

HUMBERTO RUBIO & CIA
ABOGADOS

45

Carrera 7 No. 74-64 Oficina 806
Teléfonos 313 24 06 - 313 24 10 - 313 24 23 - 313;
Fax (571) 313 16 - 47 - (571) 313 23 67
Email: rubiolaw@unete.com
Apartado Aéreo 21848
Santafé de Bogotá, D.C. - Colombia

SUPERINDUSTRIA Y COMERCIO
Radicación: C3357675 C3333331 Folios: 52
Fecha (REC): 2003-08-31 14:57:38
Trámite: C33 PATENTES D 1 REGISTRAR 329 COMPLETEN
Dependencia: 2520 DIVISION DE NUEVAS CREACIONES

Señor
SUPERINTENDENTE DE INDUSTRIA Y COMERCIO
DIVISIÓN DE NUEVAS CREACIONES
E. _____ S. _____ D. _____

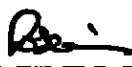
REF. Expediente: 00-057.675
Patente de Invención: METODOS PARA ESTIMAR
LA PROPAGACION
DOPPLER INCLUYENDO
HIPOTESIS DE FUNCION DE
AUTOCORRELACION Y
SISTEMAS Y RECEPTORES
RELACIONADOS.
Titular: ERICSSON, INC.

DESTINO: 09

Humberto RUBIO CAMACHO, mayor de edad, vecino de Santafé de Bogotá, D.C., identificado con la cédula de ciudadanía número 17'192.062 de Bogotá, abogado en ejercicio portador de la Tarjeta Profesional No. 50.007, expedida por el Consejo Superior de la Judicatura, en carácter de apoderado de la Sociedad ERICSSON, INC.; encontrándome dentro del termino legal establecido en el Artículo 4° del Convenio de París, me permito anexar los siguientes documentos:

- 1.- Copia certificada de la Solicitud No. 09/373,289 de 12 de Agosto de 1.999, expedida por la Autoridad Competente, junto con su respectiva traducción al Castellano; base de la prioridad reivindicada en la solicitud de registro de la Patente de Invención citada en la referencia; todo de conformidad con el Artículo 4° del Convenio de la Unión de París y el Concepto 5 de enero de 1.999 de la SIC.

Atentamente,


HUMBERTO RUBIO CAMACHO
C.C. 17'192.062 de Bogotá
T.P. 50.007 Consejo Superior
de la Judicatura
COD 4134

00/1076-03/PI

87
46

TRADUCCIÓN DE UN DOCUMENTO ESCRITO EN INGLES, HOY 30 DE AGOSTO DEL 2000, EN LA CIUDAD DE BOGOTÁ, D.C., REPÚBLICA DE COLOMBIA.

NOTA DEL TRADUCTOR: LOS DOCUMENTOS QUE SE TRADUCEN A CONTINUACIÓN FORMAN PARTE DE UN PAQUETE DE DOCUMENTOS PERTINENTES A UNA PATENTE SOLICITADA EN ESTADOS UNIDOS DE AMÉRICA, TODOS LOS CITADOS DOCUMENTOS ESTÁN UNIDOS MEDIANTE UN GANCHO.

LOS ESTADOS UNIDOS DE AMÉRICA

A TODOS A QUIENES ESTE DOCUMENTO LES INTERESE:

EL DEPARTAMENTO DE COMERCIO DE LOS ESTADOS UNIDOS DE AMÉRICA Oficina de Marcas y Patentes de los Estados Unidos.

Agosto 12, 2000.

CERTIFICA QUE LO ANEXO AQUÍ ES UNA COPIA VERDADERA DE LOS ARCHIVOS DE LA OFICINA DE PATENTES Y MARCAS DE LOS ESTADOS UNIDOS DE AMÉRICA DE AQUELLOS PAPELES DE LA SOLICITUD DE PATENTE IDENTIFICADA ABAJO Y QUE CUMPLEN LOS REQUERIMIENTOS PARA CONCEDERLE UNA FECHA DE PRESENTACIÓN BAJO 35 USC 111.

SOLICITUD NUMERO 09/373,289
FECHA DE PRESENTACIÓN : Agosto 12, 1999

**Mediante la autoridad otorgada por
EL COMISIONADO DE PATENTES Y MARCAS**

**(fdo)
T. LAWRENCE
Funcionario Certificador**

NOTA DEL TRADUCTOR: EN LA PARTE INFERIOR IZQUIERDA DEL DOCUMENTO HAY UN SELLO DORADO Y EN ALTO RELIEVE DE LA OFICINA DE MARCAS Y PATENTES DE LOS ESTADOS UNIDOS DE AMÉRICA.

REIVINDICACIONES

1. Un método para estimar una propagación Doppler para un canal de comunicaciones, y el método comprende:

El suministro de un estimado del canal de comunicaciones;

La generación de una función de autocorrelación para el estimado del canal de comunicaciones;

La selección de una de las diversas hipótesis de función de autocorrelación para aproximar la función de autocorrelación para el estimado del canal de comunicaciones en donde cada una de las hipótesis de función de autocorrelación corresponde a una hipótesis estimada de propagación Doppler respectiva;

Y,

La selección de una de las hipótesis de estimación de propagación Doppler correspondientes a las hipótesis de función de autocorrelación seleccionadas, como un estimado de la propagación Doppler para el canal de comunicaciones.

2. Un método de acuerdo con la reivindicación 1 en el cual la selección de una de las hipótesis de función de autocorrelación comprende la comparación de la función de autocorrelación para el estimado del canal de comunicaciones con cada una de las diversas hipótesis de función de autocorrelación.

3. Un método de acuerdo con la reivindicación 1 en el cual la selección de una de las hipótesis de función de autocorrelación comprende la selección de una de las diversas hipótesis de función de autocorrelación que se aproxime más a la función de autocorrelación para el estimado del canal de comunicaciones.

4. Un método de acuerdo con la reivindicación 1 en el cual la selección de una de las hipótesis de función de autocorrelación comprende:

La generación de una pluralidad de señales de error que corresponden respectivamente a la diversidad de hipótesis de función de autocorrelación en la cual cada una de las señales de error representa una diferencia entre la hipótesis de función de autocorrelación respectiva y la función de autocorrelación del estimado del canal de comunicaciones;

Y,

La comparación de las señales de error para seleccionar la hipótesis de autocorrelación para aproximar la función de autocorrelación para el estimado del canal de comunicaciones.

5. Un método de acuerdo con la reivindicación 4 en el cual la comparación de las señales de error comprende la elección de una señal de error que represente una menor diferencia entre la hipótesis de función de autocorrelación correspondiente y la función de autocorrelación para el estimado del canal de comunicaciones.
6. Un método de acuerdo con la reivindicación 5 en el cual la elección de la señal de error comprende la elección de por lo menos una de las señales de error.
7. Un método de acuerdo con la reivindicación 4 en el cual la comparación de las señales de error está precedida por:
El promediar cada una de las señales de error para proporcionar señales de error promediadas en las cuales la comparación de las señales de error comprende la comparación de las señales de error promediadas.
8. Un método de acuerdo con la reivindicación 7 en donde el cálculo del promedio de cada una de las señales de error comprende uno entre cálculo de promedio en bloque, cálculo de promedio corrido y cálculo del promedio de ventana deslizando.
9. Un método de acuerdo con la reivindicación 1 en el cual cada una de las diversas hipótesis de función de autocorrelación comprende diversas muestras y en la cual la función de autocorrelación para el estimado del canal de comunicaciones comprende una pluralidad de muestras.
10. Un método de acuerdo con la reivindicación 1 en el cual el canal de comunicaciones comprende un canal de radio.
11. Un método de acuerdo con la reivindicación 1 en el cual la función de autocorrelación comprende una diversidad de muestras y en el cual la generación de la función de autocorrelación comprende la reducción de un error de frecuencia de la pluralidad de muestras.
12. Un método de acuerdo con la reivindicación 1 que además comprende:
El suministro de un segundo estimado del canal de comunicaciones utilizando el estimado de la propagación Doppler para el canal de comunicaciones.
13. Un método de acuerdo con la reivindicación 1 en el cual el suministro de un estimado del canal de comunicaciones comprende la recepción de una pluralidad de muestras de datos sobre el canal de comunicaciones en el cual se usan muestras de datos para generar los estimados del canal, cuyo método comprende además:
La realización de un chequeo de redundancia cíclica en las muestras de datos usados para generar estimados de canal;

- La actualización de un estimado de Doppler a largo plazo con el estimado de la propagación Doppler cuando las muestras de los datos pasan el chequeo de redundancia cíclica.
14. Un método de acuerdo con la reivindicación 1 en el cual el suministro de un estimado del canal de comunicaciones comprende:
- La recepción de una pluralidad de símbolos piloto en el canal de comunicaciones;
- La reducción de la ambigüedad de fase entre los símbolos piloto;
- Y,
- La utilización de los símbolos piloto habiendo reducido la ambigüedad para generar el estimado del canal de comunicaciones.
15. Un estimador de propagación Doppler para estimar una propagación Doppler para un canal de comunicaciones; el estimador de propagación Doppler comprende:
- Una pluralidad de hipótesis de función de autocorrelación correspondiente a una pluralidad respectiva de hipótesis estimadas de propagación Doppler;
- Un estimador de canal que estima el canal de comunicaciones;
- Un generador de autocorrelación que genera una función de autocorrelación para el estimado del canal de comunicaciones;
- Un probador de hipótesis de función de autocorrelación que selecciona una de las hipótesis de función de autocorrelación para aproximar la función de autocorrelación para estimar el canal de comunicaciones; y
- Un selector de hipótesis de propagación Doppler que selecciona una de las hipótesis estimadas de propagación Doppler correspondiente a las hipótesis de función de autocorrelación seleccionadas como un estimado de la propagación Doppler para el canal de comunicaciones.
16. Un estimador de propagación Doppler de acuerdo a la reivindicación 15 en el cual el probador de hipótesis compara la función de autocorrelación para el estimado del canal de comunicaciones con cada una de las diversas hipótesis de función de autocorrelación.
17. Un estimador de propagación Doppler de acuerdo a la reivindicación 15 en el cual el probador selecciona una de las diversas hipótesis de función de autocorrelación que se aproxime más a la función de autocorrelación para el estimado del canal de comunicaciones.
18. Un estimador de propagación Doppler de acuerdo a la reivindicación 15 en el cual el probador de hipótesis genera una pluralidad de señales de error que corresponden respectivamente a la pluralidad de las hipótesis de función de autocorrelación en las cuales cada una de las señales de error representa una diferencia entre la hipótesis de función de autocorrelación respectiva y la

GR

f
50

- función de autocorrelación del estimado del canal de comunicaciones y en la
- cual el probador de hipótesis compara las señales de error para seleccionar la hipótesis de autocorrelación para aproximar la función de autocorrelación para el estimado del canal de comunicaciones.
- 19. Un estimador de propagación Doppler de acuerdo a la reivindicación 18 en el cual el probador elige una señal de error que represente una menor diferencia entre la hipótesis de función de autocorrelación correspondiente y la función de autocorrelación para el estimado del canal de comunicaciones.
- 20. Un estimador de propagación Doppler de acuerdo a la reivindicación 19 en el cual el probador de hipótesis elige por lo menos una de las señales de error.
- 21. Un estimador de propagación Doppler de acuerdo a la reivindicación 18 en el cual el probador de hipótesis promedia cada una de las señales de error para proporcionar señales de error promediadas en las cuales el probador de hipótesis compara las señales de error promediadas.
- 22. Un estimador de propagación Doppler de acuerdo a la reivindicación 21 el cual el probador de hipótesis promedia cada una de las señales de error usando uno entre: cálculo del promedio en bloque, cálculo del promedio corrido y cálculo del promedio de ventana deslizando .
- 23. Un estimador de propagación Doppler de acuerdo a la reivindicación 15 en el cual la pluralidad de las hipótesis de la función de autocorrelación comprende una pluralidad de muestras y en el cual la función de autocorrelación para el estimado del canal de comunicaciones comprende una pluralidad de muestras.
- 24. Un estimador de propagación Doppler de acuerdo a la reivindicación 15 en el cual el canal de comunicaciones comprende una canal de radio.
- 25. Un estimador de propagación Doppler de acuerdo a la reivindicación 15 en el cual la función de autocorrelación comprende una pluralidad de muestras y en el cual el generador de autocorrelación reduce un error de frecuencia de la pluralidad de muestras.
- 26. Un estimador de propagación Doppler de acuerdo a la reivindicación 15 en el cual el estimador de canal proporciona un segundo estimado del canal de comunicaciones usando el estimado de la propagación Doppler para el canal de comunicaciones.
- 27. Un estimador de propagación Doppler de acuerdo a la reivindicación 15 en el cual el estimador de canal recibe una pluralidad de muestras de datos sobre el canal de comunicaciones en el cual se usan dichas muestras de datos para estimar el canal de comunicaciones, en donde el estimador de canal realiza un chequeo de redundancia cíclica en las muestras de datos usados para generar los estimados de canal; el estimador de propagación Doppler comprende además:

Un estimador Doppler de largo plazo en donde este estimador se actualiza con el estimado de la propagación Doppler cuando las muestras de datos pasan el chequeo de redundancia cíclica.

28. Un estimador de propagación Doppler de acuerdo a la reivindicación 15 en el cual el estimador de canal recibe una pluralidad de símbolos piloto sobre el canal de comunicaciones, reduce la ambigüedad de la fase entre los símbolos piloto y utiliza estos símbolos habiendo reducido la ambigüedad para proporcionar el estimado del canal de comunicaciones.

29. Un método para recibir comunicaciones, que comprende:

Recepción de una señal de un canal de comunicaciones en donde la señal representa datos de un transmisor remoto; generación de un estimado de canal de comunicaciones sobre el cual se recibe la señal;

Generación de una función de autocorrelación para el estimado del canal de comunicaciones;

Selección de una entre varias hipótesis de función de autocorrelación correspondiente a una pluralidad respectiva de hipótesis estimadas de propagación Doppler para aproximar la función de autocorrelación para el estimado del canal de comunicaciones;

La selección de una de las hipótesis de estimado de propagación Doppler correspondiente a las hipótesis de función de autocorrelación seleccionadas como un estimado de la propagación Doppler para el canal de comunicaciones;

Y,

La reproducción de un estimado de datos transmitidos por el transmisor remoto.

30. Un método de acuerdo a la reivindicación 29 en el cual la selección de una de las hipótesis de función de autocorrelación comprende la comparación de la función de autocorrelación para el estimado del canal de comunicaciones con cada una de las diversas hipótesis de función de autocorrelación.

31. Un método de acuerdo a la reivindicación 29 en el cual la selección de una de las hipótesis de función de autocorrelación comprende la selección de una de las diversas hipótesis de función de autocorrelación que se aproxime más a la función de autocorrelación para el estimado del canal de comunicaciones.

32. Un método de acuerdo a la reivindicación 29 en el cual la selección de una de las hipótesis de función de autocorrelación comprende:

La generación de diversas señales de error que corresponden respectivamente a las diversas hipótesis de autocorrelación en las cuales cada una de las señales de error representa una diferencia entre la hipótesis de función de autocorrelación respectiva y la función de autocorrelación del estimado del canal de comunicaciones;

\$

52

Y,

La comparación de señales de error para seleccionar la hipótesis de autocorrelación para aproximar la función de autocorrelación para el estimado del canal de comunicaciones.

33. Un método de acuerdo a la reivindicación 32 en donde la comparación de señales de error comprende la elección de una señal de error que represente una menor diferencia entre la hipótesis de función de autocorrelación correspondiente y la función de autocorrelación para el estimado del canal de comunicaciones.

34. Un método de acuerdo a la reivindicación 33 en el cual la elección de la señal de error comprende elegir de por lo menos una de las señales de error.

35. Un método de acuerdo a la reivindicación 32 en el cual la comparación de las señales de error está precedida por:

El promediar cada una de las señales de error para proporcionar señales de error promediadas en las cuales la comparación de las señales de error comprende la comparación de las señales de error promediadas.

36. Un método de acuerdo a la reivindicación 35 en el cual el promediar cada una de las señales de error comprende una entre: cálculo de promedio en bloque, cálculo de promedio corrido y cálculo de ventana deslizante.

37. Un método de acuerdo a la reivindicación 29 en el cual cada una de las diversas hipótesis de función de autocorrelación comprende diversas muestras y en el cual la función de autocorrelación para el estimado del canal de comunicaciones comprende diversas muestras.

38. Un método de acuerdo a la reivindicación 29 en el cual el canal de comunicaciones comprende un canal de radio.

39. Un método de acuerdo a la reivindicación 29 en el cual la función de autocorrelación comprende diversas muestras y en el cual la generación de la función de autocorrelación comprende la reducción de un error de frecuencia de las diversas muestras.

40. Un método de acuerdo a la reivindicación 29 que comprende además:
El suministro de un segundo estimado de canal de comunicaciones utilizando el estimado de la propagación Doppler para el canal de comunicaciones.

41. Un método de acuerdo a la reivindicación 29 en el cual el suministro de un estimado de canal de comunicaciones comprende la recepción de diversas muestras de datos en el canal de comunicaciones en el cual las muestras de datos se usan para generar los estimados de canal, el método además comprende:

La realización de un chequeo de redundancia cíclica en las muestras de datos usadas para generar estimados de canal;

Actualización de un estimado Doppler a largo plazo con el estimado de la propagación Doppler cuando las muestras de datos pasan el chequeo de redundancia cíclica.

42. Un método de acuerdo a la reivindicación 29 en el cual los datos recibidos del transmisor remoto comprenden símbolos piloto y en el cual la generación de un estimado del canal de comunicaciones comprende:

La reducción de la ambigüedad de fase entre los símbolos piloto;

La utilización de los símbolos piloto habiendo reducido la ambigüedad para proporcionar el estimado del canal de comunicaciones.

43. Un receptor que comprende:

Un receptor y convertidor de radio que recibe una señal sobre un canal de comunicaciones;

Un estimador de canal que estima el canal de comunicaciones sensible a la señal recibida en el canal de comunicaciones;

Diversas hipótesis de función de autocorrelación correspondiente a diversas hipótesis de estimado de propagación Doppler respectivas;

Un generador de autocorrelación que genera una función de autocorrelación para el estimado del canal de comunicaciones;

Un probador de hipótesis de función de autocorrelación que selecciona una de las hipótesis de función de autocorrelación para aproximar la función de autocorrelación para el estimado del canal de comunicaciones;

Y,

Un selector de hipótesis de propagación Doppler que selecciona una de las hipótesis de estimado de propagación Doppler correspondiente a las hipótesis de función de autocorrelación seleccionadas, como un estimado de la propagación Doppler para el canal de comunicaciones.

44. Un receptor de acuerdo a la reivindicación 43 en el cual el probador de hipótesis compara la función de autocorrelación para el estimado del canal de comunicaciones con cada una de las diversas hipótesis de función de autocorrelación.

45. Un receptor de acuerdo a la reivindicación 43 en el cual el probador selecciona una de las diversas hipótesis de función de autocorrelación que se aproxime más a la función de autocorrelación para el estimado del canal de comunicaciones.

46. Un receptor de acuerdo a la reivindicación 43 en el cual el probador de hipótesis genera diversas señales de error que corresponden respectivamente a las diversas hipótesis de función de autocorrelación en el cual cada una de las señales de error representa una diferencia entre la hipótesis de función de autocorrelación respectiva y la función de autocorrelación del estimado del canal de comunicaciones y en el cual el probador de hipótesis compara las

señales de error para seleccionar la hipótesis de autocorrelación para aproximar la función de autocorrelación para el estimado del canal de comunicaciones.

47. Un receptor de acuerdo a la reivindicación 46 en el cual el probador de hipótesis selecciona una señal de error que representa una diferencia menor entre la hipótesis de función de autocorrelación correspondiente y la función de autocorrelación para el estimado del canal de comunicaciones.

48. Un receptor de acuerdo a la reivindicación 47 en el cual el probador de hipótesis promedia cada una de las señales de error.

49. un receptos de acuerdo con la reivindicación 46 en el cual un probador de hipótesis promedia cada una de las señales de error para generar señales de error promediadas en donde el probador de hipótesis compara las señales de error promediadas.

50. Un receptor de acuerdo a la reivindicación 49 en el cual el probador de hipótesis promedia cada una de las señales de error utilizando una entre: cálculo del promedio en bloque, cálculo de promedio corrido y cálculo de ventana deslizando.

51. Un receptor de acuerdo a la reivindicación 43 en el cual cada una de las diversas hipótesis de función de autocorrelación comprenden diversas muestras y en el cual la función de autocorrelación para el estimado del canal de comunicaciones comprende diversas muestras.

52. Un receptor de acuerdo a la reivindicación 43 que comprende además:
Un procesador de señal acoplado entre el estimador de propagación Doppler y el estimador de canal en el cual el procesador de señal modifica la operación del estimador de canal sensible al estimado de la propagación Doppler para el canal de comunicaciones.

53. Un receptor de acuerdo a la reivindicación 43 en el cual el canal de comunicaciones comprende un canal de radio.

54. Un receptor de acuerdo a la reivindicación 43 en el cual la función de autocorrelación para el estimado del canal de comunicaciones comprende diversas muestras y en el cual el generador de autocorrelación reduce un error de frecuencia de las diversas muestras.

55. Un receptor de acuerdo a la reivindicación 43 en el cual el estimador de canal proporciona un segundo estimado del canal de comunicaciones usando el estimado de la propagación Doppler para el canal de comunicaciones.

56. Un receptor de acuerdo a la reivindicación 43 en el cual la señal recibida en el canal de comunicaciones comprende diversas muestras de datos en las cuales el estimador del canal utiliza las muestras de datos para estimar el canal de comunicaciones, en el cual el estimador de canal realiza un chequeo

SP

Sc

V*

- de redundancia cíclica en las muestras de datos usadas para generar los estimados de canal, el receptor comprende además:

Un estimador Doppler a largo plazo en el cual este estimador se actualiza con el estimado de la propagación Doppler cuando las muestras de datos pasan el chequeo de redundancia cíclica.

57. Un receptor de acuerdo a la reivindicación 43 en el cual la señal recibida en el canal de comunicaciones comprende diversos símbolos piloto, en los cuales el estimador de canal reduce la ambigüedad de la fase entre los símbolos piloto y en el cual el estimador de canal usa los símbolos piloto que tienen una ambigüedad de fase reducida para proporcionar el estimado del canal de comunicaciones.

PA 287730



THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

August 21, 2000

THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM THE RECORDS OF THE UNITED STATES PATENT AND TRADEMARK OFFICE OF THOSE PAPERS OF THE BELOW IDENTIFIED PATENT APPLICATION THAT MET THE REQUIREMENTS TO BE GRANTED A FILING DATE UNDER 35 USC 111.

APPLICATION NUMBER: 09/373,289

FILING DATE: August 12, 1999



By Authority of the
COMMISSIONER OF PATENTS AND TRADEMARKS

T. Lawrence

T. LAWRENCE
Certifying Officer

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

ATTY DOCKET NO.: 8194-299

DATE: August 12, 1999

UTILITY PATENT APPLICATION TRANSMITTAL LETTER
AND FEE TRANSMITTAL FORM (37 CFR 1.53(b))

BOX PATENT APPLICATION

Assistant Commissioner for Patents
Washington, DC 20231

Sir:

Transmitted herewith for filing under 37 CFR 1.53(b) is:

- ☒ a patent application
☐ a Continuation ☐ a Divisional ☐ a Continuation-in-Part (CIP)
of prior application no.: _____; filed _____
☐ A Small Entity Statement(s) was filed in the prior application; Status still proper and desired.

Inventor(s) or Application Identifier:

Karl James Molnar, Cary, North Carolina; Leonid Kramy, Cary, North Carolina, Hüseyin Aralan, Durham, North Carolina

Entitled: METHODS FOR ESTIMATING DOPPLER SPREADS INCLUDING AUTOCORRELATION
FUNCTION HYPOTHESES AND RELATED SYSTEMS AND RECEIVERS

Enclosed are:

1. ☒ Application Transmittal Letter and Fee Transmittal Form (*A duplicate is enclosed for fee processing*)
2. ☒ 27 pages of Specification (including 57 claims)
3. ☒ 4 sheets of Formal Drawings (35 USC 113)
4. ☒ Oath or Declaration
 - a. ☒ newly executed (*original or copy*)
 - b. ☐ copy from prior application (37 CFR 1.63(d) (*for continuation/divisional*) (Note Box 5 Below)
 - c. ☐ DELETION OF INVENTOR(S) (*Signed statement deleting inventor(s) named in the prior application*)
5. ☐ Incorporation By Reference (*useable if box 4b is checked*)

The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. ☐ Microfiche Computer Program (*Appendix*)
7. ☒ Assignment papers (*cover sheet(s) and document(s)*)
8. ☐ Small Entity Statement(s)
9. ☒ Information Disclosure Statement, PTO-1449, and 8 references cited
10. ☐ Preliminary Amendment (*Please enter all claim amendments prior to calculating the filing fee.*)
11. ☐ English Translation Document
12. ☐ Certified Copy of Application No. _____; Filed _____
13. ☐ Sequence Listing/ Sequence Listing Diskette
 - a. ☐ computer readable copy
 - b. ☐ paper copy
 - c. ☐ statement in support

In re: Molnar, et al.
Filed: August 12, 1999

14. ☐ An Associate Power of Attorney
15. ☒ Return Receipt Postcard (MPEP 503) (Should be specifically itemized)
16. ☐ Other:

The fee has been calculated as shown below:

	Column 1 No. Filed	Column 2 No. Extra	Small Entity Rate Fee	Large Entity Rate Fee
BASIC FEE			\$380.00	\$760.00
TOTAL CLAIMS	57 - 20 =	37	x 9 = \$	x 18 = \$ 666.00
INDEP CLAIMS	4 - 3 =	1	x 39 = \$	x 78 = \$ 78.00
☐ MULTIPLE Dependent Claims Presented			+ 130 = \$	+ 260 = \$
If the difference in Col. 1 is less than zero, Enter "0" in Col. 2			Total \$	Total \$1504.00

☐ A check in the amount of \$_____ to cover the filing fee is enclosed.

☒ A check in the amount of \$1,544.00 is enclosed to cover the filing fee, PLUS the Assignment Recordation fee (\$40.00).

☐ The Commissioner is hereby authorized to charge payment of the following fees associated with this communication or credit any overpayment to Deposit Account No.

☐ Any additional filing fees required under 37 CFR 1.16.

☐ Any patent application processing fees under 37 CFR 1.17.

Respectfully submitted,


Scott C. Hatfield
Registration No. 38,176

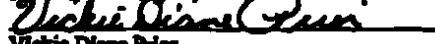
USPTO Customer Number 20792
Myers Bigel Sibley & Sajovec
Post Office Box 37428
Raleigh, North Carolina 27627
Telephone (919) 854-1400
Facsimile (919) 854-1401

CERTIFICATE OF EXPRESS MAILING

Express Mail Label No. EL299857333US

Date of Deposit: August 12, 1999

I hereby certify that this correspondence is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to Box Patent Application, Assistant Commissioner For Patents, Washington, DC 20251.


Vickie Diane Prior

Date of Signature: August 12, 1999

**METHODS FOR ESTIMATING DOPPLER SPREADS INCLUDING
AUTOCORRELATION FUNCTION HYPOTHESES AND RELATED
SYSTEMS AND RECEIVERS**

FIELD OF THE INVENTION

The present invention relates to the field of communications and more particularly to receiving radio communications.

5 BACKGROUND OF THE INVENTION

662180-682626
0373289-081299

A radio channel for a mobile terminal in a cellular radiotelephone communications system may be difficult to operate. In particular, the transmitted signals are often reflected, scattered, diffracted, delayed, and attenuated by the surrounding environment. Moreover, the radio channel for
10 a mobile terminal is often not stationary because of movement of the mobile terminal and movement of objects near the mobile terminal. The mobile terminal may move rapidly when used in an automobile, and other vehicles may also be in motion near the mobile terminal.

Characteristics of the radio channel may also vary from one area to another due to differences in terrain/buildings, climate, and/or other factors.
15 The propagation of a radio signal along the radio channel may thus be subject to multi-path fading, shadowing, and path loss. Of these factors, multi-path fading may be the most significant, and multi-path fading can be characterized by envelope fading, Doppler spread, and time-delay spread.

Doppler shift is the frequency shift experienced by the radio signal
20 when the mobile terminal is in motion, and the Doppler spread is a measure of the spectral broadening caused by the time rate of change of the mobile radio channel. Doppler spread thus leads to frequency dispersion, and the Doppler spread in the frequency domain is closely related to the rate of change in the
25 observed signal. The adaptation time of an algorithm used in an adaptive receiver should thus be faster than the rate of change of the channel to be able to accurately track the fluctuations in the received signal.

A mobile terminal in a DAMPS cellular radiotelephone communications system, for example, may experience a Doppler spread in the range of 0Hz to

250Hz depending on the vehicle speed, carrier frequency, and other factors. Knowledge of the rate of change of the radio channel can be used to improve receiver performance and/or reduce receiver complexity. Moreover, the adaptation parameters for an adaptive receiver can be varied as a function of the Doppler spread. Instead of fixing the tracker and interpolation parameters for the worst case expected Doppler spread, for example, the parameters can be changed adaptively as a function of the Doppler information to improve performance. Similarly, Doppler spread information can be used to control the receiver adaptively for different speeds at which the mobile may be traveling. In other words, different receiver algorithms can be used depending on the speed at which the mobile terminal is traveling.

Estimates of the Doppler spread can thus be used to increase receiver performance. The parameters of a receiver adaptation algorithm can be varied as a function of the Doppler spread to adaptively optimize a coherent detector in a receiver, for example. In addition, the hand-off process in a cellular mobile telephone system can be enhanced if an estimate of the Doppler spread is available. Handoff of a fast moving mobile terminal to a micro cell can thus be avoided.

Doppler spread estimation is discussed, for example, in U.S. Patent No. 4,723,303 to Koch entitled "METHOD OF AND CIRCUIT ARRANGEMENT FOR MEASURING THE QUALITY OF RADIO-TRANSMISSION CHANNELS OF A RADIO-TRANSMISSION SYSTEM", and U.S. Patent No. 5,016,017 to Ralith entitled "METHOD OF CONTROLLING THE FREQUENCY OF A COHERENT RADIO RECEIVER AND APPARATUS FOR CARRYING OUT THE METHOD". The disclosures of each of these patents is hereby incorporated herein in their entirety by reference.

A method of estimating Doppler spreads from a sequence of channel estimates is discussed, for example, in the thesis by Lars Lindborn entitled "Adaptive Equalization For Fading Mobile Radio Channels", (Techn.Lic.Thesis No. UPTEC 92124R, November 1992, Department of Technology, Uppsala University, Uppsala Sweden), the disclosure of which is hereby incorporated herein in its entirety by reference. In the Lindborn thesis, differentials of the channel estimate, which comprise differences of values between two points in time, are used to estimate Doppler spreads. These differentials, however,

62

61 13

may be noisy so that averaging may be needed. As a result, the averaging may give biased estimates of the Doppler spread.

Other Doppler spread estimation techniques are discussed in the reference by Karim Jamal et al. entitled "Adaptive MSLE Performance On The D-AMPS 1900 Channel" (*IEEE Trans. Vehic. Technol.*, vol. 46, Aug. 1997), and the reference by M. Morelli et al. entitled "Further Results In Carrier Frequency Estimation For Transmissions Over Flat Fading Channels" (*IEEE Commun. Letters*, vol. 2, pp. 327-330, Dec. 1998). The disclosures of these references are also incorporated herein in their entirety by reference.

Notwithstanding the approaches discussed above, there continues to exist a need in the art for improved Doppler spread estimation approaches.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide improved methods of estimating Doppler spreads for communications channels and related systems and receivers.

It is another object of the present invention to provide less complex methods of estimating Doppler spreads and related systems and receivers.

These and other objects can be provided according to the present invention by providing an estimate of the communications channel and generating an autocorrelation function for the estimate of the communications channel. One of a plurality of autocorrelation function hypotheses is selected to approximate the autocorrelation function for the estimate of the communications channel wherein each of the autocorrelation function hypotheses corresponds to a respective Doppler spread estimate hypothesis. The Doppler spread estimate hypothesis corresponding to the selected autocorrelation function hypothesis is then selected as an estimate of the Doppler spread for the communications channel.

The autocorrelation function hypotheses can thus be saved in a memory of a Doppler spread estimator according to the present invention and compared to the autocorrelation function of the estimate of the communications channel, with the closest autocorrelation function hypotheses being accepted as an estimate of the actual autocorrelation function for the communications channel. The Doppler spread hypothesis corresponding to

09372289.0 1249

63

62 19

the closest autocorrelation function can thus be used as an estimate of the actual Doppler spread for the communications channel. The complexity of calculations used to estimate the Doppler spread can thus be reduced while providing a relatively accurate estimate of the Doppler spread. In addition, the number of autocorrelation function hypotheses used can be increased to provide a more accurate estimation, or decreased to reduce the number of calculations and amount of memory used.

In greater detail, the selection of one of the autocorrelation function hypotheses can include comparing the autocorrelation function for the estimate of the communications channel with each of the plurality of autocorrelation function hypotheses. In addition, the selection of one of the autocorrelation function hypotheses can include selecting one of the plurality of autocorrelation function hypotheses most closely approximating the autocorrelation function for the estimate of the communications channel.

Moreover, the selection of one of the autocorrelation function hypotheses can include generating a plurality of error signals respectively corresponding to the plurality of autocorrelation function hypotheses wherein each of the error signals represents a difference between the respective autocorrelation function hypothesis and the autocorrelation function of the estimate of the communications channel, and comparing the error signals to select the autocorrelation hypothesis to approximate the autocorrelation function for the estimate of the communications channel. In particular, the error signals can be compared to choose the error signal representing a least difference between the corresponding autocorrelation function hypothesis and the autocorrelation function for the estimate of the communications channel. In addition, the comparison of the error signals can be preceded by averaging each of the error signals to provide averaged error signals wherein comparing the error signals comprises comparing the averaged error signals.

Methods, systems, and receivers according to the present invention can thus be used to provide estimates of Doppler spreads for a communications channel with reduced complexity.

09372289-0822E7E60

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram of a communications system including a receiver according to the present invention.

5 Figures 2-4 are block diagrams of receivers according to the present invention.

Figure 5 is a block diagram of a Doppler spread estimator according to the present invention.

Figure 6 is a graph illustrating autocorrelation functions for radio channels at different speeds of a receiver relative to a base station.

10 Figure 7 is a table illustrating a storage of samples of the autocorrelation functions of Figure 6.

DETAILED DESCRIPTION

15 The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

20 Figure 1 illustrates a transmitter T and a receiver R according to the present invention wherein data d is transmitted by the transmitter T over the radio channel c. The received signal r is a function of the transmitted data d, the radio channel c, and noise n. In a flat fading channel:

25

$$r=h \cdot d+n. \quad (\text{equation 1})$$

30 As discussed above, receiver performance can be improved by estimating the Doppler spread and using the estimated Doppler spread to adapt receiver functions. More particularly, the estimated Doppler spread can be used to more accurately estimate the radio channel h. The use of Doppler spread estimators in receivers is discussed in co-pending U.S. Patent Application Serial No. _____ to Leonid Krasny et al. entitled "DOPPLER SPREAD

65

64 | 28

ESTIMATION SYSTEM" filed on March 22, 1999 (Docket No. P10367-RCUR and 1280.00105). The Krasny et al. application is assigned to the assignee of the present application, and the Krasny et al. application shares a common inventor with the present application. In addition, the disclosure of the Krasny et al. application is hereby incorporated herein in its entirety by reference.

Various receivers Ra, Rb, and Rc including Doppler spread estimators according to the present invention are illustrated in Figures 2-4. In particular, the receiver Ra of Figure 2 is adapted for use with known pilot symbols, and this receiver includes an antenna 21 that receives the signal r, a radio receiver and converter 23a, a channel estimator 25a, a Doppler spread estimator 27a, a known symbol block 29a, and a signal processor 31a. The antenna 21a receives the radio signals r, and the radio receiver and converter 23a filters, amplifies, and converts the received radio signals r into digital samples for processing. More particularly, the received radio signals can be converted to a form such as complex numerical sample values suitable for processing. The channel estimator receives the converted radio signals and known symbols from the known symbol block 29a.

In particular, the known symbol block 29a can provide pilot symbols or other known reference symbols, such as synchronization symbols, included in the received signal r that can be used to calculate channel estimates. Moreover, the known symbol block 29a can include a memory where the known symbols are stored or a code generator that can generate the known symbols. The channel estimator 25a correlates the received digital samples with the known symbols to provide an estimate of the channel c to be used by the Doppler spread estimator 27a. The Doppler spread estimator estimates the Doppler spread using the channel estimates and then sends the estimated Doppler spread to the signal processor 31a. The operation of the Doppler spread estimator will be discussed in greater detail below. The signal processor 31a processes the sampled signal to extract information, and the signal processor 31a provides feedback to the channel estimator 25a so that the channel estimates can be improved after the Doppler spread estimation.

The receiver Rb of Figure 3 is adapted for use without known pilot symbols. This receiver includes an antenna 21b that receives the signal r, a radio receiver and converter 23b, a channel estimator 25b, a Doppler spread

0937328 . 01299

66

65 28

estimator 27b, a symbol estimator 29b, and a signal processor 31b. The receiver Rb is similar to the receiver Ra of Figure 2 with the exception that the symbol estimator 29b is used instead of the known symbol block 29a used in the receiver of Figure 2. The symbol estimator 29b can be used in applications where symbols are not known. The symbol estimator 29b, for example, can use error detection and correction techniques to estimate received symbols with a high level of accuracy. These estimated symbols can then be used by the channel estimator 25b to estimate the channel h. The Doppler spread estimator 27b uses the channel estimates to estimate the Doppler spread as discussed in greater detail below.

In code-division multiple access (CDMA) cellular systems (such as IS-95 systems), a transmitter transmits a stream of known symbols known as the pilot code. The pilot code is transmitted on the same channel and at the same time as other information bearing symbols using different spreading codes. The receiver Rc of Figure 4 provides Doppler spread estimations in such a CDMA system. The receiver Rc of Figure 4 is adapted for use with known pilot symbols, and this receiver includes an antenna 21c that receives the signal r, a radio receiver and converter 23c, a channel estimator 25c, a Doppler spread estimator 27c, and a signal processor 31c. In this CDMA receiver, the channel can be estimated directly by the channel estimator 25c without the known symbol block 29a of Figure 1 or the symbol estimator 29b of Figure 2, and the channel estimates used for Doppler spread estimation.

The channel estimator 25c correlates the received signal r including the known pilot code and other codes in additive superimposition, and filters the resultant complex correlation to obtain channel estimates. The received signal can also be correlated with other codes carrying information to be decoded. The results of correlating with information carrying codes are multiplied by the conjugate of pilot code correlations for the same delay, and the results added to coherently combine the multi-path signals. In wide band CDMA (WBCDMA) systems, modulation symbol intervals may be much shorter thus allowing multiple propagation paths to be resolved with much finer time resolution.

The receivers of Figures 2-4 thus illustrate various receivers including Doppler spread estimators according to the present invention. In each

09373289-08129

67

66

75

receiver, channel estimates are provided to the Doppler spread estimator for calculation of the Doppler spread estimates. Receivers including Doppler spread estimators according to the present invention are not limited to the channel estimators discussed above, and those having skill in the art will recognize that any channel estimation technique can be used to provide channel estimates.

In particular, the channel estimator can generate an estimate of the channel over a TDMA time slot using symbols representing data samples received during the time slot. For example, the receiver Rb of Figure 3 can include the symbol estimator 296 to estimate the symbols. The Doppler spread estimator can then use the channel estimate for the current time slot to calculate a Doppler spread estimate for the current time slot, and the signal processor can use this Doppler spread estimate in calculations for subsequent time slots, such as calculations of channel estimates for subsequent time slots. In other words, the Doppler spread estimate for the current time slot can be used to update a long term Doppler estimate in the signal processor which is used in subsequent calculations. The long term Doppler estimate can be updated, for example, using averaging techniques discussed in greater detail below.

When a symbol estimator is used as discussed with reference to Figure 3, it may be useful to perform a cyclical redundancy check (CRC) on the estimated symbols used to calculate the Doppler spread estimate for the time slot. If the cyclical redundancy check passes, the channel estimate should be relatively accurate, and the resulting Doppler spread estimate can be used to update the long term Doppler estimate. If the cyclical redundancy check fails, however, the channel estimate may be unreliable, and it may thus be desirable to not update the long term Doppler estimate using a Doppler spread estimate based on a potentially unreliable channel estimate.

The Doppler spread estimation will now be discussed in greater detail with reference to the Doppler spread estimator of Figure 5. The Doppler spread estimator can be used, for example, with receivers of radiotelephone communication systems operating according to either the DAMPS or DAMPS+ standards. In DAMPS+, known pilot symbols are provided. In DAMPS, with a multi-pass demodulation, the Class 1 bits demodulated in the

09373289.081299

first pass can be used as pilot symbols if they pass the cyclical redundancy check (CRC). Preferably, phase ambiguities between the pilot slots is reduced to increase the reliability of the results. A method of resolving phase ambiguity is discussed, for example, in the reference by T. Fulghum entitled

5 "Channel Interpolation On Second Pass Demodulation", (Tech. Rep. TR/X 98:1230, Ericsson, RTP, NC, Feb. 22, 1999) the disclosure of which is hereby incorporated herein in its entirety by reference.

Assuming that the pilot symbols are available and that the phase ambiguity between pilot symbols has been reduced to an acceptable level,

10 samples of the autocorrelation function $\hat{R}_e$ can be found by the autocorrelation calculator 51 using the channel estimates obtained from the pilot symbols. The samples of the autocorrelation function are then compared with different hypotheses ($H_1, H_2, H_3, \dots H_k$) of the true autocorrelation function of different Doppler spread values using the hypothesis comparator

15 53 to provide error calculations ($e_{1(m)}, e_{2(m)}, e_{3(m)}, \dots e_{k(m)}$) for the autocorrelation function samples with respect to each of the hypotheses. Each of the error calculations can then be averaged over several slots using the averager 55 to provide a respective plurality of averaged error values ($e_{av,1}, e_{av,2}, e_{av,3}, \dots e_{av,k}$). The Doppler spread corresponding to the

20 hypothesis resulting in the lowest averaged error value is then selected by the minimum error selector 57 to provide the estimated Doppler spread $\hat{f}_{\text{doppler}}$.

In greater detail, the channel estimates can be determined using techniques available now or in the future, and the hypotheses of the different autocorrelation functions ($H_1, H_2, H_3, \dots H_k$) corresponding to different Doppler spread values can be calculated and stored in memory. In particular, actual

25 radio channels and corresponding Doppler spread values can be determined at different mobile terminal speeds relative to the base station, and the resulting autocorrelation functions can be calculated for each speed. Graphical examples of hypotheses of different autocorrelation functions

30 (correlation vs. τ) corresponding to radio channels measured at different speeds and corresponding to different Doppler spread values are illustrated in Figure 6.

69

68

7/

Samples of each autocorrelation function representing a respective hypothesis H_k can be stored in memory for the hypothesis comparator 53 to provide the hypothesis $H_1, H_2, H_3, \dots H_k$ shown in Figure 5. For example, samples of each autocorrelation function of the graph of Figure 6 corresponding to different values of τ can be stored in memory as illustrated in Figure 7. While five different hypotheses are shown in the graph of Figure 6, any number can be used. A greater number (k) of hypotheses can be used to provide a greater accuracy in the estimation of Doppler spread values, while a fewer number (k) of hypotheses can provide less complicated operation with fewer calculations and a lower memory requirement. Moreover, the number of samples z saved for each hypothesis can be varied depending on the desired level of accuracy for the Doppler spread estimation.

The autocorrelation function estimation for a channel with frequency error can be calculated using the autocorrelation estimator 51 using the channel estimates over the known field as:

$$\hat{R}_e(\tau) = \frac{1}{L-\tau} \sum_{k=\tau+1}^L \hat{h}_e(k) \hat{h}_e^*(k-\tau). \quad (\text{equation 2})$$

In this equation, $\hat{R}_e$ is the estimated autocorrelation function including the frequency error, and $\hat{h}_e$ is the channel estimates over the known fields (or pilot symbols). Note that when there is a frequency error in the received signal, it may directly effect the channel estimates which may be rotated by the amount of the frequency error thus effecting the autocorrelation estimate. Designating the frequency error as f_e , the rotation in the channel estimates can be calculated as:

$$\hat{h}_e(k) = \hat{h} e^{j2\pi f_e kT}, \quad (\text{equation 3})$$

where $\hat{h}$ represents the channel estimates when there is no frequency error.

The autocorrelation function with frequency error can thus be rewritten as:

09373289-081299

$$\hat{R}_\tau(\tau) = \frac{1}{L-\tau} \sum_{k=\tau+1}^L \hat{h}(k) e^{j2\pi f_c k T} \hat{h}^*(k-\tau) e^{j2\pi f_c (k-\tau) T}, \quad (\text{equation 4})$$

or:

$$\hat{R}_\tau(\tau) = \hat{R}(\tau) e^{-j2\pi f_c \tau T}, \quad (\text{equation 5})$$

5

where $\hat{R}(\tau)$ is the autocorrelation estimate without the frequency error.

The frequency error f_c can be calculated using known methods as discussed for example in the reference by Morelli et al. entitled "Further Results In Carrier Frequency Estimation For Transmissions Over Flat Fading Channels", (IEEE Commun. Letters, vol. 2, pp. 327-330, Dec. 1998), the disclosure of which is hereby incorporated herein in its entirety by reference. The effect of the frequency error can thus be removed from the correlation of the channel estimates as:

10

$$R(\tau) = R_\tau(\tau) e^{j2\pi f_c \tau T}, \quad (\text{equation 6})$$

15

The frequency error-free correlation estimates can then be compared with the different hypotheses ($H_1, H_2, H_3, \dots, H_K$) of the hypothesis comparator 53.

The hypotheses ($H_1, H_2, H_3, \dots, H_K$) can be determined and stored in memory as discussed above with regard to Figures 6 and 7. The error $e_K(m)$ of the autocorrelation estimate $\hat{R}_\tau$ with respect to each of the hypotheses is calculated using:

20

$$e_K(m) = \sum_{n=1}^N |\hat{R}(n) - \hat{R}(0) R_{H,K}(n)|^2. \quad (\text{equation 7})$$

25

In this equation, $e_K(m)$ is the error corresponding to the m th slot between the estimated autocorrelation function and the different samples of the k th hypothesis of the normalized true autocorrelation function $R_{H,K}(n)$ given as:

✱

20

✱

$$R_{H,k}(n) = J_0(2\pi f_{\text{doppler},k}nT), \quad (\text{equation 8})$$

where $f_{\text{doppler},k}$ is the k th Doppler spread hypothesis. The error term e_k is averaged over several slots at the averager 55 (filter) using the equation:

5

$$e_{av,k} = \frac{1}{M} \sum_{m=1}^M e_k(m), \quad (\text{equation 9})$$

where $e_{av,k}$ is the averaged error corresponding to the k th hypothesis, and M is the length of the averaging window. In this example, block averaging is used to average the error. Alternately, other averaging techniques such as running averaging or sliding window averaging can be used. Averaging thus reduces statistical errors.

The minimum error selector 57 determines the lowest of the averaged errors $e_{av,k}$ to select the autocorrelation function hypothesis H_k most closely approximating the autocorrelation function for the received channel. The Doppler spread hypothesis selector selects the Doppler spread hypothesis corresponding to the selected autocorrelation function hypothesis as the estimate of the Doppler spread $\hat{f}_{\text{doppler}}$. In other words, the minimum of the averaged errors $e_{av,k}$ is used to select the autocorrelation function hypothesis resulting in the lowest averaged error (at the minimum error selector 57), and the Doppler spread hypothesis corresponding to the selected autocorrelation function hypothesis is selected as the estimate of the Doppler spread (at the Doppler spread hypothesis selector 59) according to the following equation.

25

$$\hat{f}_{\text{doppler}} = \arg \min_{f_{\text{doppler},k}} e_{av,k}. \quad (\text{equation 10})$$

Alternately, the autocorrelation function with frequency error can be calculated as discussed in the Morelli et al reference. Instead of finding the frequency error and removing it from the estimated autocorrelation function,

30

09/23/2016 10:08:29

27

21

28

we can take the absolute value of the estimated autocorrelation to obtain the envelope autocorrelation function as:

$$\tilde{R}(\tau) = |\hat{R}(\tau)| = |\hat{R}(\tau)e^{j2\pi f_d \tau}| = |\hat{R}(\tau)|. \quad (\text{equation 11})$$

This absolute value of the autocorrelation function estimate (without frequency error) can then be compared with the different hypotheses of the true envelope autocorrelation function corresponding to the different Doppler spread values as:

$$e_k(m) = \sum_{n=1}^N |\tilde{R}(n) - \tilde{R}(0)\tilde{R}_{H,k}(n)|^2 \quad (\text{equation 12})$$

where,

$$\tilde{R}_{H,k}(n) = |J_0(2\pi f_{\text{doppler},k} nT)|. \quad (\text{equation 13})$$

The error terms are used as before to determine the hypothesis that provides the least error in the estimation of the Doppler spread value.

In DAMPS systems, phase ambiguity can be substantially removed within a time slot using known techniques. Phase ambiguity across time slots, however, may still exist. According to the present invention, the correlation within slots can be estimated and compared with the different hypotheses. Errors across slots, however, are averaged.

As previously discussed, the number of hypotheses can be varied depending on the desired accuracy and complexity of the Doppler spread estimator and receiver. A greater number of hypotheses can provide greater accuracy while requiring more memory and computation. A fewer number of hypotheses can reduce memory use and computation while providing a less accurate Doppler spread estimation.

The Doppler spread estimation methods according to the present invention can thus be implemented with relative computational efficiency, and good results. In particular, the use of the envelope correlation function can

09273289.0812

72

72

provide a level of performance close to that of other techniques without requiring frequency error estimation.

Doppler estimation, according to the present invention, can be performed, for example, in the context of a DAMPS cellular radio telephone system using the following downlink slot and transmission formats: $\pi/4$ -DQPSK with root raised cosine pulse shaping; TDMA frame of 20ms; and 3 users sharing the TDMA frame. Moreover, each user can transmit twice during a frame with a slot duration of 6.667 ms. The transmission medium can be a Rayleigh fading channel, and the channel can be simulated using Jake's fading model. A single antenna receiver and a carrier frequency of 1900 MHz can be used.

In downlink joint demodulation, only one Doppler spread needs to be estimated for both desired and interfering signals because both desired and interfering base stations are fixed and the mobile terminal is moving. This assumption is reasonable assuming there is no direct path. The Doppler spreads can thus be estimated using information corresponding to the stronger user which is the desired user in most cases.

In the receiver, ideal sync location can be assumed to be known, and the received samples can be used to coherently demodulate the user's information sequences. Kalman based channel estimation using a second order autoregressive model (AR-2) can be used for channel tracking. As discussed above, channel tracking depends on the Doppler information. As the Doppler information may not be known initially, the tracker parameters can be initially set to a relatively high Doppler spread of 100Hz. As the Doppler spread estimate converges to the actual Doppler spread, the tracker parameters should also be changed in the adaptive receiver.

The present invention may be embodied as methods or devices. In addition, the invention may take the form of an entirely hardware embodiment, an entirely software embodiment, or an embodiment combining both hardware and software aspects. The present invention has been described in part with respect to the block diagrams of Figures 1-5. It will be understood that each block of the illustrations, and combinations of blocks, can be implemented by

27

73

27

computer program instructions. These program instructions, which may represent steps, may be provided to a processor to produce a machine.

Accordingly, blocks of the block diagrams support combinations of means for performing the specified functions in combinations of steps for performing the specified functions. It will be understood that each block of the illustrations, and combinations of blocks, can be implemented by special purpose hardware-based systems which perform the specified functions or steps, or combinations of special purpose hardware and computer instructions.

In the drawings and specification, there have been disclosed typical preferred embodiments of the invention and, although specific terms are employed, they are used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention being set forth in the following claims.

25

24

26

THAT WHICH IS CLAIMED IS:

1. A method for estimating a Doppler spread for a communications channel, the method comprising:
 - providing an estimate of the communications channel;
 - generating an autocorrelation function for the estimate of the
 - 5 communications channel;
 - selecting one of a plurality of autocorrelation function hypotheses to approximate the autocorrelation function for the estimate of the communications channel wherein each of the autocorrelation function hypotheses corresponds to a respective Doppler spread estimate hypothesis;
 - 10 and
 - selecting one of the Doppler spread estimate hypotheses corresponding to the selected autocorrelation function hypotheses as an estimate of the Doppler spread for the communications channel.
2. A method according to Claim 1 wherein selecting one of the autocorrelation function hypotheses comprises comparing the autocorrelation function for the estimate of the communications channel with each of the plurality of autocorrelation function hypotheses.
3. A method according to Claim 1 wherein selecting one of the autocorrelation function hypotheses comprises selecting one of the plurality of autocorrelation function hypotheses most closely approximating the autocorrelation function for the estimate of the communications channel.
4. A method according to Claim 1 wherein selecting one of the autocorrelation function hypotheses comprises:
 - generating a plurality of error signals respectively corresponding to the plurality of autocorrelation function hypotheses wherein each of the error
 - 5 signals represents a difference between the respective autocorrelation function hypothesis and the autocorrelation function of the estimate of the communications channel; and

09373289-081299

26

25 22

10 comparing the error signals to select the autocorrelation hypothesis to approximate the autocorrelation function for the estimate of the communications channel.

5. A method according to Claim 4 wherein comparing the error signals comprises choosing an error signal representing a least difference between the corresponding autocorrelation function hypothesis and the autocorrelation function for the estimate of the communications channel.

6. A method according to Claim 5 wherein choosing the error signal comprises choosing a least one of the error signals.

7. A method according to Claim 4 wherein comparing the error signals is preceded by:

5 averaging each of the error signals to provide averaged error signals wherein comparing the error signals comprises comparing the averaged error signals.

8. A method according to Claim 7 wherein averaging each of the error signals comprises one of block averaging, running averaging, and sliding window averaging.

9. A method according to Claim 1 wherein each of the plurality of autocorrelation function hypotheses comprises a plurality of samples and wherein the autocorrelation function for the estimate of the communications channel comprises a plurality of samples.

10. A method according to Claim 1 wherein the communications channel comprises a radio channel.

11. A method according to Claim 1 wherein the autocorrelation function comprises a plurality of samples and wherein generating the autocorrelation function comprises reducing a frequency error of the plurality of samples.

09373339.0 1299 6621 0.68232E60

27

26 27

12. A method according to Claim 1 further comprising:
providing a second estimate of the communications channel using the
estimate of the Doppler spread for the communications channel.

13. A method according to Claim 1 wherein providing an estimate of
the communications channel comprises receiving a plurality of samples of
data over the communications channel wherein the samples of data are used
to generate the channel estimates, the method further comprising:

- 5 performing a cyclical redundancy check on the samples of data used to
generate the channel estimates;
updating a long term Doppler estimate with the estimate of the Doppler
spread when the samples of data pass the cyclical redundancy check.

14. A method according to Claim 1 wherein providing an estimate of
the communications channel comprises:

- receiving a plurality of pilot symbols over the communications channel;
reducing phase ambiguity between the pilot symbols; and
5 using the pilot symbols having reduced ambiguity to provide the
estimate of the communications channel.

15. A Doppler spread estimator for estimating a Doppler spread for
a communications channel, the Doppler spread estimator comprising:

- a plurality of autocorrelation function hypotheses corresponding to a
respective plurality of Doppler spread estimate hypotheses;
5 a channel estimator that estimates the communications channel;
an autocorrelation generator that generates an autocorrelation function
for the estimate of the communications channel;
an autocorrelation function hypothesis tester that selects one of the
autocorrelation function hypotheses to approximate the autocorrelation
10 function for the estimate of the communications channel; and
a Doppler spread hypothesis selector that selects one of the Doppler
spread estimate hypotheses corresponding to the selected autocorrelation

093732 9-081299

function hypotheses as an estimate of the Doppler spread for the communications channel.

16. A Doppler spread estimator according to Claim 15 wherein the hypothesis tester compares the autocorrelation function for the estimate of the communications channel with each of the plurality of autocorrelation function hypotheses.

17. A Doppler spread estimator according to Claim 15 wherein the hypothesis tester selects one of the plurality of autocorrelation function hypotheses most closely approximating the autocorrelation function for the estimate of the communications channel.

18. A Doppler spread estimator according to Claim 15 wherein the hypothesis tester generates a plurality of error signals respectively corresponding to the plurality of autocorrelation function hypotheses wherein each of the error signals represents a difference between the respective autocorrelation function hypothesis and the autocorrelation function of the estimate of the communications channel, and wherein the hypothesis tester compares the error signals to select the autocorrelation hypothesis to approximate the autocorrelation function for the estimate of the communications channel.

19. A Doppler spread estimator according to Claim 18 wherein the hypothesis tester chooses an error signal representing a least difference between the corresponding autocorrelation function hypothesis and the autocorrelation function for the estimate of the communications channel.

20. A Doppler spread estimator according to Claim 19 wherein the hypothesis tester chooses a least one of the error signals.

21. A Doppler spread estimator according to Claim 18 wherein the hypothesis tester averages each of the error signals to provide averaged error signals wherein the hypothesis tester compares the averaged error signals.

7A

7878

22. A Doppler spread estimator according to Claim 21 wherein the hypothesis tester averages each of the error signals using one of block averaging, running averaging, and sliding window averaging.

23. A Doppler spread estimator according to Claim 15 wherein each of the plurality of autocorrelation function hypotheses comprises a plurality of samples and wherein the autocorrelation function for the estimate of the communications channel comprises a plurality of samples.

24. A Doppler spread estimator according to Claim 15 wherein the communications channel comprises a radio channel.

25. A Doppler spread estimator according to Claim 15 wherein the autocorrelation function comprises a plurality of samples and wherein the autocorrelation generator reduces a frequency error of the plurality of samples.

26. A Doppler spread estimator according to Claim 15 wherein the channel estimator provides a second estimate of the communications channel using the estimate of the Doppler spread for the communications channel.

27. A Doppler spread estimator according to Claim 15 wherein the channel estimator receives a plurality of samples of data over the communications channel wherein the samples of data are used to estimate the communications channel, wherein the channel estimator performs a cyclical redundancy check on the samples of data used to generate the channel estimates, the Doppler spread estimator further comprising:

a long term Doppler estimator wherein the long term Doppler estimator is updated with the estimate of the Doppler spread when the samples of data pass the cyclical redundancy check.

28. A Doppler spread estimator according to Claim 15 wherein the channel estimator receives a plurality of pilot symbols over the

662180. 8232560

80

79 2/b

communications channel, reduces phase ambiguity between the pilot symbols, and uses the pilot symbols having reduced ambiguity to provide the estimate of the communications channel.

29. A method for receiving communications, the method comprising:
receiving a signal over a communications channel wherein the signal represents data from a remote transmitter;
generating an estimate of the communications channel over which the signal is received;
generating an autocorrelation function for the estimate of the communications channel;
selecting one of a plurality of autocorrelation function hypotheses corresponding to a respective plurality of Doppler spread estimate hypotheses to approximate the autocorrelation function for the estimate of the communications channel;
selecting one of the Doppler spread estimate hypotheses corresponding to the selected autocorrelation function hypotheses as an estimate of the Doppler spread for the communications channel; and
reproducing an estimate of the data transmitted by the remote transmitter.

30. A method according to Claim 29 wherein selecting one of the autocorrelation function hypotheses comprises comparing the autocorrelation function for the estimate of the communications channel with each of the plurality of autocorrelation function hypotheses.

31. A method according to Claim 29 wherein selecting one of the autocorrelation function hypotheses comprises selecting one of the plurality of autocorrelation function hypotheses most closely approximating the autocorrelation function for the estimate of the communications channel.

32. A method according to Claim 29 wherein selecting one of the autocorrelation function hypotheses comprises:

09373289-682E/E60

3A

30

3A

generating a plurality of error signals respectively corresponding to the plurality of autocorrelation function hypotheses wherein each of the error signals represents a difference between the respective autocorrelation function hypothesis and the autocorrelation function of the estimate of the communications channel; and

comparing the error signals to select the autocorrelation hypothesis to approximate the autocorrelation function for the estimate of the communications channel.

33. A method according to Claim 32 wherein comparing the error signals comprises choosing an error signal representing a least difference between the corresponding autocorrelation function hypothesis and the autocorrelation function for the estimate of the communications channel.

34. A method according to Claim 33 wherein choosing the error signal comprises choosing a least one of the error signals.

35. A method according to Claim 32 wherein comparing the error signals is preceded by:

averaging each of the error signals to provide averaged error signals wherein comparing the error signals comprises comparing the averaged error signals.

36. A method according to Claim 35 wherein averaging each of the error signals comprises one of block averaging, running averaging, and sliding window averaging.

37. A method according to Claim 29 wherein each of the plurality of autocorrelation function hypotheses comprises a plurality of samples and wherein the autocorrelation function for the estimate of the communications channel comprises a plurality of samples.

38. A method according to Claim 29 wherein the communications channel comprises a radio channel.

81

31 23

39 A method according to Claim 29 wherein the autocorrelation function comprises a plurality of samples and wherein generating the autocorrelation function comprises reducing a frequency error of the plurality of samples.

40. A method according to Claim 29 further comprising:
providing a second estimate of the communications channel using the estimate of the Doppler spread for the communications channel.

41. A method according to Claim 29 wherein providing an estimate of the communications channel comprises receiving a plurality of samples of data over the communications channel wherein the samples of data are used to generate the channel estimates, the method further comprising:

5 performing a cyclical redundancy check on the samples of data used to generate the channel estimates;

updating a long term Doppler estimate with the estimate of the Doppler spread when the samples of data pass the cyclical redundancy check.

42. A method according to Claim 29 wherein the data received from the remote transmitter comprises pilot symbols, and wherein generating an estimate of the communications channel comprises:

5 reducing phase ambiguity between the pilot symbols; and
using the pilot symbols having reduced ambiguity to provide the estimate of the communications channel.

43. A receiver comprising:

a radio receiver and converter that receives a signal over a communications channel;

5 a channel estimator that estimates the communications channel responsive to the signal received over the communications channel;

a plurality of autocorrelation function hypotheses corresponding to a respective plurality of Doppler spread estimate hypotheses;

82

82

an autocorrelation generator that generates an autocorrelation function for the estimate of the communications channel;

- 10 an autocorrelation function hypothesis tester that selects one of the autocorrelation function hypotheses to approximate the autocorrelation function for the estimate of the communications channel; and

- a Doppler spread hypothesis selector that selects one of the Doppler spread estimate hypotheses corresponding to the selected autocorrelation function hypotheses as an estimate of the Doppler spread for the
15 communications channel.

44. A receiver according to Claim 43 wherein the hypothesis tester compares the autocorrelation function for the estimate of the communications channel with each of the plurality of autocorrelation function hypotheses.

45. A receiver according to Claim 43 wherein the hypothesis tester selects one of the plurality of autocorrelation function hypotheses most closely approximating the autocorrelation function for the estimate of the communications channel.

46. A receiver according to Claim 43 wherein the hypothesis tester generates a plurality of error signals respectively corresponding to the plurality of autocorrelation function hypotheses wherein each of the error signals represents a difference between the respective autocorrelation function
5 hypothesis and the autocorrelation function of the estimate of the communications channel, and wherein the hypothesis tester compares the error signals to select the autocorrelation hypothesis to approximate the autocorrelation function for the estimate of the communications channel.

47. A receiver according to Claim 46 wherein the hypothesis tester chooses an error signal representing a least difference between the corresponding autocorrelation function hypothesis and the autocorrelation function for the estimate of the communications channel.

7A

83 50

48. A receiver according to Claim 47 wherein the hypothesis tester chooses a least one of the error signals.

49. A receiver according to Claim 48 wherein the hypothesis tester averages each of the error signals to provide averaged error signals wherein the hypothesis tester compares the averaged error signals.

50. A receiver according to Claim 49 wherein the hypothesis tester averages each of the error signals using one of block averaging, running averaging, and sliding window averaging.

51. A receiver according to Claim 43 wherein each of the plurality of autocorrelation function hypotheses comprises a plurality of samples and wherein the autocorrelation function for the estimate of the communications channel comprises a plurality of samples.

52. A receiver according to Claim 43 further comprising:
a signal processor coupled between the Doppler spread estimator and the channel estimator wherein the signal processor modifies the operation of the channel estimator responsive to the estimate of the Doppler spread for the communications channel.

5

53. A receiver according to Claim 43 wherein the communications channel comprises a radio channel.

54. A receiver according to Claim 43 wherein the autocorrelation function for the estimate of the communications channel comprises a plurality of samples and wherein the autocorrelation generator reduces a frequency error of the plurality of samples.

55. A receiver according to Claim 43 wherein the channel estimator provides a second estimate of the communications channel using the estimate of the Doppler spread for the communications channel.

09373228.081299

85 34

56. A receiver according to Claim 43 wherein the signal received over the communications channel comprises a plurality of samples of data wherein the channel estimator uses the samples of data to estimate the communications channel, wherein the channel estimator performs a cyclical redundancy check on the samples of data used to generate the channel estimates, the receiver further comprising:

a long term Doppler estimator wherein the long term Doppler estimator is updated with the estimate of the Doppler spread when the samples of data pass the cyclical redundancy check.

57. A receiver according to Claim 43 wherein the signal received over the communications channel comprises a plurality of pilot symbols, wherein the channel estimator reduces phase ambiguity between the pilot symbols, and wherein the channel estimator uses the pilot symbols having reduced phase ambiguity to provide the estimate of the communications channel.

662180.682E/360

7/3 35 2

**METHODS FOR ESTIMATING DOPPLER SPREADS INCLUDING
AUTOCORRELATION FUNCTION HYPOTHESES AND RELATED
SYSTEMS AND RECEIVERS**

ABSTRACT

A Doppler spread for a communications channel is measured by providing an estimate of the communications channel and generating an autocorrelation function for the estimate of the communications channel. One of a plurality of autocorrelation function hypotheses is selected to approximate the autocorrelation function for the estimate of the communications channel wherein each of the autocorrelation function hypotheses corresponds to a respective Doppler spread estimate hypothesis. One of the Doppler spread estimate hypotheses is selected corresponding to the selected autocorrelation function hypotheses as an estimate of the Doppler spread for the communications channel.

5

10

662780-68227E60

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION
Attorney Docket No. 8194-299

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **METHODS FOR ESTIMATING DOPPLER SPREADS INCLUDING AUTOCORRELATION FUNCTION HYPOTHESES AND RELATED SYSTEMS AND RECEIVERS**, the specification of which

☒ is attached hereto

OR

☐ was filed on _____ as United States Application No. or PCT International Application Number _____ and was amended on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37 Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, § 119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate, or § 365(a) of any PCT International application which designated at least one country other than the United States of America, listed below and have also identified below any foreign application for patent or inventor's certificate, or of any PCT International application having a filing date before that of the application on which priority is claimed.

None			☐ Yes ☐ No
Number	Country	MM/DD/YYYY Filed	Priority Claimed

			☐ Yes ☐ No
Number	Country	MM/DD/YYYY Filed	Priority Claimed

87 87

I hereby claim the benefit under Title 35, United States Code, § 119(e) of any United States provisional application(s) listed below.

None	
Application Number(s)	Filing Date (MM/DD/YYYY)

Application Number(s)	Filing Date (MM/DD/YYYY)

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) or § 365(c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application(s) in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application (37 C.F.R. § 1.63(d)).

None		
Appln. Serial No.	Filing Date	Status Patented/Pending/Abandoned

Appln. Serial No.	Filing Date	Status Patented/Pending/Abandoned

Appln. Serial No.	Filing Date	Status Patented/Pending/Abandoned

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false

662780-682216

statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following registered attorney(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

Customer Number 20792

Send correspondence to: Scott C. Hatfield
Myers Bigel Sibley & Sajovec
Post Office Box 37428
Raleigh, North Carolina 27627

Direct telephone calls to: Scott C. Hatfield
(919) 854-1400

Facsimile: (919) 854-1401

Full name of first inventor: Karl James Molnar

Inventor's
Signature: Karl James Molnar **Date:** Aug 9, 1999

Residence: Cary, North Carolina

Citizenship: United States of America

Post Office Address: 110 Flying Leaf Court
Cary, North Carolina 27513

98 89 86

Full name of second inventor: Leonid Krasny

Inventor's
Signature: Leonid Krasny Date: 08/02/99

Residence: Cary, North Carolina

Citizenship: Ukraine

Post Office Address: 111 Gray Mare's Lane
Cary, North Carolina 27511

662180-68227E60

9/1
90
9/1

Full name of third inventor: Hüseyin Arslan

Inventor's
Signature: H. Arslan Date: 8/9/1999

Residence: Durham, North Carolina

Citizenship: Turkey

Post Office Address: 600 Aaron Circle, #612
Durham, North Carolina 27713

662780 68287860

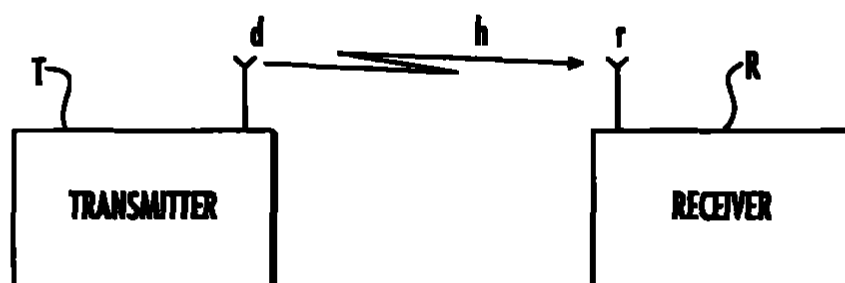


FIG. 1.

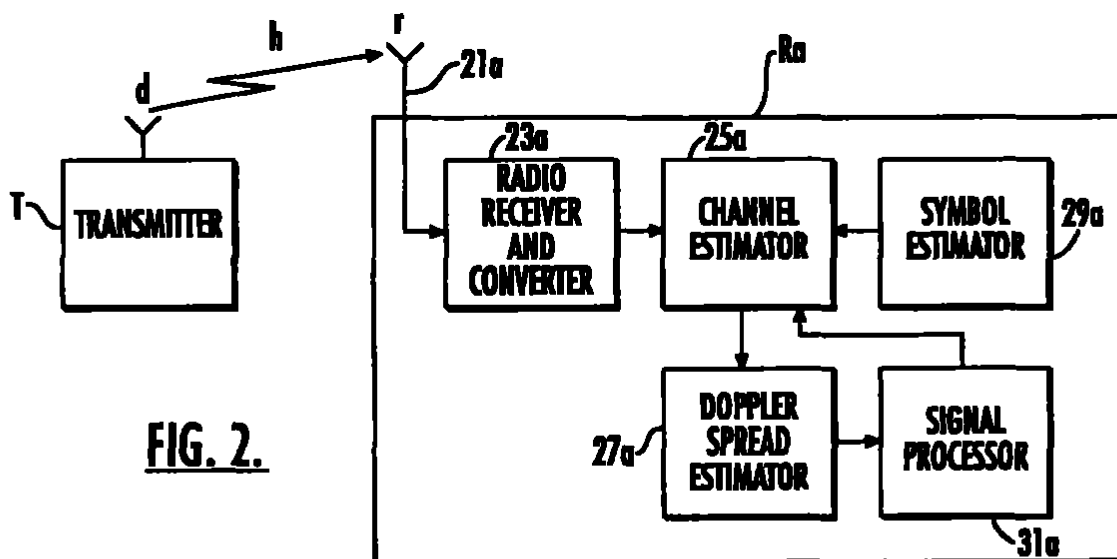
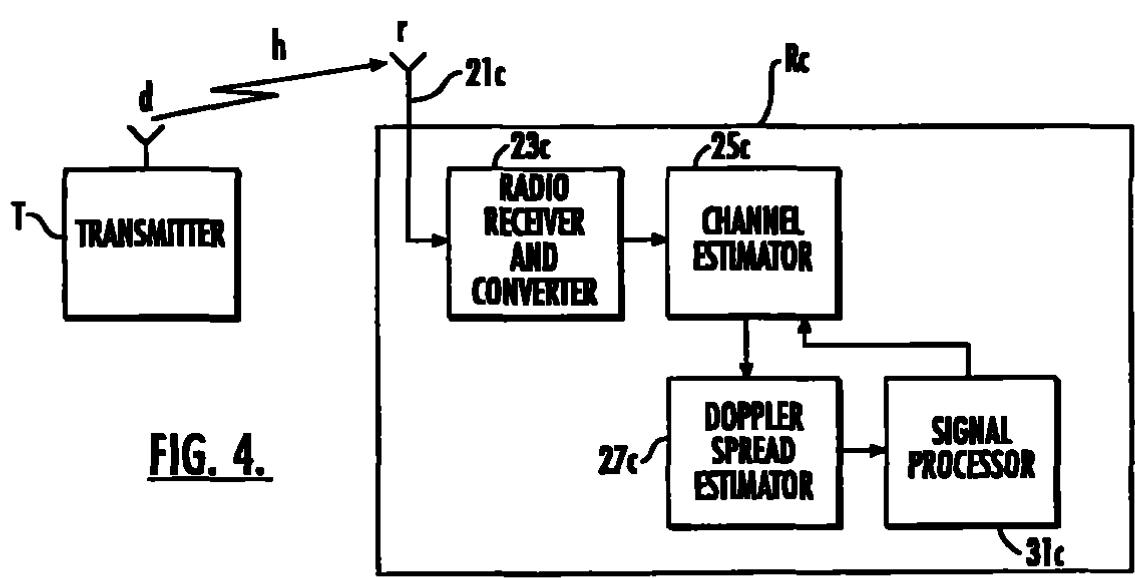
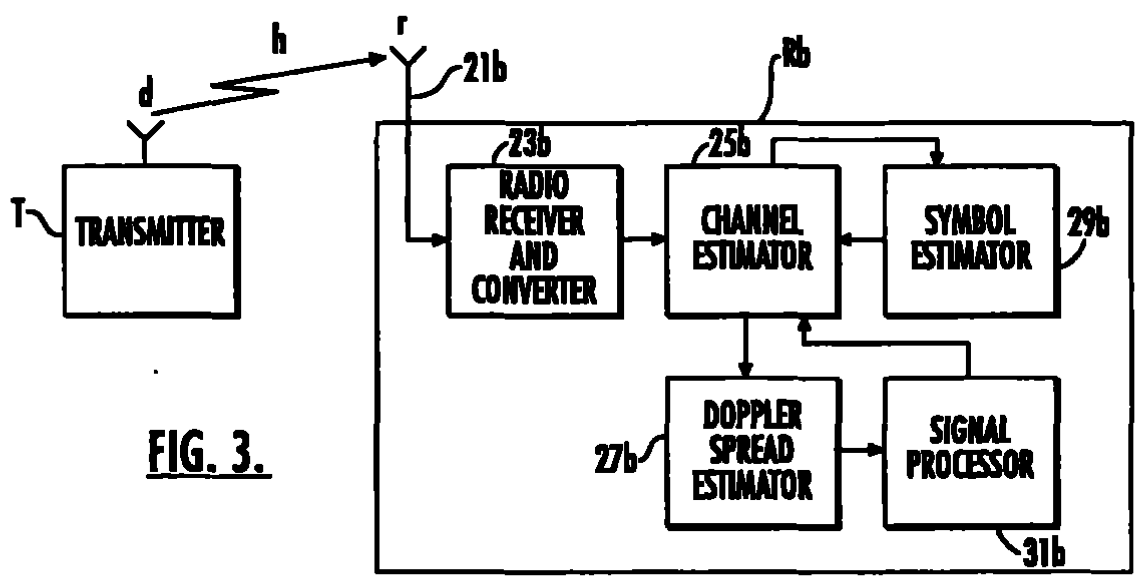


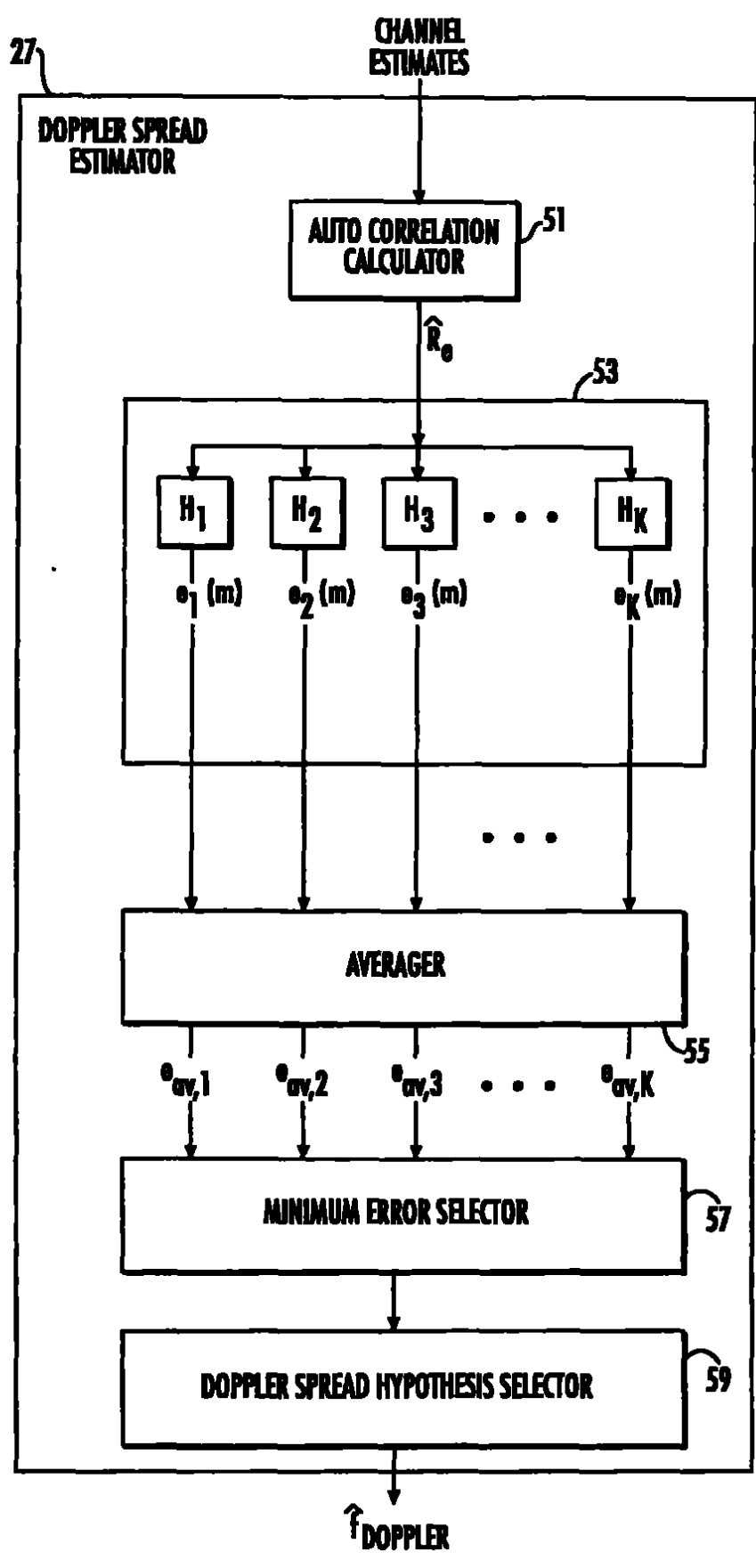
FIG. 2.



6 2180" 682267860

662780-68227860

FIG. 5.



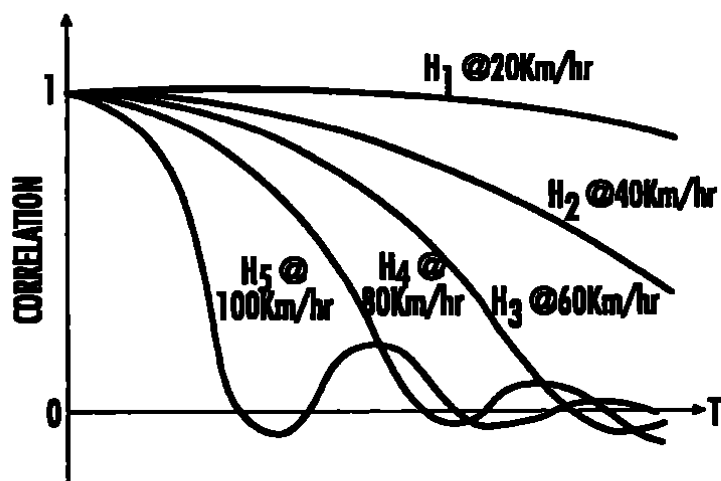


FIG. 6.

$H_1 @ 20\text{Km/hr}$	$R_{H,1}(0)$	$R_{H,1}(T_1)$	$\dots$	$R_{H,1}(T_z)$
$H_2 @ 40\text{Km/hr}$	$R_{H,2}(0)$	$R_{H,2}(T_1)$	$\dots$	$R_{H,2}(T_z)$
$H_3 @ 60\text{Km/hr}$	$R_{H,3}(0)$	$R_{H,3}(T_1)$	$\dots$	$R_{H,3}(T_z)$
$H_4 @ 80\text{Km/hr}$	$R_{H,4}(0)$	$R_{H,4}(T_1)$	$\dots$	$R_{H,4}(T_z)$
$H_5 @ 1000\text{Km/hr}$	$R_{H,5}(0)$	$R_{H,5}(T_1)$	$\dots$	$R_{H,5}(T_z)$

FIG. 7.

662T80' 682E2E60