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Attorney Docket No. 80165

METHOD FOR COMMUNICATION USING ADAPTIVE MODEM

STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefore.

CROSS-REFERENCE TO RELATED APPLICATIONS

This patent application is co-pending with a related patent application entitled Adaptive Modem (Attorney Docket No. 80032) by the same inventor as this patent application.

BACKGROUND OF THE INVENTION

(1) Field of the Invention

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

(2) Description of the Prior Art

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

There is currently no method that measures the channel's time and frequency characteristics to adapt the transmission modulation scheme.

What is needed is a method that actively measures the communication channel multipath and doppler characteristics, and uses such multipath and doppler measurements to determine communication system modulation and demodulation schemes.

SUMMARY OF THE INVENTION

It is a general purpose and object of the present invention to improve communication system error and transmission data rates. It is another object of the present invention to provide such improvement through a method that utilizes adaptive modems to measure the communication channel's doppler and multipath characteristics. A further object is to estimate the communication channel's scattering function using the doppler and multipath measurements and modem position estimates. Still another object of the present invention is to utilize such communication channel scattering function, together with channel characteristic data, strategic information, and propagation models, to select one of multiple modulation schemes for the communication scenario.

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

These objects are accomplished with the present invention by a method that utilizes an adaptive modem to estimate the communication channel scattering function and select one of multiple modulation schemes. The scattering function is derived from measurements of the channel's frequency (doppler) and time (multipath) spreading characteristics. The communication channel's doppler and multipath are measured by a channel probe signal that is transmitted from a first modem to a second modem. The second modem processes the received channel probe signal and transmits the channel spreading factors to the first modem. The first modem combines the channel spreading factors and modem position estimates to estimate the channel scattering function. The first modem uses the channel scattering function estimate, channel characteristic data, strategic information, and propagation models to select the optimum available modulation scheme, each modulation scheme comprised of a modulation technique and encoder. Subsequent data transmissions from the first modem to the second modem contain data modulated by the selected modulation scheme and coded with a modulation mode identifier. The second modem uses the modulation mode identifier to select a demodulation scheme comprising a demodulation and decoder pairing. Upon the occurrence of predetermined criteria, the channel scattering function estimate may be updated and a new modulation scheme may be selected to continue transmission. Because each modem is equipped with the probe signal, bi-directional channel characterization can be performed.

BRIEF DESCRIPTION OF THE DRAWINGS

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

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

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

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1, there is shown a block diagram of the adaptive modem paradigm **10**. Each modem contains modules for transmitting and receiving, and adaptive modem modules shall be described while referring to FIG. 1 as though the FIG. 1 modem is performing both transmit and receive functions.

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

Modulator module **12** receives the data to be encoded, modulated, and transmitted from a modem external data source **18**. Data source **18** may provide voice, text, image, or any other data type compatible with modem requirements. Modulator module **12** encodes and modulates data before transferring data to the transmission hardware **14**. Additionally, modulator module **12** codes the encoded, modulated data with a modulation mode identifier to indicate the modulation scheme.

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

Intelligence module **20** estimates the channel scattering function using modem external inputs including channel characteristic data **22**, propagation models **24**, source and receiver position estimates **26**, and strategic information **28**. Channel characteristic data **22** includes any information characterizing the channel, and examples include oceanographic data or atmospheric data. Strategic information **28** is a general term for data regarding the goals or objectives for the transmission. Examples of strategic information **28** include the criteria for updating the scattering function (i.e., re-transmit the probe signal), desired SNR values or error rates before changing modulation schemes, limitations on specific modulation schemes, etc. The most significant component to intelligence module's **20** channel scattering function estimation is the modem internal input from a signal processor module **30** that contains the channel spreading factors. Signal processor module **30** derives the channel spreading factors from the received channel probe signal characteristics.

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

Signal processor module **30** is also responsible for interfacing with the receive hardware **32** that accepts the received signal **34**, identifying the modulation scheme, selecting the corresponding demodulation scheme, and performing all demodulation and decoding functionality to reduce the data to its original form (i.e., voice, text, imagery, etc.). For each modulator module **12** modulation technique, signal processor module **30** maintains a corresponding demodulator technique. Similarly, for each modulator module **12** encoder, signal processor module **30** contains the decoder. Signal processor module **30** demodulation schemes comprise combinations of demodulation techniques and decoders, thereby producing a unique correspondence between modulator module **12** modulation schemes and signal processor module **30** demodulation schemes. Accordingly, signal processor module **30** demodulation schemes are designated in FIG. 1 as "Type A", "Type B", etc., to "Type X", just as modulator module **12** modulation schemes are designated. Signal processor module **30** uses the modulation mode identifier provided by modulator module **12** to select the correct demodulation scheme. Signal processor module **30** maintains a modem external interface **36** to transfer the demodulated, decoded data to the output device **38**.

Referring now to FIG. 2, there is shown a block diagram of the basic modem operation. The first step is to define a communication system strategy **50**. The strategy includes modem configuration (initial modem locations; one transmit/one receive; one transmit/multiple receive, etc.), data transmission rates, performance measures (e.g., criteria to update the scattering function), available modulation techniques and encoders (i.e., modulation schemes), etc. Once the modems are configured **52** according to the strategy **50**, a link **54** is established between a transmit modem and a receive modem. In the preferred embodiment, a transmit modem transmits to a distinct, identically configured receive modem, and for simplification, FIG. 2 shall be referenced for both transmit and receive functionality. FIG. 2 may therefore be extended to various configurations utilizing two or more modems. The transmit modem shall hereinafter be referred to as the first modem, and the receive modem shall be known as the second modem.

Once the link between first and second modem is established **54**, first modem transmits the probe signal **56** to second modem. In the preferred embodiment, second modem's signal processing module determines the spreading factors **58** from the received probe signal, and passes the spreading factors to the intelligence module. The intelligence module estimates the channel scattering function **60** and extracts the scattering parameters **62** for transmission to first modem. First modem receives the scattering function parameters and first modem's intelligence module determines the modulation scheme **64** using the channel scattering function, channel characteristic data, strategic information, propagation models, and modem position estimates. First modem's modulator module encodes and modulates the data to be transmitted according to the selected modulation scheme, and codes the data with a modulation mode identifier **66** that indicates the modulation scheme. The coded modulated data is transmitted **68** and transmission continues until first modem's intelligence module issues a command to update the scattering function **70**, whereupon, in the preferred embodiment, the probe signal is transmitted **56** to update the scattering function estimate. Once the scattering function is estimated with the update **60**, **62**, a modulation scheme is again selected **66**, and data transmission **68** continues with the new modulation scheme.

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

What has thus been described is a method to improve communication system performance using an adaptive modem that estimates the communication channel scattering function to select one of several modulation schemes comprised of a modulation technique and encoder. The scattering function is estimated from the channel's frequency (doppler) and time (multipath) spreading effects on a probe signal. The probe signal is transmitted from a first modem to a second modem. The second modem processes the channel measurements and transmits the channel spreading factors to the first modem. Based upon the channel scattering function estimate, channel characteristic data, propagation models, strategic information, and modem position estimates, the first modem selects one of several modulation schemes. Subsequent data transmissions from the first modem to the second modem contain a modulation mode identifier. The second modem uses the modulation mode identifier to select the correct demodulation scheme. Demodulation schemes correspond to modulation schemes, and are comprised of a demodulator and decoder. Upon the occurrence of predetermined criteria, the channel scattering function estimate may be updated and a new modulation scheme selected to continue transmission. Each modem is equipped with the probe signal to allow bidirectional channel characterization.

Although the present invention has been described relative to a specific embodiment thereof, it is not so limited. Obviously many modifications and variations of the present invention may become apparent in light of the above teachings. For example, the criteria to update the scattering function estimate (i.e., re-transmit the probe signal) may be fixed or performance-based (e.g., SNR, error rate, etc.), and selection of a modulation scheme may be based upon criteria other than a channel scattering function. Embodiments utilizing the channel function estimation could include continual scattering function updating and modulation selection to eliminate multiple probe signal transmissions. The data transmission can be coherent or noncoherent. Probe signal characteristics may vary depending upon the communication channel to maximize the channel effects on the probe signal. The available modulation/demodulation techniques may be one providing the number of encoders/decoders is greater than one. Functionality may be otherwise divided amongst the modems, for example, allowing the receive modem to process the probe signal, generate the scattering function, select the modulation/demodulation technique, and then transmit merely the modulation technique to the transmit modem. Alternately, the receive modem could determine when the scattering function should be updated. Various means of identifying the modulation scheme (modulation mode identifier) may be used. Although the preferred embodiment presented strategic information, propagation models, and channel characteristic data as external modem inputs, this information is not so limited and could reside within the modem. The channel could be the ocean, atmosphere, or other channel. The preferred embodiment contained a signal processor module capable of multiple demodulation techniques, however the signal processor module could comprise multiple signal processors.

Many additional changes in the details, materials, steps and arrangement of parts, herein described and illustrated to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention. It is therefore understood that the invention may be practiced otherwise than as specifically described.

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METHOD FOR COMMUNICATION USING ADAPTIVE MODEM

ABSTRACT OF THE DISCLOSURE

A method to improve communication system performance using an adaptive modem that estimates the communication channel scattering function to select one of several modulation schemes. The scattering function is estimated from the channel's frequency (doppler) and time (multipath) spreading effects on a probe signal. The probe signal is transmitted from a first modem to a second modem. The second modem processes the channel measurements and transmits the channel spreading factors to the first modem. Based upon the channel scattering function estimate, channel characteristic data, propagation models, strategic information, and modem position estimates, the first modem selects one of several modulation schemes. Subsequent data transmissions from the first modem to the second modem contain a modulation mode identifier. The second modem uses the modulation mode identifier to select the correct demodulation scheme. Upon the occurrence of predetermined criteria, the channel scattering function estimate may be updated and a new modulation scheme

selected to continue transmission. Each modem is equipped with the probe signal to allow bi-directional channel characterization.

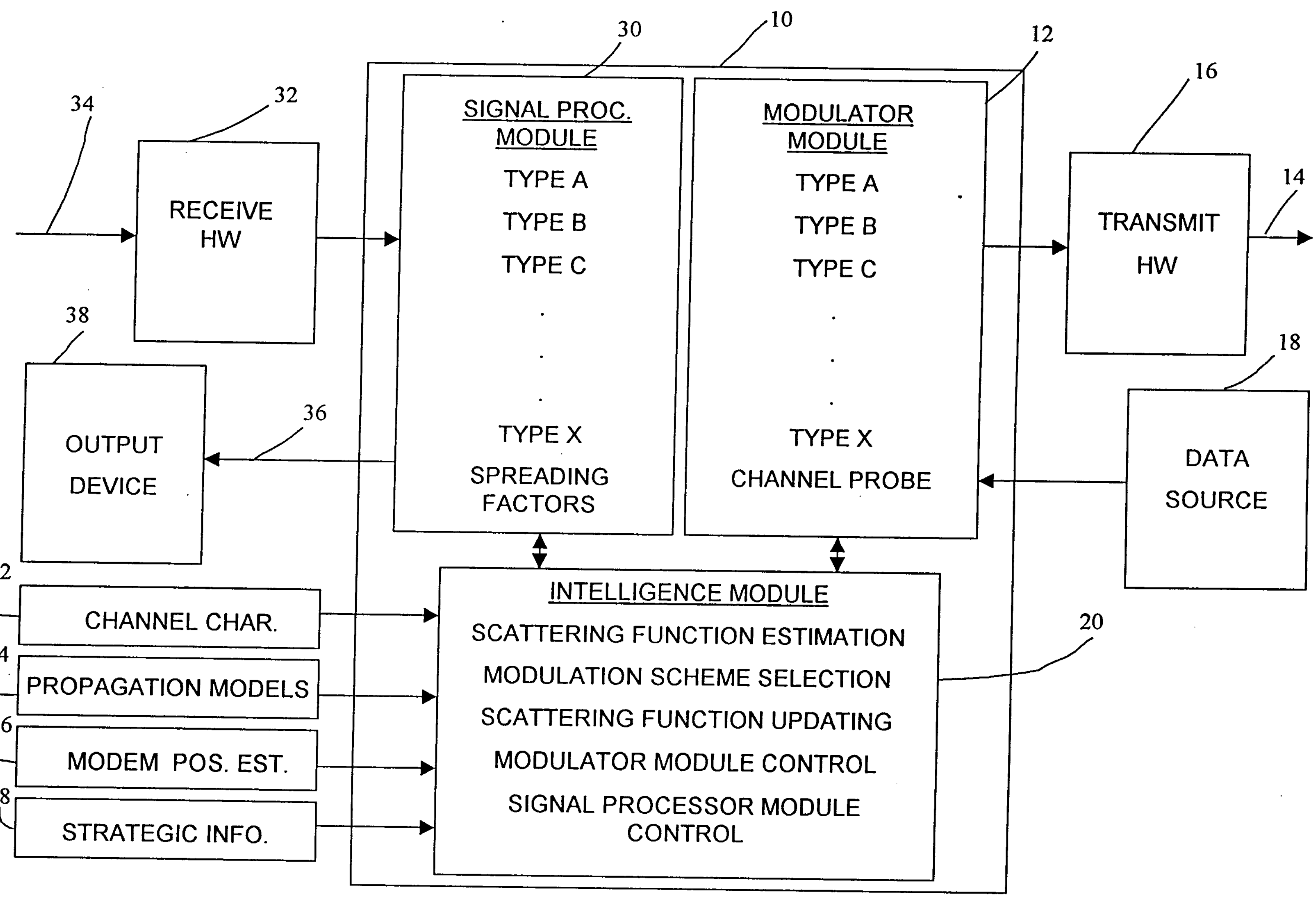
34
32
RECEIVE HW
38
OUTPUT DEVICE
36
30
10
SIGNAL PROC. MODULE
TYPE A
TYPE B
TYPE C
TYPE X
SPREADING FACTORS
12
MODULATOR MODULE
TYPE A
TYPE B
TYPE C
TYPE X
CHANNEL PROBE
16
TRANSMIT HW
14
18
DATA SOURCE
22
CHANNEL CHAR.
24
PROPAGATION MODELS
26
MODEM POS. EST.
28
STRATEGIC INFO.
INTELLIGENCE MODULE
SCATTERING FUNCTION ESTIMATION
MODULATION SCHEME SELECTION
SCATTERING FUNCTION UPDATING
MODULATOR MODULE CONTROL
SIGNAL PROCESSOR MODULE CONTROL
20

FIG. 1

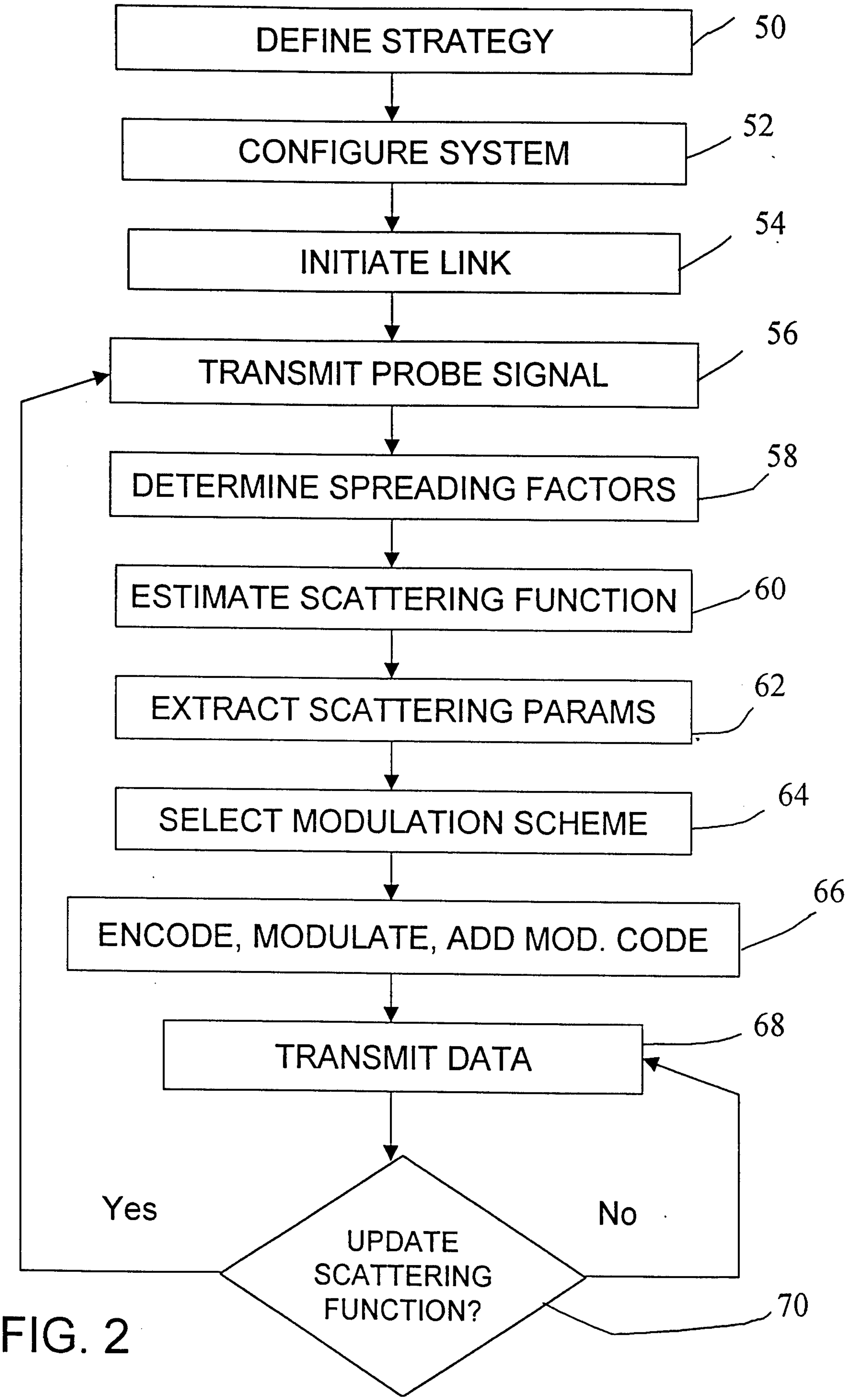
DEFINE STRATEGY
50
CONFIGURE SYSTEM
52
INITIATE LINK
54
TRANSMIT PROBE SIGNAL
56
DETERMINE SPREADING FACTORS
58
ESTIMATE SCATTERING FUNCTION
60
EXTRACT SCATTERING PARAMS
62
SELECT MODULATION SCHEME
64
ENCODE, MODULATE, ADD MOD. CODE
66
TRANSMIT DATA
68
Yes
No
UPDATE SCATTERING FUNCTION?
70

FIG. 2