PATROLL Winning Submission

U.S. Patent 7,260,153

U.S. Patent 7,260,153 ("*Fleet Connect Solutions LLC*" or the "patent-at-issue") was filed on April 28, 2003. According to its cover page the patent claims priority of provisional application No. 60/409,048, filed on September 9, 2002. Claim 1 of the patent-at-issue is generally directed to a method of evaluating a channel in a Multiple-Input Multiple-Output (MIMO) wireless communication system with at least two devices using multiple radiating elements for parallel data transmission. The method includes defining a channel matrix metric based on predefined functions of channel matrix singular values for each data sub-stream, providing a measure of cross-talk Signal-to-Noise Ratio (SNR). An estimated channel matrix is obtained, followed by performing Singular Value Decomposition (SVD) on the estimated matrix to derive singular values. These singular values are then used to calculate a crosstalk measure for each sub-stream, combining the channel matrix metric and estimated singular values to assess cross-talk in the system.

A primary reference, U.S. Patent 7,020,490 ("*Philips*"), was filed on January 23, 2002. According to its cover page, the publication claims a priority date of January 30, 2001 on the basis of a prior application. The patent is directed to a radio communication system that has a communication channel with many paths between two terminals having many antennas. One of the terminals has a receiver and a transmitter, where the receiver is configured to determine the directions from which the strongest signals arrive from the other terminal, corresponding to particular paths. The transmitter separates a signal for transmission into sub-streams and transmits each sub-stream in the respective directions determined by the receiver.

A primary reference, U.S. Patent 8,406,200 ("*Qualcomm*"), was filed on July 27, 1986. According to its cover page, the publication claims a priority date of January 8, 2002, on the basis of a prior application. The patent describes a method for scheduling terminals in a MIMO-OFDM system based on the spatial and/or frequency characteristics, referred to as "signatures," of the terminals. The process involves forming sets of terminals for potential data transmission in various frequency bands. Sub-hypotheses are generated for each hypothesis, indicating specific assignments of transmit antennas for downlink or a specific order for processing uplink data transmissions. The performance of each sub-hypothesis is assessed using performance metrics, and the best sub-hypothesis is selected for each frequency band. Terminals in the chosen sub-hypotheses are then scheduled for data transmission on the corresponding frequency bands.

A secondary reference, U.S. Pat. App. 2003/0186650 ("*Nokia*"), was filed on March 29, 2002 and claims priority on the same date. The patent application is directed to a method of communication using one or more antennas that distributes a signal's energy over at least one transmission path in response to the air interface characteristics. The energy of the signal is adjusted or weighted by considering the possible transmission paths available. Each available propagation path has a transmissive quality based on the air interface characteristics. Consequently, each signal, given its associated energy, is directed along the path(s) in response to its attenuation characteristics, for example, derived from the air interface characteristics.

A sample claim chart comparing claim 1 of *Fleet Connect Solutions LLC* to *Philips*, *Qualcomm*, and *Nokia* is provided below.

US7260153 ("*Fleet Connect Solutions LLC*")	**A. US7020490** (*"Philips"*) **B. US8406200** (*"Qualcomm"*) **C. US20030186650** (*"Nokia"*)
1.pre A method for evaluating a **channel of a multiple-input multiple-output (MIMO) wireless communication system**, wherein said communication system comprises at least **two communication devices having a plurality of radiating elements** for the **parallel transmission of data sub-streams**, comprising:	**A. US7020490** "FIG. 1 illustrates **a known MIMO radio system**. A plurality of applications 102 (AP1 to AP4) generate data streams for transmission. An application 102 could also generate a plurality of data streams." *Philips* at col. 4:8-11 "A receiver (Rx) 112, also provided with a plurality of antennas 108, **receives signals from the multiple paths which it then combines**, decodes and demultiplexes to provide respective data streams to each application. Although both the transmitter 110 and receiver 112 are shown as having the same number of antennas, this is not necessary in practice and the numbers of antennas can be optimised depending on space and capacity constraints. Similarly, **the transmitter** 106 **may support any number of applications (for example, a single application on a voice-only mobile telephone or a large number of applications on a PDA)**." *Philips* at col. 4:39-49 "FIG. 3 is a block schematic diagram of a transmitter 106. Incoming data S(t) is separated by a demultiplexer 302 into J sub-streams sj(t) (1≦j≦J), where J≦M and M is the number of antennas 108. The **number of sub-streams may be varied depending on radio channel characteristics** or other requirements." *Philips* at col. 6:56-61 "Hence, once the **transfer matrix has been determined, by a channel characterising block** 608, via some training scheme, the problem is essentially that of solving the set of simultaneous equations presented in equation 8 (assuming J≧K)." *Philips* at col. 10:37-41 **B. US8406200** "FIG. 1 is a diagram of **a multiple-input multiple-output communication system** 100 **that utilizes orthogonal frequency division multiplexing (i.e., a MIMO-OFDM system). MIMO-OFDM system** 100 employs multiple (NT) transmit antennas and multiple (NR) receive antennas for data transmission." *Qualcomm* at col. 3:54-59

(cont.) 1.pre A method for evaluating a **channel of a multiple-input multiple-output (MIMO) wireless communication system**, wherein said communication system comprises at least **two communication devices having a plurality of radiating elements** for the **parallel transmission of data sub-streams**, comprising:	"**The MIMO channel is then formed by the NT transmit antennas from all communicating terminals and the base station's NR receive antennas**. The number of spatial subchannels is limited by the number of transmit antennas. . . ." *Qualcomm* at col. 4:60-63 "In an actual operating environment, the channel response typically varies across the system bandwidth, and a more detailed **channel characterization may be used for the MIMO channel**." *Qualcomm* at col. 9:32-35 **C. US20030186650** "More particularly, a method (10) is depicted for distributing the energy of a signal along the **propagation path(s) in response to the air interface characteristics**." *Nokia* at par. 0025 "In one example, **the communications units are part of a Multi-Input, Multi-Output ("MIMO") communication system. Each propagation path has a transmissive quality** given the matrix of propagation coefficients—i.e., some propagation paths characterized as having less attenuation than other propagation paths." *Nokia* at par. 0027
1.a defining **a channel matrix metric**, said channel matrix metric comprising **a respective predefined function of channel matrix singular values for each of said data sub-streams**, such that each of said predefined functions provides **a measure of cross-talk signal to noise ratio (SNR)** for said respective sub-stream;	**A. US7020490** "A system made in accordance with the present invention provides an alternative wireless transceiver architecture to known systems such as BLAST, the basis of the invention being the transmission of K separate sub-streams into K different directions and the reception of multipath signals from J distinct directions. **The chosen directions, in each case, will depend on the directions from which multipath signals with greatest power or Signal to Noise Ratio (SNR)** were received, as determined from a measurement of angular power spectrum A(Ω)." *Philips* at col. 5:20-29 "**The J sub-streams are fed into a multiple-beam weighting matrix** 304. **This applies a set of complex weights wmj to the J input sub-streams sj to generate M output sub-streams** {hacek over (S)}m according to the following equation. . . which can also be written as {hacek over (s)}=Ws. which can also be written as {hacek over (s)}=Ws. **The result of applying the complex weight matrix W to the vector of signals s is the vector of signals** {hacek over (s)}, the mth element of which is the signal applied to the mth antenna 108

(cont.) 1.a defining **a channel matrix metric**, said channel matrix metric comprising **a respective predefined function of channel matrix singular values for each of said data sub-streams**, such that each of said predefined functions provides **a measure of cross-talk signal to noise ratio (SNR)** for said respective sub-stream;	of the array. **Essentially, the weighting matrix** 304 **is beamforming for each of the J sub-streams**." *Philips* at col. 7:1-20 "In choosing the weights for the jth sub-stream, it is desirable to minimise the power sent into other directions corresponding to q≠j, in order to **minimise the Signal to Interference plus Noise Ratio (SINR)** for the jth sub-stream at the receiver." *Philips* at col. 7:55-59 **B. US8406200** "In equation (1), **H(k) is the channel response matrix for the MIMO channel for the k-th frequency subchannel group**, and hi,j(k) is the coupling (i.e., the complex gain) between the j-th transmit antenna and the i-th receive antenna for the k-th frequency subchannel group." *Qualcomm* at col. 9:2-6 "**Each element of the matrix H(k) describes the response for a respective transmit-receive antenna pair for the k-th frequency subchannel group**. For a flat fading channel (or when NG=1), **one complex value may be used for the entire system bandwidth** (i.e., for all NF frequency subchannels) **for each transmit-receive antenna pair**." *Qualcomm* at col. 9:26-31 "The information given by the channel estimates may also be distilled into (1) **a post-processed signal-to-noise-and-interference ratio (SNR) estimate** (described below) **for each spatial subchannel of each frequency subchannel group**, and/or (2) some other statistic that allows the transmitter to select the proper rate for each independent data stream." *Qualcomm* at col. 9:53-58 **C. US20030186650** "Initially, the characteristics of the **air interface between at least one transmit antenna and at least one receive antenna** are determined (20). In performing this step, the matrix of propagation coefficients are derived by one of any number of techniques, disclosed. . . ." *Nokia* at par. 0026 "Thereafter, **one or more transmission paths for the signal are defined using at least one transmission antenna** (120). **This defining step contemplates the air interface characterized by the matrix of propagation coefficients. As each transmission path has a degree of attenuation, the air interface, and thusly, the matrix of propagation coefficients are considered**." *Nokia* at par. 0032

1.b obtaining **an estimated channel matrix**;	**A. US7020490** "**At step** 208 **elements of the transfer matrix H are determined**, where hjk is the complex transfer coefficient of the channel between the kth transmit direction and the jth receive direction. Finally, for the receiver 112, at step 210 standard multiuser detection techniques are used to extract the K transmitted sub-streams, where sk is the kth sub-stream." *Philips* at col. 6:12-18 **B. US8406200** "At a particular instant in time, the response for a MIMO channel formed by an array of NT transmit antennas and an array of NR receive antennas may be characterized by **a matrix H(k) whose elements are composed of independent Gaussian random variables**, as follows. . . ." *Qualcomm* at col. 8:49-53 "The scheduling for MIMO terminals may also be performed based on full-CSI. In this case, the statistic to be used for scheduling terminals is the complex channel gains between the base station's transmit antennas and the terminal's receive antennas, which are, used to **form the channel response matrix, H(k)**, shown in equation (1)." *Qualcomm* at col. 21:3-8 **C. US20030186650** "In this embodiment, the air interface is initially characterized (110). By this characterization, the **matrix of propagation coefficients (H) may be derived. Various techniques may be employed for deriving the matrix of propagation**." *Nokia* at par. 0031
1.c performing **a singular value decomposition (SVD)** of said estimated channel matrix **to obtain estimated channel singular values**, said singular value decomposition comprising **a left-hand unitary weighting matrix, a diagonal matrix of said estimated channel singular values, and a right-hand unitary weighting matrix**; and	**A. US7020490** "Stated simply, **the set of weights needed for the jth sub-stream is just the jth row of the inverse matrix of A. Hence, once the directions Ωj have been determined, the steering matrix A can be constructed and the inverse A−1 (or A+) calculated**. This is all the information required: the correct weights for each sub-stream are just the appropriate rows of the inverse matrix." *Philips* at col. 8:43-49 **B. US8406200** "The solution for A(k) does not require H(k) to be a square matrix, which is the case when NU≠NT. However, if H(k) is a square matrix, **then the solution in equation (10) can be**

(cont.) 1.c performing **a singular value decomposition (SVD)** of said estimated channel matrix **to obtain estimated channel singular values**, said singular value decomposition comprising **a left-hand unitary weighting matrix, a diagonal matrix of said estimated channel singular values, and a right-hand unitary weighting matrix**; and	**rewritten as A(k)=H −1(k), where H −1(k) is the inverse of H(k),** so that H −·(k)H(k)=H(k)H −1(k)=I, where I is the square identity matrix with ones on the diagonal and zeros elsewhere.” *Qualcomm* at col. 22:35-42 “However, in order to maintain the orthogonality between the rows of H(k) and the columns of A(k), **all entries within each column of A(k) need be scaled by the same value**. **The scaling is accomplished by the scaling matrix, S(k),** in equation (9), which has the following form:” *Qualcomm* at col. 22:45-50 **C. US20030186650** “In one example of the present embodiment, **the weighting step is realized by first calculating a right Eigen value matrix (Ψ) from a mathematical decomposition of the air interface, and then multiplying the signal by the right Eigen value matrix (Ψ).** It should be noted here that the mathematical decomposition of the air interface might be an Eigen value decomposition and/or a **Single value decomposition**.” *Nokia* at par. 0034 “. . . where **Λ is a diagonal matrix**. **It should be noted that diagonal matrix, Λ, is equivalent to the singular value matrix from the singular value decomposition of the matrix of propagation coefficients, H**. As a result, **the left Eigen matrix**, d, **may be computed** using the following expression” *Nokia* at par. 0055
1.d calculating **a respective crosstalk measure for each of said sub-streams** from said **channel matrix metric and said estimated channel singular values**.	**A. US7020490** “For transmission, each sub-stream may be transmitted with the same power and bitrate, or **the individual powers and/or bitrates of the sub-streams could be varied depending on some quality parameter such as signal to noise ratio**.” *Philips* at col. 2:56-60 “10. A terminal for use in a radio communication system having a communication channel comprising a plurality of paths between the terminal and another terminal, wherein receiving means are provided having direction determining means for determining a plurality of directions from which signals arrive from the other terminal, and transmitting means are provided having means for separating a signal for transmission into a plurality of sub-streams, the transmitting means being configured for transmitting each sub-stream into a

(cont.) 1.d calculating **a respective crosstalk measure for each of said sub-streams** from said **channel matrix metric and said estimated channel singular values**.	respective one of the plurality of directions determined by the receiving means, **wherein the transmitting means includes control means for independently adjusting the power and/or bitrate of each sub-stream depending on a signal quality parameter of the sub-stream**." *Philips* at claim 10 **B. US8406200** "The scheduler examines the priority for all active terminals in the list and selects the set of NT highest priority terminals, at step 412. **The remaining active terminals in the list are not considered for scheduling for this frequency subchannel group in this scheduling interval. The channel estimates for each selected terminal are then retrieved, at step** 414. **For example, the post-processed SNRs for the NT selected terminals may be retrieved and used to form the hypothesis matrix Γ(k)**." *Qualcomm* at col. 19:54-62 **C. US20030186650** "13. The method of claim 12, wherein the **signal's energy is distributed over at least one virtual sub-channel** corresponding with the at least one transmission path, and **the step of distributing the signal's energy comprises**: **adjusting the energy distributed over the at least one virtual sub-channel in response to the matrix of propagation coefficients by multiplying the signal by the right Eigen value matrix**." *Nokia* at claim 13