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ADAPTIVE MODEM

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STATEMENT OF GOVERNMENT INTEREST

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CROSS-REFERENCE TO RELATED APPLICATIONS

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BACKGROUND OF THE INVENTION

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(1) Field of the Invention

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The present invention relates generally to communication systems, and more particularly to an adaptive modem for communication systems that utilizes multiple modulation and signal processing schemes to minimize detection, demodulation, and decoding errors while maximizing transmission data rates.

1 (2) Description of the Prior Art

2 Doppler and multipath are two well-known effects presented
3 by communication channels. The doppler effect is characterized
4 by an alteration of the transmitted signal frequency when there
5 is relative movement between the transmitter and receiver.
6 Alternately, multipath describes the multiple and time-delayed
7 received signals resulting from a single transmission that
8 travels multiple and varying length paths between the transmitter
9 and receiver. U.S. Patent No. 5,301,167 to Proakis et al.
10 describes the ocean acoustic channel behavior and the resulting
11 variant multipath that must be recognized as a basic channel
12 characteristic. Proakis et al. describe an underwater acoustic
13 communications apparatus using doppler removal, a specialized
14 sample timing control technique, and decision feedback
15 equalization to achieve high data rates for phase coherent
16 modulation and demodulation. Proakis et al. present an apparatus
17 in which digitized data streams are preceded by a synchronization
18 signal and training sequence that are Phase-Shift-Keyed (PSK)
19 modulated. This technique, although more efficient than other
20 Frequency-Shift-Keying (FSK) techniques, provides a single
21 transmit modulation and receive demodulation scheme regardless of
22 channel characteristics. Experimentation with the FSK technique
23 indicates communication difficulties even with a relatively high
24 signal-to-noise ratio (SNR).

1 Other objects and advantages of the present invention will
2 become more obvious hereinafter in the specification and
3 drawings.

4 These objects are accomplished with the present invention by
5 an apparatus that uses multiple modulation schemes comprising
6 modulation technique and encoder pairings. Corresponding
7 demodulation technique and decoder combinations provide
8 demodulation schemes that uniquely correspond to the modulation
9 schemes. As communication system performance and objectives
10 change, different modulation schemes may be selected. Modulation
11 schemes may also be selected upon the communication channel
12 scattering function estimate, and the apparatus estimates the
13 channel scattering function from measurements of the channel's
14 frequency (doppler) and time (multipath) spreading
15 characteristics. An intelligence module measures the
16 communication channel's doppler and multipath using a probe
17 signal that is transmitted from a first modem to a second modem.

18 Extrinsic data ports allow modem inputs for modem position
19 estimates, channel characteristic data, strategic information,
20 and propagation models to assist in scattering function
21 estimation and modulation scheme selection. A coding module
22 provides a modulation mode identifier to identify the modulation
23 scheme. The second modem uses the modulation mode identifier to
24 select the correct demodulation scheme. The intelligence module

1 controls any probe signal transmission, scattering function
2 estimate updating, and modulation scheme selection. The first
3 and second modems are identically structured to allow bi-
4 directional scattering function estimation.

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BRIEF DESCRIPTION OF THE DRAWINGS

7 A more complete understanding of the invention and many of
8 the attendant advantages thereto will be readily appreciated as
9 the same becomes better understood by reference to the following
10 detailed description when considered in conjunction with the
11 accompanying drawings, wherein like reference numerals refer to
12 like parts and wherein:

13 FIG. 1 is a block diagram of the adaptive modem paradigm;
14 and

15 FIG. 2 is a block diagram of a communication system design
16 using the adaptive modem.

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DESCRIPTION OF THE PREFERRED EMBODIMENT

19 Referring now to FIG. 1, there is shown a block diagram of
20 the adaptive modem paradigm 10. Since the adaptive modem
21 structure is identical for transmit and receive modems, adaptive
22 modem modules shall be described while referring to FIG. 1 as
23 though the FIG. 1 modem is performing both transmit and receive
24 functions.

1 Each modem contains a modulator module 12 capable of
2 multiple modulation schemes. A modulation scheme is comprised of
3 a modulation technique and an encoder. Adaptive modem therefore
4 comprises either multiple modulation techniques paired with at
5 least one encoder, or at least one modulation technique paired
6 with multiple encoders. Examples of modulation techniques
7 include Frequency Shift Keying (FSK) and Phase Shift Keying
8 (PSK). The maximum number of modulation schemes contained within
9 modulator module 12 is equal to the number of different pairings
10 of modulation techniques with encoders, or the number of
11 modulation techniques multiplied by the number of encoders.
12 Referring to FIG. 1, the modulation schemes are designated "Type
13 A", "Type B", etc., to "Type X". Modulator module 12 must also
14 be capable of selecting the channel probe signal. Modulator
15 module 12 provides the encoded, modulated signal to external
16 hardware 14 for transmission 16.

17 Modulator module 12 receives the data to be encoded,
18 modulated, and transmitted from a modem external data source 18.

19 Data source 18 may provide voice, text, image, or any other data
20 type compatible with modem requirements. Modulator module 12
21 encodes and modulates data before transferring data to the
22 transmission hardware 14. Additionally, modulator module 12
23 codes the encoded, modulated data with a modulation mode
24 identifier to indicate the modulation scheme.

1 Modulator module 12 maintains modem internal input and
2 output communications with the modem's intelligence module 20.
3 Intelligence module 20 estimates the channel's scattering
4 function and determines the modulation scheme to be used by
5 modulator module 12. Intelligence module 20 additionally
6 determines when modulator module 12 selects the channel probe
7 signal. In the preferred embodiment, channel probing occurs
8 prior to data transmission, and at subsequent intervals that may
9 be fixed or based upon transmission error rate, signal-to-noise
10 ratio, or other predefined criteria. Intelligence module 20
11 therefore provides modulator module 12 with modulation scheme,
12 channel probe selection, and modulator module 12 initialization
13 data. Alternately, modulator module 12 provides intelligence
14 module 20 with current modulation scheme and modulator module 12
15 status data.

16 Intelligence module 20 estimates the channel scattering
17 function using modem external inputs including channel
18 characteristic data 22, propagation models 24, source and
19 receiver position estimates 26, and strategic information 28.
20 Channel characteristic data 22 includes any information
21 characterizing the channel, and examples include oceanographic
22 data or atmospheric data. Strategic information 28 is a general
23 term for data regarding the goals or objectives for the
24 transmission. Examples of strategic information 28 include the

1 criteria for updating the scattering function (i.e., re-transmit
2 the probe signal), desired SNR values or error rates before
3 changing modulation schemes, limitations on specific modulation
4 schemes, etc. The most significant component to intelligence
5 module's 20 channel scattering function estimation is the modem
6 internal input from a signal processor module 30 that contains
7 the channel spreading factors. Signal processor module 30
8 derives the channel spreading factors from the received channel
9 probe signal characteristics.

10 The modem internal interface between intelligence module 20
11 and signal processor module 30 is similar to that between
12 intelligence module 20 and modulator module 12. Intelligence
13 module 20 provides signal processor module 30 with signal
14 processor module 30 initialization requirements. Signal
15 processor module 30 provides intelligence module 20 with signal
16 processor module 30 mode and status. Channel spreading factors
17 computed by signal processor module 30 upon receipt of the
18 channel probe signal are also communicated to intelligence module
19 20.

20 Signal processor module 30 is also responsible for
21 interfacing with the receive hardware 32 that accepts the
22 received signal 34, identifying the modulation scheme, selecting
23 the corresponding demodulation scheme, and performing all
24 demodulation and decoding functionality to reduce the data to its

1 original form (i.e., voice, text, imagery, etc.). For each
2 modulator module 12 modulation technique, signal processor module
3 30 maintains a corresponding demodulator technique. Similarly,
4 for each modulator module 12 encoder, signal processor module 30
5 contains the decoder. Signal processor module 30 demodulation
6 schemes comprise combinations of demodulation techniques and
7 decoders, thereby producing a unique correspondence between
8 modulator module 12 modulation schemes and signal processor
9 module 30 demodulation schemes. Accordingly, signal processor
10 module 30 demodulation schemes are designated in FIG. 1 as "Type
11 A", "Type B", etc., to "Type X", just as modulator module 12
12 modulation schemes are designated. Signal processor module 30
13 uses the modulation mode identifier provided by modulator module
14 12 to select the correct demodulation scheme. Signal processor
15 module 30 maintains a modem external interface 36 to transfer the
16 demodulated, decoded data to the output device 38.

17 Referring now to FIG. 2, there is shown a block diagram of
18 the basic modem operation. The first step is to define a
19 communication system strategy 50. The strategy includes modem
20 configuration (initial modem locations; one transmit/one receive;
21 one transmit/multiple receive, etc.), data transmission rates,
22 performance measures (e.g., criteria to update the scattering
23 function), available modulation techniques and encoders (i.e.,
24 modulation schemes), etc. Once the modems are configured 52

1 according to the strategy 50, a link 54 is established between a
2 transmit modem and a receive modem. In the preferred embodiment,
3 a transmit modem transmits to a distinct, identically configured
4 receive modem, and for simplification, FIG. 2 shall be referenced
5 as both transmit and receive modem, and FIG. 2 may therefore be
6 extended to various configurations utilizing two or more modems.

7 The transmit modem shall hereinafter be referred to as the first
8 modem, and the receive modem shall be known as the second modem.

9 Once the link between first and second modem is established
10 54, first modem transmits the probe signal 56 to second modem.
11 In the preferred embodiment, second modem's signal processing
12 module determines the spreading factors 58 from the received
13 probe signal, and passes the spreading factors to the
14 intelligence module. The intelligence module estimates the
15 channel scattering function 60 and extracts the scattering
16 parameters 62 for transmission to first modem. First modem
17 receives the scattering function parameters and first modem's
18 intelligence module determines the modulation scheme 64 using the
19 channel scattering function, channel characteristic data,
20 strategic information, propagation models, and modem position
21 estimates. First modem's modulator module encodes and modulates
22 the data to be transmitted according to the selected modulation
23 scheme, and codes the data with a modulation mode identifier 66
24 that indicates the modulation scheme. The coded modulated data

1 is transmitted 68 and transmission continues until first modem's
2 intelligence module issues a command to update the scattering
3 function 70, whereupon, in the preferred embodiment, the probe
4 signal is transmitted 56 to update the scattering function
5 estimate. Once the scattering function is estimated with the
6 update 60, 62, a modulation scheme is again selected 66, and data
7 transmission 68 continues with the new modulation scheme.

8 In the preferred embodiment, all modems maintain the same
9 structure, and therefore any modem may be configured to transmit
10 or receive data. The channel scattering function may thus be
11 estimated bidirectionally by transmitting the probe signal from
12 both transmit and receive modems.

13 What has thus been described is an adaptive modem to improve
14 communication system performance that uses multiple modulation
15 schemes comprising modulation technique and encoder combinations.

16 Corresponding demodulation technique and decoder combinations
17 provide demodulation schemes that uniquely correspond to the
18 modulation schemes. As communication system performance and
19 objectives change, different modulation schemes may be selected.

20 Modulation schemes may also be selected upon the communication
21 channel scattering function estimate, and the modem estimates the
22 channel scattering function from measurements of the channel's
23 frequency (doppler) and time (multipath) spreading
24 characteristics. An intelligence module measures the

1 communication channel's doppler and multipath using a probe
2 signal transmitted from a first modem to a second modem.
3 Extrinsic data ports allow modem inputs for modem position
4 estimates, channel characteristic data, strategic information,
5 and propagation models to assist in scattering function
6 estimation and modulation scheme selection. A coding module
7 provides a modulation mode identifier to identify the modulation
8 scheme. The second modem uses the modulation mode identifier to
9 select the correct demodulation scheme. The intelligence module
10 controls any probe signal transmission, channel scattering
11 function estimation updating, and modulation scheme selection.

12 Although the present invention has been described relative
13 to a specific embodiment thereof, it is not so limited.
14 Obviously many modifications and variations of the present
15 invention may become apparent in light of the above teachings.
16 For example, the criteria to update the scattering function
17 estimate (i.e., re-transmit the probe signal) may be fixed or
18 performance-based (e.g., SNR, error rate, etc.), and selection of
19 a modulation scheme may be based upon criteria other than a
20 channel scattering function. Embodiments utilizing the channel
21 function estimation could include continual scattering function
22 updating and modulation selection to eliminate multiple probe
23 signal transmissions. The data transmission can be coherent or
24 noncoherent. Probe signal characteristics may vary depending

1 upon the communication channel to maximize the channel effects on
2 the probe signal. The available modulation/demodulation
3 techniques may be one providing the number of encoders/decoders
4 is greater than one. Functionality may be otherwise divided
5 amongst the modems, for example, allowing the receive modem to
6 process the probe signal, generate the scattering function,
7 select the modulation/demodulation technique, and then transmit
8 merely the modulation technique to the transmit modem.
9 Alternately, the receive modem could determine when the
10 scattering function should be updated. Various means of
11 identifying the modulation scheme (modulation mode identifier)
12 may be used. Although the preferred embodiment presented
13 strategic information, propagation models, and channel
14 characteristic data as external modem inputs, this information is
15 not so limited and could reside within the modem. The channel
16 could be the ocean, atmosphere, or other channel. The preferred
17 embodiment contained a signal processor module capable of
18 multiple demodulation techniques, however the signal processor
19 module could comprise multiple signal processors.

20 Many additional changes in the details, materials, steps and
21 arrangement of parts, herein described and illustrated to explain
22 the nature of the invention, may be made by those skilled in the
23 art within the principle and scope of the invention. It is
24 therefore understood that .

1 the invention may be practiced otherwise than as
2 specifically described.