization array \( RSYNC \) and FWATE uses it to compute the SBAR array.

The interpolator sets \( X \) to

\[
X(K) = X(K-NRB)
\]

ERFC sets \( X = Z \)

The noise filter sets \( X \) to

\[
X(I) = S(I) \text{ where } I = 1,NX
\]

\[
X(K) = (0.,0.)
\]

\[
X(K) = X(K) + V(I) * XFREQ
\]

\[
X(K) = SLK + IBDEL) - X(K)
\]

b) local variable

set & used Gauran
set Dpgen
used Sinc

HSQ SINC Input

Gauran sets \( X \) to

\[
X = SQRT(-2.0*SVAR*A\log(A))
\]

Dpgen sets \( X \) to

\[
X = CMPLX(D(1),D(2))
\]

\( X \) is the real variable input to the function SINC
28b. XC

local variable used channel

XC corresponds to $S$ in the call to Gauran

**Channel Gaussian Random Number**

XC is the complex Gaussian random number returned by GAURAN to the Channel subprogram. It is used in updating the complex $H$ array.

289. XERR

local variable set & used differential decoder

The differential decoder sets XERR to

$$XERR = AERR \times XERR + (1.-AERR) \times DR \text{ if } REF=3$$

290. XF1

local variable set & used noise filter

291. XF2

local variable set & used noise filter

292. XFREQ

local variable set, used, & output noise filter

$$XFREQ = (0.,0.)$$

$$XFREQ = AIX \times XF1 - CIX \times XF2 + BIX \times S(K)$$

293. XKSET

local variable set & used Parin

XKSET is set by Parin to

$$XKSET = TSR \times DELAY(I) \times 0.5$$
XX

local variable pages (4-7 back)
set & used update input

Interpolator SINC Function Input

XX is the real variable input to the function SINC for computing the Interpolator SINK array

XX = FLOAT(I)/NTR-TI

Y

array pages (3-41, 3-43, 3-44)
set & used forward filter
used & output compressor

Y(K), Input array (Complex, K=1,2,..,NY, NY=NRB ≤ 80.
The forward filter sets Y to

Y(K) = (Ø, Ø.)
Y(K) = Y(K) + W(I) * S(J + IBDEL)
Y(K) = Y(K) + W(I) * X(J)
Y(K) = Y(K) - X(K)

YC

local variable
set & used channel

YC = HP(J)
Z

local variable set & used compressor output differential decoder used ERFC used detector

Z = COMPRESSOR output (Complex).

The cross correlation operation which accomplishes the bandwidth compression is

\[ Z = (NY)^{-1} \sum_{I=1}^{NY} PN(I)Y(I). \]

Z is initially set

\[ Z = (0.,0) \] by the compressor.

ZC

local variable set & used detector output differential decoder

Predecision Sample of Detector

The predecision sample is the sum of the compressor and backward filter outputs, viz., as set in the Detector subprogram

\[ ZC = KGAIN*Z+C \]

ZERO

algorithm

local variable set & used Parin

Parin sets ZERO using a Data Statement to

\[ ZERO = 0.0 \]
CROSS-REFERENCE LIST

KEY
A = set, used, and output
B = set and used
C = used and output
D = set and output
O = output (printed out)
S = set
U = used
BIBLIOGRAPHY

Signatron, Inc Decision-Feedback Equalizer Simulation (DFES) program performance specification, Lexington, MA, July 1978

Signatron, Inc HF Channel Adaptive Equalization Algorithm interim technical report, contract N66001-77-C-0248, Lexington, MA, December 2, 1977
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