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1c951 U.S. PTO
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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

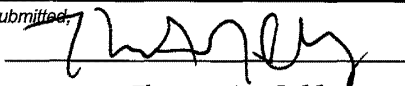
Express Mail Label No. EL 760486167US

1c951 U.S. PTO
60/287163
04/27/01

INVENTOR(S)					
Given Name (first and middle [if any])		Family Name or Surname		Residence (City and either State or Foreign Country)	
William J.		Crilly, Jr.		Liberty Lake, WA	
☐ Additional inventors are being named on the ___ separately numbered sheets attached hereto					
TITLE OF THE INVENTION (280 characters max)					
Improved Multipath Communication Methods And Arrangements					
Direct all correspondence to: CORRESPONDENCE ADDRESS					
☒ Customer Number		21718		 Place Customer Number Bar Code Label here PATENT TRADEMARK OFFICE	
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ENCLOSED APPLICATION PARTS (check all that apply)					
☒ Specification		Number of Pages		55	
☐ Drawing(s)		Number of Sheets			
☐ Application Data Sheet. See 37 CFR 1.76		☐ CD(s), Number			
		☒ Other (specify)		Title Page	
METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT					
☐ Applicant claims small entity status. See 37 CFR 1.27.				FILING FEE AMOUNT (\$)	
☒ A check or money order is enclosed to cover the filing fees					
☐ The Commissioner is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number:				\$75.00	
☐ Payment by credit card. Form PTO-2038 is attached.					
The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.					
☒ No.					
☐ Yes, the name of the U.S. Government agency and the Government contract number are: _____					

Respectfully submitted,

SIGNATURE



Date

4 / 27 / 01

TYPED or PRINTED NAME

Thomas A. Jolly

REGISTRATION NO.

39,241

(if appropriate)

Docket Number:

MN1-001USP1

TELEPHONE

(509) 324-9256

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

This collection of information is required by 37 CFR 1.51. The information is used by the public to file (and by the PTO to process) a provisional application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 8 hours to complete, including gathering, preparing, and submitting the complete provisional application to the PTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, Washington, D.C. 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Box Provisional Application, Assistant Commissioner for Patents, Washington, D.C. 20231.

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PTO/SB/17 (11-00)

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**FEE TRANSMITTAL
for FY 2001**

Patent fees are subject to annual revision.

TOTAL AMOUNT OF PAYMENT

(\$) 75.00

Complete if Known

Application Number

Filing Date

First Named Inventor

Grilly, Jr.

Examiner Name

Group Art Unit

Attorney Docket No.

MNI-001 USPI

METHOD OF PAYMENT

- 1.
- ☒
- The Commissioner is hereby authorized to charge indicated fees and credit any overpayments to:

Deposit
Account
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12-0769

Deposit
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Name

Lee + Hayes, PLLC

- ☒
- Charge Any Additional Fee Required
-
- Under 37 CFR 1.16 and 1.17

- ☐
- Applicant claims small entity status.
-
- See 37 CFR 1.27

- 2.
- ☒
- Payment Enclosed:

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FEE CALCULATION**1. BASIC FILING FEE**

Large Entity Small Entity

Fee Fee Fee Fee Fee Description

Code (\$) Code (\$) Code (\$) Code (\$)

101 710 201 355 Utility filing fee

106 320 206 160 Design filing fee

107 490 207 245 Plant filing fee

108 710 208 355 Reissue filing fee

114 150 214 75 Provisional filing fee

Fee Paid

SUBTOTAL (1) (\$) 75.00

2. EXTRA CLAIM FEES

Total Claims		-20** =		X	Fee from below	=	Fee Paid
Independent Claims		-3** =		X		=	
Multiple Dependent						=	

Large Entity Small Entity

Fee Fee Fee Fee

Code (\$) Code (\$) Code (\$) Code (\$)

103 18 203 9 Claims in excess of 20

102 80 202 40 Independent claims in excess of 3

104 270 204 135 Multiple dependent claim, if not paid

109 80 209 40 ** Reissue independent claims
over original patent110 18 210 9 ** Reissue claims in excess of 20
and over original patent

SUBTOTAL (2)

(\$) 0

**or number previously paid, if greater; For Reissues, see above

FEE CALCULATION (continued)**3. ADDITIONAL FEES**

Large Entity Small Entity

Fee Fee Fee Fee

Code (\$) Code (\$) Code (\$) Code (\$)

Fee Description

Fee Paid

105 130 205 65 Surcharge - late filing fee or oath

127 50 227 25 Surcharge - late provisional filing fee or
cover sheet

139 130 139 130 Non-English specification

147 2,520 147 2,520 For filing a request for ex parte reexamination

112 920* 112 920* Requesting publication of SIR prior to
Examiner action113 1,840* 113 1,840* Requesting publication of SIR after
Examiner action

115 110 215 55 Extension for reply within first month

116 390 216 195 Extension for reply within second month

117 890 217 445 Extension for reply within third month

118 1,390 218 695 Extension for reply within fourth month

128 1,890 228 945 Extension for reply within fifth month

119 310 219 155 Notice of Appeal

120 310 220 155 Filing a brief in support of an appeal

121 270 221 135 Request for oral hearing

138 1,510 138 1,510 Petition to institute a public use proceeding

140 110 240 55 Petition to revive - unavoidable

141 1,240 241 620 Petition to revive - unintentional

142 1,240 242 620 Utility issue fee (or reissue)

143 440 243 220 Design issue fee

144 600 244 300 Plant issue fee

122 130 122 130 Petitions to the Commissioner

123 50 123 50 Processing fee under 37 CFR 1.17(q)

126 180 126 180 Submission of Information Disclosure Stmt

581 40 581 40 Recording each patent assignment per
property (times number of properties)146 710 246 355 Filing a submission after final rejection
(37 CFR § 1.129(a))149 710 249 355 For each additional invention to be
examined (37 CFR § 1.129(b))

179 710 279 355 Request for Continued Examination (RCE)

169 900 169 900 Request for expedited examination
of a design application

Other fee (specify)

*Reduced by Basic Filing Fee Paid

SUBTOTAL (3) (\$) 0

SUBMITTED BY

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Date

4/27/01

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventorship Crilly, Jr.
Applicant Mabuhay Networks
Attorney's Docket No. MN1-001USP1
Title: Improved Mutlipath Communication Methods And Arrangements

TRANSMITTAL LETTER AND CERTIFICATE OF MAILING

To: Commissioner of Patents and Trademarks,
Washington, D.C. 20231

From: Thomas A. Jolly (Tel. 509-324-9256; Fax 509-323-8979)
Customer No. 21718



21718

PATENT TRADEMARK OFFICE

The following enumerated items accompany this transmittal letter and are being submitted for the matter identified in the above caption.

1. Transmittal letter including Certificate of Mailing
2. Fee Transmittal (if applicable)
3. Check in the Amount of \$75.00
4. Provisional Application for Patent Cover Sheet
5. Provisional Patent Application – title page plus 55 pages
6. Return Post Card

Large Entity Status []

Small Entity Status [X]

Date: 4/27/01

By:
Thomas A. Jolly
Reg. No. 39,241

CERTIFICATE OF MAILING

I hereby certify that the items listed above as enclosed are being deposited with the U.S. Postal Service as either first class mail, or Express Mail if the blank for Express Mail No. is completed below, in an envelope addressed to The Commissioner of Patents and Trademarks, Washington, D.C. 20231, on the below-indicated date. Any Express Mail No. has also been marked on the listed items.

EL764086167

Express Mail No. (if applicable) _____

Date: 4/27/01

By:
LeAnn M. Sassman

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

PROVISIONAL PATENT APPLICATION

**Improved Multipath Communication Methods And
Arrangements**

Inventor:
William J. Crilly, Jr.

ATTORNEY'S DOCKET NO. MN1-001USP1

Wireless communication systems often operate under the conditions of multipath propagation. Multipath is primarily the result of reflections and diffraction from objects in the overlapping regions covered by the transmitting and receiving antenna patterns. High data rate communication systems may be subject to detrimental intersymbol interference caused by this multipath. As the symbol rate increases, the multipath from one symbol affects the next symbol, making it impossible to identify the desired symbol and therefore determine its information content. The multipath effect may also be observed by examining the frequency domain characteristics of the channel. Multipath causes channel transfer function to have frequency-dependent responses, thus affecting the amplitude and phase modulation content of a received signal. Symbols with high information content are difficult to separately identify when even small amplitude and phase shifts exist across the modulation bandwidth of the signal.

Many modulation techniques have been used independently, and in combinations, to ameliorate or avoid intersymbol interference.

A common technique uses equalization placed at the receiver, transmitter, or both. These equalization techniques are designed to calculate a channel correction in the time and/or frequency domain, thus acting to cancel or correct the multipath effects. Correct symbol identification decisions may also be used to estimate the channel at subsequent times.

A second modulation method uses Orthogonal Frequency Division Multiplexing (OFDM) modulation to greatly increase the symbol time, thus preventing a delayed symbol from affecting the desired symbol. OFDM operates by coding a series of bits into a set of modulated orthogonal sub-carriers, thus producing a symbol to be transmitted. The transmitted OFDM symbol usually

includes a guard interval containing a cyclic extension of the basic symbol. If a guard interval is used, it is designed to be longer than the expected multipath delay spread of the channel. OFDM is usually generated using an IFFT, and received using an FFT. Techniques to establish the correct timing of the FFT blocks, and channel correction techniques for multipath delay spread less than the guard interval are well known. A common method is to use a complex correction value for each OFDM sub-carrier. The magnitude of the complex correction value is obtained from the inverse of the sub-carrier magnitude, and the phase is determined from a linear regression of the phase of pilot sub-carriers and other signals in training symbols.

A third modulation method uses spread spectrum techniques to encode a bit into a long coded sequence having a narrow autocorrelation function. The spread spectrum receiver uses devices such as a RAKE receiver with cross correlators to identify and use individual multipath signals arriving at the receiver.

Other modulation techniques rely on rapidly changing channels to produce an adequate signal at a different time. For example, see the John Bingham paper.

In general, the modulation methods described in the above paragraphs use time and frequency diversity. The modulation systems spread the information over a band of frequencies or in time to provide improved performance under multipath conditions and are highly effective at reducing multipath up to their design constraints.

In addition to modulation techniques, antennas are used to ameliorate the effects of multipath. A subset of these methods is commonly referred to as spatial division techniques. Transmitting antennas with narrow beamwidth reduce the multipath reflected from objects by not illuminating those objects. Only local

diffraction and reflection from objects behind the receiving antenna remain to produce multipath. A receiving antenna with a narrow beamwidth helps to reduce some remaining multipath, with the disadvantage that the user must know, or the receiver must calculate, the direction of the arriving direct path and multipath signals. Spatial division techniques are performed with single or multielement transmitting and receiving antennas. Some multielement antennas are also referred to as phased array antennas. Multielement transmitting antennas are advantageous for several reasons. Multielement transmitting antennas distribute required average signal power over a number of separate low power power amplifiers, thus reducing the complexity of each of the power amplifiers. Multielement transmitting and receiving antennas have the advantage of reducing or eliminating antenna pointing requirements. Phased arrays are capable of providing flexible antenna patterns, and are capable of simultaneously transmitting and receiving in several directions using the same antenna aperture. Due to this flexibility, and the other advantages described, phased arrays are very helpful in the reception and amelioration of signals which are affected by multipath propagation.

Antenna spatial diversity is a second subset of antenna techniques used to reduce multipath. Multiple transmitting antennas, spaced by more than a wavelength, have the ability to produce different amplitude and phase shifts over the frequency band used. Computation or selection of the received signals from the antennas may be used to establish one or more paths between the transmitting and receiving sites. In addition, the SNR may be improved by combining signal paths coherently, or errors reduced in multiple post-detection decoders. Coherent combining techniques overlap spatial division techniques, because coherent

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combining enhances antenna patterns in some directions and minimizes the pattern in other directions.

Antenna processing techniques are also used to take advantage of multipath. In an extension of spatial diversity, multiple transmitting antennas having spacing of more than a few wavelengths are used to illuminate scattering areas with slightly different wavefronts. The separate transmit signals diffract or reflect off the illuminated areas, and a receive antenna array receives each multipath signal. In effect, the scattering regions become a very poor, yet very large, pseudo-lens illuminated by the distant transmitting antennas. A large pseudo-lens has the ability to resolve closely spaced distant points, as determined by the Aires Disk of the effective pseudo-lens aperture. Receive signal processing acts to correct the phase and amplitude errors of the large pseudo-lens. The number of separate possible paths between the transmitter and receiver is determined by the rank of the matrix establishing the paths between the transmitter and receiver antennas. This rank is determined by the richness of the scattering paths and the number of receiving and transmitting antennas. When the rank is high, it is possible to provide high spectral efficiency as measured in bits per second per Hz.

All of the antenna signal processing techniques described are limited by a fundamental capability of the average-power-limited transmitter to adequately transmit the signals to the receiver. Shannon's Capacity Theorem determines the bit rate capacity of each of the effective multipath channels between the transmitter and receiver. For example, in a multipath channel with equal-amplitude direct and reflecting paths, an identical minimum signal to noise ratio (SNR) is required for each received path. Adequate received signal power must be available

to maintain the SNR above this minimum value. The SNR may be increased by increasing the average transmitter power, by directing greater power at the receiver and at the scattering object, or by gathering more power at the receiver using a larger receiver antenna aperture. In the case of a larger receive antenna aperture, a multielement large aperture receive antenna may be used in combination with signal processing to separately extract user data from each multipath. At the transmitting site, single element antennas or multielement transmit antennas with array signal processing are well known and capable of directing power in specific directions.

Equalization techniques are usually limited by the capability to estimate and correct the channel. Some difficulty is caused by the changing nature of the multipath channel. Computation of multipath correction made at the receiver must be repeated if the channel changes. Examples of multipath changes are trees moving in the wind, and nearby vehicular traffic. These changes have time scales ranging from a few milliseconds to a few seconds, depending on environmental conditions.

All of the equalization techniques described have an effect on the complexity of transmitters and receivers. As signal processing costs are reduced, techniques involving greater computation are preferred over those requiring more transmitter power. Desirable techniques generally attempt to place computation complexity at the location least subject to complexity restrictions, such as the base station in a cellular system.

Many materials are electromagnetically isotropic, a property resulting from symmetry in their associated permittivity and permeability tensors. The Lorentz Reciprocity Theorem applies to such materials. Refraction and dielectric reflection

from materials therefore often show reciprocity, or equivalence of forward and reverse channel characteristics. Diffraction and reflection is inherently reciprocal due to minimal media affecting the electromagnetic wave. Reciprocity has been used to determine the channel characteristics required to pre-equalize a transmitted path. The use of a reciprocal channel is most useful when Time Division Duplex channels are implemented.

Although the techniques described greatly improve the capacity of the wireless system to carry information, there are remaining difficulties. Channel equalization of high symbol rate systems requires many taps in a transversal filter, or requires long IFFT/FFTs to be calculated. Low symbol rate systems such as OFDM are very robust to a designed level of multipath delay spread, by providing a guard interval longer than the longest expected multipath delay spread. However, this potentially long guard interval in OFDM primarily sets the time duration of the FFT processing step in OFDM. A long guard interval reduces capacity, and long FFT processing increases latency. Long FFTs require data to be placed in large blocks, or zero-padded, adding overhead if few bits need to be sent. Spread spectrum systems lose the orthogonality of sequences when multipath is present, reducing capacity. Transmit spatial division antenna processing is capable of eliminating some highly-delayed multipath, but is not capable of eliminating retroreflected multipath. Spatial receive diversity techniques increase the reliability, and potentially the capacity of the channel, with a disadvantage that antenna signal processing at the receiving site is required. Receive antenna signal processing usually requires separate receive antennas and receivers for each path.

The combination of OFDM and other techniques has been shown, for example, see the Wi-Lan patent OFDM-w/o GI, Harris patent OFDM with cross-

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correlating equalizer in Rx. The transmitter described by Wi-LAN uses a measurement of the differential channel amplitude and estimates the differential channel phase based on the assumption of a minimum phase multipath characteristic. A training signal and guard interval are not required. However, multiple point channel equalization is not possible within a single OFDM sub-channel. This limits the maximum delay spread to approximately the symbol duration. The Harris OFDM equalizer requires two symbols to be transmitted per desired symbol.

None of the above-described systems provide equalization for large delay spread when the radio chipsets and associated physical layer standards do not include amelioration of these long delay spreads.

The present invention provides an improved system considering the stated shortcomings.

In accord with certain aspects of this invention a wireless communication system is provided which is capable of operating in multipath conditions. In accord with certain aspects of this invention methods and arrangements are provided that significantly minimize the complexity of signal processing required at the receiver, and use single or multiple receive antennas. Some conventional techniques teach the use of OFDM signal sequences to correct for multipath effects due to multipath delay spread shorter than the guard interval. A new wireless system described here uses a novel combination of new and known techniques to reduce the complexity of signal processing at the receiver. The signal processing combination described in this disclosure uses transmitter antenna spatial division processing, antenna diversity processing, receiver OFDM sub-carrier equalization techniques, and an OFDM pre-equalization technique. The

OFDM pre-equalization technique acts essentially within the frequency band of each OFDM sub-carrier to pre-equalize the multipath channel to handle multipath delay spread greater than the delay protection provided by some conventional techniques OFDM signal processing. Receiver OFDM equalization corrects multipath effects less than the guard interval. The novel pre-equalization technique uses substantially known training sequences contained within a reverse link received OFDM burst. The substantially known training sequences are not part of the header and equalization sequences provided for in the chipset or standard. OFDM symbols substantially less than those required by some conventional techniques may be transmitted.

Referring to Fig. 1, the overall processing steps are shown and described in the following example. A set of coded user data may comprise 96 bits. The bits are applied in pairs to an OFDM processor, which generates a QPSK modulation value on each of 48 OFDM sub-carriers. The OFDM modulated sub-carriers, output from the OFDM IFFT, are coupled to a pre-equalization processor, which may consist of a tapped transversal filter, or FFT/multipliers/IFFT filter of length on the order of the longest expected multipath. The complex coefficients of the tapped filter, or the complex multiplier values may be derived from the complex cross-correlation of the known OFDM signal sequences and the sequences received from the reverse path signal. The result of a sample cross-correlation output is shown in Fig. 2, indicating a multipath delay spread greater than the OFDM guard interval used. Well known techniques are used to invert the measured channel response so that the transmitter pre-equalization and the channel response error substantially cancel. Thus, the OFDM receiver receives a signal essentially free of multipath signals longer than the guard interval, and is able to

output coded user data with correctable errors. These correctable errors are corrected using well known error control coding techniques.

The typical guard interval used in an OFDM system is a small portion of the overall symbol time. For example, an OFDM symbol time of 10 microseconds results from a 64 subcarrier OFDM system operating in a 6.4 MHz bandwidth. A guard interval may be chosen to be 1 microsecond to reduce overhead. Delay spread is the time difference between the first and last arriving multipath. In this example, the first and last arriving multipaths must arrive within 1 microsecond of each other to allow conventional OFDM reception to take place. Retroreflected multipath from 1 km behind the receiver results in approximately 6.6 microseconds of delay spread. This composite signal cannot be handled by conventional OFDM reception using a 1 microsecond guard interval.

When a phased array is used to ameliorate the effect of multipath, antenna element coefficients may be determined by evaluating, for example, the Discrete Fourier Transform of the signals received on the elements of the phased array. Referring to Fig. 3, the effect of a direct and multipath signal is shown. After computation using an FFT to derive the angular distribution of received signals, and cross-correlation with known sequences is performed, the delay and angle of arrival of the direct and mutipath signal may be determined. Fig. 4 shows the result of this calculation. In some cases the direct and multipath signals may be combined to improve the SNR. In the case shown, the additional delay of a multipath signal exceeds the guard interval used in the OFDM modulation. Knowing that the channel is reciprocal allows a pre-equalization of the signals applied to the phased array during forward path transmission. Alternatively, the pre-equalized signals may be applied at only one angle. In this case, pre-

equalization is unnecessary. In some cases two delays, in the same direction, are determined from cross-correlation. This may be the result of retroreflected multipath. Pre-equalization is then used to correct the channel.

In cases where only a few transmit antennas are used, transmit antenna diversity may be implemented in place of phased array processing. The reverse link processing shown in Fig. 1 determines from measurements of the reverse link the best antenna to be used for reception. SNR, cross-correlation of the known sequences, or other measurements may be made. Multipath signals longer in duration than the guard interval may be present. A determination is made as to which antenna to select for the transmission of the pre-equalized signals. Pre-equalization and diversity then reduce the multipath signals at the receiver to a level which allows the detection of user data with correctable errors. Alternatively, transmit diversity may be implemented using simultaneous transmission of coded user data on the diversity antennas. In cases where many transmit elements are used, transmit antenna diversity may be implemented in combination with phased array processing.

For example, a system may be produced which generates two simultaneous beams illuminating separate areas of a multipath environment. The transmit signals applied to the two antennas are adjusted in phase and amplitude to produce a signal at the receiver which is substantially free of multipath greater in delay than the guard interval. If a strong composite signal is received still containing large delay spread, pre-equalization techniques may be applied at the transmitters driving the two beams to ameliorate the long delay spread of one or both of the multipaths. The system may be expanded to include antenna patterns other than a

dual beam approach. The transmitted pattern may be determined by the incident reverse path power pattern.

The reverse path transmission of substantially or perfectly known training signals is accomplished by enclosing the signals in the data or payload section of the OFDM symbols. The training signals may take a number of modulated forms, such as spread spectrum signals or OFDMA signals. The information required to perform the desired modulation is applied to the payload portion of the symbols, as differentiated from the header portion of the signal.

Cross-correlation, FFT processing and filtering may be produced by various means. For example, it is possible to combine OFDM FFT processing and pre-equalization filtering. Cross-correlation is best performed in the frequency domain using the previously calculated DFTs of the known OFDM signal sequences. The resulting calculations reduce to the calculation of a single FFT and a set of multiplications. Many other signal processing techniques are known and may be used.

Other implementations of this invention may be derived from the disclosed contents of this invention. By way of example, a practitioner may implement a high data rate communication system using separately calculated multipaths, all paths transmitting on the same frequency. Another implementation may use receiver OFDM channel equalization for delays greater than the guard interval, improving performance. A reverse channel quality indicator, or the measured forward channel impulse response, may be transmitted on the reverse path when channel reciprocity is not available. Such a system can be useful when Frequency Division Duplex or Half Frequency Division Duplex is used. In Frequency Division Duplex systems, short training signals may be periodically transmitted

using Time Division Duplex on each of the frequencies used for Frequency Division Duplex. Multiple RF signals, operating on the same and different frequencies, may be simultaneously transmitted and received. The operation of the described wireless system on the forward path may be similarly implemented in a wireless system on the reverse path.

Thus, a wireless communication system operating in substantially reciprocal multipath conditions has been described. Certain exemplary implementations have a receiving system that includes one or more receive antennas coupled to one or more OFDM receivers. Preferably, each OFDM receiver has a guard interval shorter than the longest expected multipath delay spread. Intersymbol interference caused by multipath delay spread greater than the OFDM guard interval can be advantageously reduced using transmit spatial division processing, transmit spatial diversity processing and/or transmit pre-equalization.

Further examples:

1. A wireless communication system operating under substantially reciprocal multipath conditions may include a coded user data source, a forward path transmitter coupled to the data source, the transmitter generating pre-equalized OFDM signal sequences, a forward path transmitting antenna arranged to convert the OFDM signal sequences into electromagnetic waves directed towards an intended forward path receive antenna, the forward path receive antenna arranged to receive the electromagnetic waves affected by multipath conditions, a forward path receiver coupled to the forward path receive antenna,

the receiver processing received OFDM signal sequences, the received OFDM signal sequences including modifications caused by multipath conditions, to output the coded user data with correctable errors, a reverse path substantially electromagnetically reciprocal to the forward path, the pre-equalized OFDM signal sequences calculated to provide multipath protection in the forward path for multipath delay spread greater than the guard interval used in the OFDM signal sequence, the pre-equalized OFDM signal sequences calculated using information obtained by processing training signals propagated on the reverse path, the training signals contained in the data or payload portion of the reverse path OFDM symbols.

2. A wireless communication system operating under substantially reciprocal multipath conditions may include a coded user data source, at least one forward path transmitter coupled to the data source, the transmitter or transmitters generating pre-equalized OFDM signal sequences, a plurality of forward path transmitting antennas, coupled to the forward path transmitter or transmitters, arranged to convert the OFDM signal sequences into electromagnetic waves directed towards an intended forward path receive antenna, the forward path receive antenna arranged to receive the electromagnetic waves affected by multipath conditions, a forward path receiver coupled to the forward path receive antenna, the receiver processing received OFDM signal sequences, the received OFDM signal sequences including modifications caused by multipath conditions, to output the coded user data with correctable errors, a reverse path substantially electromagnetically reciprocal to the forward path, the pre-equalized OFDM signal sequences calculated to provide multipath protection in the forward path for

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multipath delay spread greater than the guard interval used in the OFDM signal sequence, the pre-equalized OFDM signal sequences calculated using information obtained by processing training signals propagated on the reverse path, the training signals contained in the data or payload portion of the reverse path OFDM symbols, the plurality of forward path transmitting antennas arranged to provide transmit diversity.

3. A wireless communication system operating under substantially reciprocal multipath conditions may include a coded user data source, a forward path transmitter coupled to the data source, the transmitter generating pre-equalized OFDM signal sequences, a forward path phased array processor coupled to the transmitter, the processor arranged to convert the OFDM signal sequences into forward path phased array signals, a forward path phased array antenna coupled to the forward path phased array processor, the antenna arranged to convert the forward path phased array signals into electromagnetic waves directed towards an intended forward path receive antenna, the forward path receive antenna arranged to receive the electromagnetic waves affected by multipath conditions, a forward path receiver coupled to the forward path receive antenna, the receiver processing received OFDM signal sequences, the received OFDM signal sequences including modifications caused by multipath conditions, to output the coded user data with correctable errors, a reverse path substantially electromagnetically reciprocal to the forward path, the pre-equalized OFDM signal sequences calculated to provide multipath protection in the forward path for multipath delay spread greater than the guard interval used in the OFDM signal sequence, the pre-equalized OFDM signal sequences calculated using information

obtained by processing training signals propagated on the reverse path, the training signals contained in the data or payload portion of the reverse path OFDM symbols.

4. A wireless communication system operating under substantially reciprocal multipath conditions may include a coded user data source, at least one forward path transmitter coupled to the data source, the transmitter or transmitters generating pre-equalized OFDM signal sequences, at least one forward path phased array processor coupled to the transmitter or transmitters, the processor or processors arranged to convert the OFDM signal sequences into forward path phased array signals, a plurality of forward path phased array antennas coupled to the forward path phased array processor or processors, the antennas arranged to convert the forward path phased array signals into electromagnetic waves directed towards an intended forward path receive antenna, the forward path receive antenna arranged to receive the electromagnetic waves affected by multipath conditions, a forward path receiver coupled to the forward path receive antenna, the receiver processing received OFDM signal sequences, the received OFDM signal sequences including modifications caused by multipath conditions, to output the coded user data with correctable errors, a reverse path substantially electromagnetically reciprocal to the forward path, the pre-equalized OFDM signal sequences calculated to provide multipath protection in the forward path for multipath delay spread greater than the guard interval used in the OFDM signal sequence, the pre-equalized OFDM signal sequences calculated using information obtained by processing training signals propagated on the reverse path, the

training signals contained in the data or payload portion of the reverse path OFDM symbols.

5. A wireless communication system operating under substantially reciprocal multipath conditions may include a coded user data source, at least one forward path transmitter coupled to the data source, the transmitter or transmitters generating pre-equalized OFDM signal sequences, at least one forward path phased array processor coupled to the transmitter or transmitters, the processor or processors arranged to convert the OFDM signal sequences into forward path phased array signals, a plurality of forward path phased array antennas coupled to the forward path phased array processor or processors, the antennas arranged to convert the forward path phased array signals into electromagnetic waves directed towards an intended forward path receive antenna, the forward path receive antenna arranged to receive the electromagnetic waves affected by multipath conditions, a forward path receiver coupled to the forward path receive antenna, the receiver processing received OFDM signal sequences, the received OFDM signal sequences including modifications caused by multipath conditions, to output the coded user data with correctable errors, a reverse path substantially electromagnetically reciprocal to the forward path, the forward path phased array signals calculated to provide multipath protection at the forward path receiver for multipath delay spread greater than the guard interval used in the OFDM signal sequence, the forward path phased array signals calculated using information obtained by processing training signals propagated on the reverse path, the training signals contained in the data or payload portion of the reverse path OFDM symbols.

6. A wireless communication system operating under substantially reciprocal multipath conditions may include a coded user data source, a forward path transmitter coupled to the data source, the transmitter generating pre-equalized OFDM signal sequences, a forward path phased array processor coupled to the transmitter, the processor arranged to convert the OFDM signal sequences into forward path phased array signals, a forward path phased array antenna coupled to the forward path phased array processor, the antenna arranged to convert the forward path phased array signals into electromagnetic waves directed towards an intended forward path receive antenna, the forward path receive antenna arranged to receive the electromagnetic waves affected by multipath conditions, a forward path receiver coupled to the forward path receive antenna, the receiver processing received OFDM signal sequences, the received OFDM signal sequences including modifications caused by multipath conditions, to output the coded user data with correctable errors, a reverse path substantially electromagnetically reciprocal to the forward path, the forward path phased array signals calculated to provide multipath protection at the forward path receiver for multipath delay spread greater than the guard interval used in the OFDM signal sequence, the forward path phased array signals calculated using information obtained by processing training signals propagated on the reverse path, the training signals contained in the data or payload portion of the reverse path OFDM symbols.

7. A wireless communication system operating under substantially reciprocal multipath conditions may include a coded user data source, a forward

path transmitter coupled to the data source, the transmitter generating pre-equalized OFDM signal sequences, a forward path transmitting antenna arranged to convert the OFDM signal sequences into electromagnetic waves directed towards an intended forward path receive antenna, the forward path receive antenna arranged to receive the electromagnetic waves affected by multipath conditions, a forward path receiver coupled to the forward path receive antenna, the receiver processing received OFDM signal sequences, the received OFDM signal sequences including modifications caused by multipath conditions, to output the coded user data with correctable errors, a reverse path substantially electromagnetically reciprocal to the forward path, the pre-equalized OFDM signal sequences calculated to provide multipath protection in the forward path for multipath delay spread greater than the guard interval used in the OFDM signal sequence, the pre-equalized OFDM signal sequences calculated using information obtained by processing training signals propagated on the reverse path, the training signals contained in the data or payload portion of the reverse path OFDM symbols, the signals propagated on the reverse path include substantially known signal sequences contained within an OFDM burst, the signal sequences longer in duration than the guard interval used in the OFDM signal sequence.

8. A wireless communication system operating under substantially reciprocal multipath conditions may include a coded user data source, at least one forward path transmitter coupled to the data source, the transmitter or transmitters generating pre-equalized OFDM signal sequences, a plurality of forward path transmitting antennas, coupled to the forward path transmitter or transmitters, arranged to convert the OFDM signal sequences into electromagnetic waves

convert the forward path phased array signals into electromagnetic waves directed towards an intended forward path receive antenna, the forward path receive antenna arranged to receive the electromagnetic waves affected by multipath conditions, a forward path receiver coupled to the forward path receive antenna, the receiver processing received OFDM signal sequences, the received OFDM signal sequences including modifications caused by multipath conditions, to output the coded user data with correctable errors, a reverse path substantially electromagnetically reciprocal to the forward path, the pre-equalized OFDM signal sequences calculated to provide multipath protection in the forward path for multipath delay spread greater than the guard interval used in the OFDM signal sequence, the pre-equalized OFDM signal sequences calculated using information obtained by processing training signals propagated on the reverse path, the training signals contained in the data or payload portion of the reverse path OFDM symbols, the signals propagated on the reverse path include substantially known signal sequences contained within a reverse path OFDM burst, the signal sequences longer in duration than the guard interval used in the OFDM signal sequence.

10. A wireless communication system operating under substantially reciprocal multipath conditions may include a coded user data source, at least one forward path transmitter coupled to the data source, the transmitter or transmitters generating pre-equalized OFDM signal sequences, at least one forward path phased array processor coupled to the transmitter or transmitters, the processor or processors arranged to convert the OFDM signal sequences into forward path phased array signals, a plurality of forward path phased array antennas coupled to

the forward path phased array processor or processors, the antennas arranged to convert the forward path phased array signals into electromagnetic waves directed towards an intended forward path receive antenna, the forward path receive antenna arranged to receive the electromagnetic waves affected by multipath conditions, a forward path receiver coupled to the forward path receive antenna, the receiver processing received OFDM signal sequences, the received OFDM signal sequences including modifications caused by multipath conditions, to output the coded user data with correctable errors, a reverse path substantially electromagnetically reciprocal to the forward path, the pre-equalized OFDM signal sequences calculated to provide multipath protection in the forward path for multipath delay spread greater than the guard interval used in the OFDM signal sequence, the pre-equalized OFDM signal sequences calculated using information obtained by processing training signals propagated on the reverse path, the training signals contained in the data or payload portion of the reverse path OFDM symbols, the signals propagated on the reverse path include substantially known signal sequences contained within a reverse path OFDM burst, the signal sequences longer in duration than the guard interval used in the OFDM signal sequence.

11. A wireless communication system operating under substantially reciprocal multipath conditions may include a coded user data source, at least one forward path transmitter coupled to the data source, the transmitter or transmitters generating pre-equalized OFDM signal sequences, at least one forward path phased array processor coupled to the transmitter or transmitters, the processor or processors arranged to convert the OFDM signal sequences into forward path

phased array signals, a plurality of forward path phased array antennas coupled to the forward path phased array processor or processors, the antennas arranged to convert the forward path phased array signals into electromagnetic waves directed towards an intended forward path receive antenna, the forward path receive antenna arranged to receive the electromagnetic waves affected by multipath conditions, a forward path receiver coupled to the forward path receive antenna, the receiver processing received OFDM signal sequences, the received OFDM signal sequences including modifications caused by multipath conditions, to output the coded user data with correctable errors, a reverse path substantially electromagnetically reciprocal to the forward path, the forward path phased array signals calculated to provide multipath protection at the forward path receiver for multipath delay spread greater than the guard interval used in the OFDM signal sequence, the forward path phased array signals calculated using information obtained by processing training signals propagated on the reverse path, the training signals contained in the data or payload portion of the reverse path OFDM symbols, the signals propagated on the reverse path include substantially known signal sequences contained within a reverse path OFDM burst, the signal sequences longer in duration than the guard interval used in the OFDM signal sequence.

12. A wireless communication system operating under substantially reciprocal multipath conditions may include a coded user data source, a forward path transmitter coupled to the data source, the transmitter generating pre-equalized OFDM signal sequences, a forward path phased array processor coupled to the transmitter, the processor arranged to convert the OFDM signal sequences

into forward path phased array signals, a forward path phased array antenna coupled to the forward path phased array processor, the antenna arranged to convert the forward path phased array signals into electromagnetic waves directed towards an intended forward path receive antenna, the forward path receive antenna arranged to receive the electromagnetic waves affected by multipath conditions, a forward path receiver coupled to the forward path receive antenna, the receiver processing received OFDM signal sequences, the received OFDM signal sequences including modifications caused by multipath conditions, to output the coded user data with correctable errors, a reverse path substantially electromagnetically reciprocal to the forward path, the forward path phased array signals calculated to provide multipath protection at the forward path receiver for multipath delay spread greater than the guard interval used in the OFDM signal sequence, the forward path phased array signals calculated using information obtained by processing training signals propagated on the reverse path, the training signals contained in the data or payload portion of the reverse path OFDM symbols, the signals propagated on the reverse path include substantially known signal sequences contained within a reverse path OFDM burst, the signal sequences longer in duration than the guard interval used in the OFDM signal sequence.

13. A wireless communication system operating under substantially reciprocal multipath conditions may include a coded user data source, a forward path transmitter coupled to the data source, the transmitter generating pre-equalized OFDM signal sequences, a forward path transmitting antenna arranged to convert the OFDM signal sequences into electromagnetic waves directed

towards a plurality of intended forward path receive antennas, the forward path receive antennas arranged to receive the electromagnetic waves affected by multipath conditions, at least one forward path receiver coupled to the forward path receive antennas, the receiver or receivers processing received OFDM signal sequences, the received OFDM signal sequences including modifications caused by multipath conditions, to output the coded user data with correctable errors, a reverse path substantially electromagnetically reciprocal to the forward path, the pre-equalized OFDM signal sequences calculated to provide multipath protection in the forward path for multipath delay spread greater than the guard interval used in the OFDM signal sequence, the pre-equalized OFDM signal sequences calculated using information obtained by processing training signals propagated on the reverse path, the training signals contained in the data or payload portion of the reverse path OFDM symbols.

14. A wireless communication system operating under substantially reciprocal multipath conditions may include a coded user data source, at least one forward path transmitter coupled to the data source, the transmitter or transmitters generating pre-equalized OFDM signal sequences, a plurality of forward path transmitting antennas, coupled to the forward path transmitter or transmitters, arranged to convert the OFDM signal sequences into electromagnetic waves directed towards a plurality of intended forward path receive antennas, the forward path receive antennas arranged to receive the electromagnetic waves affected by multipath conditions, at least one forward path receiver coupled to the forward path receive antennas, the receiver or receivers processing received OFDM signal sequences, the received OFDM signal sequences including modifications caused

by multipath conditions, to output the coded user data with correctable errors, a reverse path substantially electromagnetically reciprocal to the forward path, the pre-equalized OFDM signal sequences calculated to provide multipath protection in the forward path for multipath delay spread greater than the guard interval used in the OFDM signal sequence, the pre-equalized OFDM signal sequences calculated using information obtained by processing training signals propagated on the reverse path, the training signals contained in the data or payload portion of the reverse path OFDM symbols, the plurality of forward path transmitting antennas arranged to provide transmit diversity.

15. A wireless communication system operating under substantially reciprocal multipath conditions may include a coded user data source, a forward path transmitter coupled to the data source, the transmitter generating pre-equalized OFDM signal sequences, a forward path phased array processor coupled to the transmitter, the processor arranged to convert the OFDM signal sequences into forward path phased array signals, a forward path phased array antenna coupled to the forward path phased array processor, the antenna arranged to convert the forward path phased array signals into electromagnetic waves directed towards a plurality of intended forward path receive antennas, the forward path receive antennas arranged to receive the electromagnetic waves affected by multipath conditions, at least one forward path receiver coupled to the forward path receive antennas, the receiver or receivers processing received OFDM signal sequences, the received OFDM signal sequences including modifications caused by multipath conditions, to output the coded user data with correctable errors, a reverse path substantially electromagnetically reciprocal to the forward path, the

pre-equalized OFDM signal sequences calculated to provide multipath protection in the forward path for multipath delay spread greater than the guard interval used in the OFDM signal sequence, the pre-equalized OFDM signal sequences calculated using information obtained by processing training signals propagated on the reverse path, the training signals contained in the data or payload portion of the reverse path OFDM symbols.

16. A wireless communication system operating under substantially reciprocal multipath conditions may include a coded user data source, at least one forward path transmitter coupled to the data source, the transmitter or transmitters generating pre-equalized OFDM signal sequences, at least one forward path phased array processor coupled to the transmitter or transmitters, the processor or processors arranged to convert the OFDM signal sequences into forward path phased array signals, a plurality of forward path phased array antennas coupled to the forward path phased array processor or processors, the antennas arranged to convert the forward path phased array signals into electromagnetic waves directed towards a plurality of intended forward path receive antennas, the forward path receive antennas arranged to receive the electromagnetic waves affected by multipath conditions, at least one forward path receiver coupled to the forward path receive antennas, the receiver or receivers processing received OFDM signal sequences, the received OFDM signal sequences including modifications caused by multipath conditions, to output the coded user data with correctable errors, a reverse path substantially electromagnetically reciprocal to the forward path, the pre-equalized OFDM signal sequences calculated to provide multipath protection in the forward path for multipath delay spread greater than the guard interval used

in the OFDM signal sequence, the pre-equalized OFDM signal sequences calculated using information obtained by processing training signals propagated on the reverse path, the training signals contained in the data or payload portion of the reverse path OFDM symbols.

17. A wireless communication system operating under substantially reciprocal multipath conditions may include a coded user data source, at least one forward path transmitter coupled to the data source, the transmitter or transmitters generating pre-equalized OFDM signal sequences, at least one forward path phased array processor coupled to the transmitter or transmitters, the processor or processors arranged to convert the OFDM signal sequences into forward path phased array signals, a plurality of forward path phased array antennas coupled to the forward path phased array processor or processors, the antennas arranged to convert the forward path phased array signals into electromagnetic waves directed towards a plurality of intended forward path receive antennas, the forward path receive antennas arranged to receive the electromagnetic waves affected by multipath conditions, at least one forward path receiver coupled to the forward path receive antennas, the receiver or receivers processing received OFDM signal sequences, the received OFDM signal sequences including modifications caused by multipath conditions, to output the coded user data with correctable errors, a reverse path substantially electromagnetically reciprocal to the forward path, the forward path phased array signals calculated to provide multipath protection at the forward path receiver for multipath delay spread greater than the guard interval used in the OFDM signal sequence, the forward path phased array signals calculated using information obtained by processing training signals propagated

on the reverse path, the training signals contained in the data or payload portion of the reverse path OFDM symbols.

18. A wireless communication system operating under substantially reciprocal multipath conditions may include a coded user data source, a forward path transmitter coupled to the data source, the transmitter generating pre-equalized OFDM signal sequences, a forward path phased array processor coupled to the transmitter, the processor arranged to convert the OFDM signal sequences into forward path phased array signals, a forward path phased array antenna coupled to the forward path phased array processor, the antenna arranged to convert the forward path phased array signals into electromagnetic waves directed towards a plurality of intended forward path receive antennas, the forward path receive antennas arranged to receive the electromagnetic waves affected by multipath conditions, at least one forward path receiver coupled to the forward path receive antennas, the receiver or receivers processing received OFDM signal sequences, the received OFDM signal sequences including modifications caused by multipath conditions, to output the coded user data with correctable errors, a reverse path substantially electromagnetically reciprocal to the forward path, the forward path phased array signals calculated to provide multipath protection at the forward path receiver for multipath delay spread greater than the guard interval used in the OFDM signal sequence, the forward path phased array signals calculated using information obtained by processing training signals propagated on the reverse path, the training signals contained in the data or payload portion of the reverse path OFDM symbols.

19. A wireless communication system operating under substantially reciprocal multipath conditions may include a coded user data source, a forward path transmitter coupled to the data source, the transmitter generating pre-equalized OFDM signal sequences, a forward path transmitting antenna arranged to convert the OFDM signal sequences into electromagnetic waves directed towards a plurality of intended forward path receive antennas, the forward path receive antennas arranged to receive the electromagnetic waves affected by multipath conditions, at least one forward path receiver coupled to the forward path receive antennas, the receiver or receiver processing received OFDM signal sequences, the received OFDM signal sequences including modifications caused by multipath conditions, to output the coded user data with correctable errors, a reverse path substantially electromagnetically reciprocal to the forward path, the pre-equalized OFDM signal sequences calculated to provide multipath protection in the forward path for multipath delay spread greater than the guard interval used in the OFDM signal sequence, the pre-equalized OFDM signal sequences calculated using information obtained by processing training signals propagated on the reverse path, the training signals contained in the data or payload portion of the reverse path OFDM symbols, the signals propagated on the reverse path include substantially known signal sequences contained within an OFDM burst, the signal sequences longer in duration than the guard interval used in the OFDM signal sequence.

20. A wireless communication system operating under substantially reciprocal multipath conditions may include a coded user data source, at least one forward path transmitter coupled to the data source, the transmitter or transmitters

generating pre-equalized OFDM signal sequences, a plurality of forward path transmitting antennas, coupled to the forward path transmitter or transmitters, arranged to convert the OFDM signal sequences into electromagnetic waves directed towards a plurality of intended forward path receive antennas, the forward path receive antennas arranged to receive the electromagnetic waves affected by multipath conditions, at least one forward path receiver coupled to the forward path receive antenna, the receiver or receivers processing received OFDM signal sequences, the received OFDM signal sequences including modifications caused by multipath conditions, to output the coded user data with correctable errors, a reverse path substantially electromagnetically reciprocal to the forward path, the pre-equalized OFDM signal sequences calculated to provide multipath protection in the forward path for multipath delay spread greater than the guard interval used in the OFDM signal sequence, the pre-equalized OFDM signal sequences calculated using information obtained by processing training signals propagated on the reverse path, the training signals contained in the data or payload portion of the reverse path OFDM symbols, the signals propagated on the reverse path include substantially known signal sequences contained within a reverse path OFDM burst, the signal sequences longer in duration than the guard interval used in the OFDM signal sequence, the plurality of forward path transmitting antennas arranged to provide transmit diversity.

21. A wireless communication system operating under substantially reciprocal multipath conditions may include a coded user data source, a forward path transmitter coupled to the data source, the transmitter generating pre-equalized OFDM signal sequences, a forward path phased array processor coupled

to the transmitter, the processor arranged to convert the OFDM signal sequences into forward path phased array signals, a forward path phased array antenna coupled to the forward path phased array processor, the antenna arranged to convert the forward path phased array signals into electromagnetic waves directed towards a plurality of intended forward path receive antennas, the forward path receive antennas arranged to receive the electromagnetic waves affected by multipath conditions, at least one forward path receiver coupled to the forward path receive antennas, the receiver or receiver processing received OFDM signal sequences, the received OFDM signal sequences including modifications caused by multipath conditions, to output the coded user data with correctable errors, a reverse path substantially electromagnetically reciprocal to the forward path, the pre-equalized OFDM signal sequences calculated to provide multipath protection in the forward path for multipath delay spread greater than the guard interval used in the OFDM signal sequence, the pre-equalized OFDM signal sequences calculated using information obtained by processing training signals propagated on the reverse path, the training signals contained in the data or payload portion of the reverse path OFDM symbols, the signals propagated on the reverse path include substantially known signal sequences contained within a reverse path OFDM burst, the signal sequences longer in duration than the guard interval used in the OFDM signal sequence.

22. A wireless communication system operating under substantially reciprocal multipath conditions may include a coded user data source, at least one forward path transmitter coupled to the data source, the transmitter or transmitters generating pre-equalized OFDM signal sequences, at least one forward path

phased array processor coupled to the transmitter or transmitters, the processor or processors arranged to convert the OFDM signal sequences into forward path phased array signals, a plurality of forward path phased array antennas coupled to the forward path phased array processor or processors, the antennas arranged to convert the forward path phased array signals into electromagnetic waves directed towards a plurality of intended forward path receive antennas, the forward path receive antennas arranged to receive the electromagnetic waves affected by multipath conditions, at least one forward path receiver coupled to the forward path receive antennas, the receiver or receivers processing received OFDM signal sequences, the received OFDM signal sequences including modifications caused by multipath conditions, to output the coded user data with correctable errors, a reverse path substantially electromagnetically reciprocal to the forward path, the pre-equalized OFDM signal sequences calculated to provide multipath protection in the forward path for multipath delay spread greater than the guard interval used in the OFDM signal sequence, the pre-equalized OFDM signal sequences calculated using information obtained by processing training signals propagated on the reverse path, the training signals contained in the data or payload portion of the reverse path OFDM symbols, the signals propagated on the reverse path include substantially known signal sequences contained within a reverse path OFDM burst, the signal sequences longer in duration than the guard interval used in the OFDM signal sequence.

23. A wireless communication system operating under substantially reciprocal multipath conditions may include a coded user data source, at least one forward path transmitter coupled to the data source, the transmitter or transmitters

generating pre-equalized OFDM signal sequences, at least one forward path phased array processor coupled to the transmitter or transmitters, the processor or processors arranged to convert the OFDM signal sequences into forward path phased array signals, a plurality of forward path phased array antennas coupled to the forward path phased array processor or processors, the antennas arranged to convert the forward path phased array signals into electromagnetic waves directed towards a plurality of intended forward path receive antennas, the forward path receive antennas arranged to receive the electromagnetic waves affected by multipath conditions, at least one forward path receiver coupled to the forward path receive antennas, the receiver or receivers processing received OFDM signal sequences, the received OFDM signal sequences including modifications caused by multipath conditions, to output the coded user data with correctable errors, a reverse path substantially electromagnetically reciprocal to the forward path, the forward path phased array signals calculated to provide multipath protection at the forward path receiver for multipath delay spread greater than the guard interval used in the OFDM signal sequence, the forward path phased array signals calculated using information obtained by processing training signals propagated on the reverse path, the training signals contained in the data or payload portion of the reverse path OFDM symbols, the signals propagated on the reverse path include substantially known signal sequences contained within a reverse path OFDM burst, the signal sequences longer in duration than the guard interval used in the OFDM signal sequence.

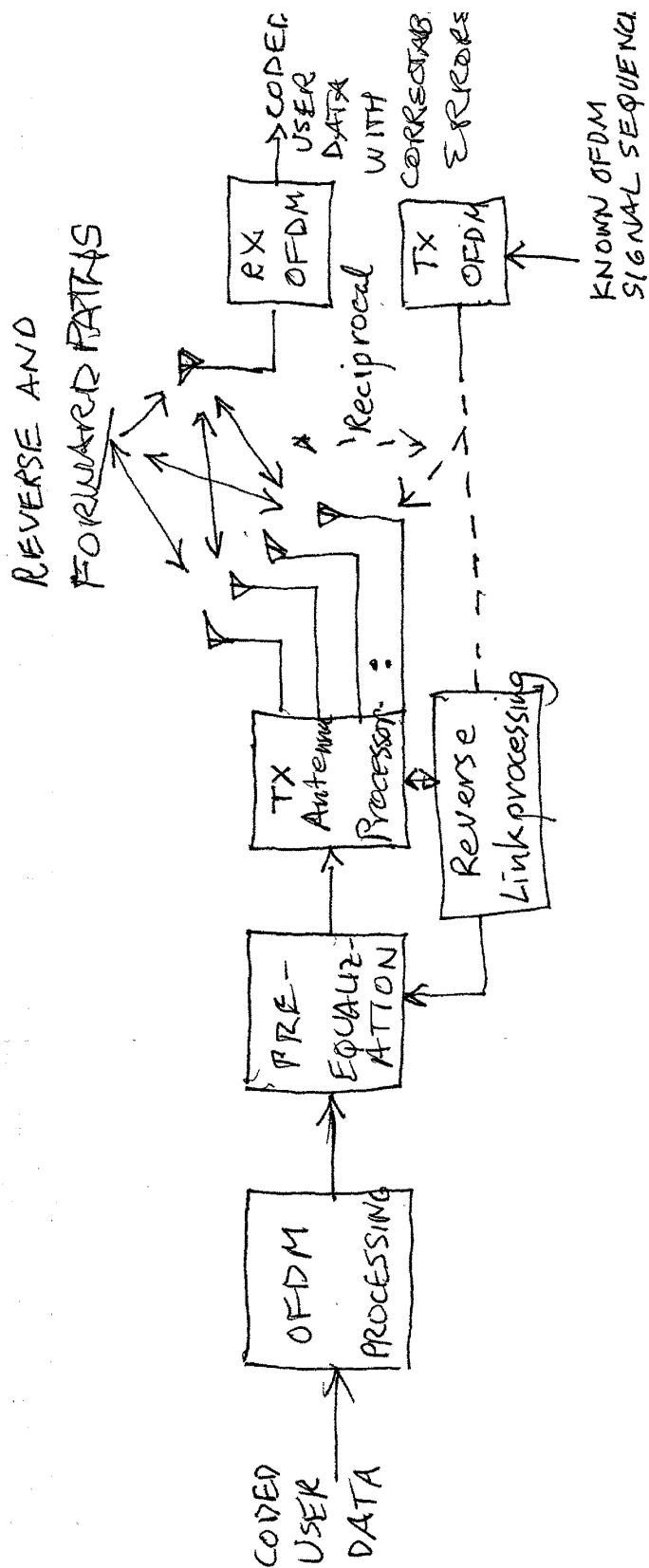
24. A wireless communication system operating under substantially reciprocal multipath conditions may include a coded user data source, a forward

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path transmitter coupled to the data source, the transmitter generating pre-equalized OFDM signal sequences, a forward path phased array processor coupled to the transmitter, the processor arranged to convert the OFDM signal sequences into forward path phased array signals, a forward path phased array antenna coupled to the forward path phased array processor, the antenna arranged to convert the forward path phased array signals into electromagnetic waves directed towards a plurality of intended forward path receive antennas, the forward path receive antennas arranged to receive the electromagnetic waves affected by multipath conditions, at least one forward path receiver coupled to the forward path receive antennas, the receiver or receivers processing received OFDM signal sequences, the received OFDM signal sequences including modifications caused by multipath conditions, to output the coded user data with correctable errors, a reverse path substantially electromagnetically reciprocal to the forward path, the forward path phased array signals calculated to provide multipath protection at the forward path receiver for multipath delay spread greater than the guard interval used in the OFDM signal sequence, the forward path phased array signals calculated using information obtained by processing training signals propagated on the reverse path, the training signals contained in the data or payload portion of the reverse path OFDM symbols, the signals propagated on the reverse path include substantially known signal sequences contained within a reverse path OFDM burst, the signal sequences longer in duration than the guard interval used in the OFDM signal sequence.

Additional information is provided in the attached copies of an engineering notebook and other figures, including a copy of a color JPEG image print out of a wall-mounted white board.

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FOIA b7 - Exempt from disclosure

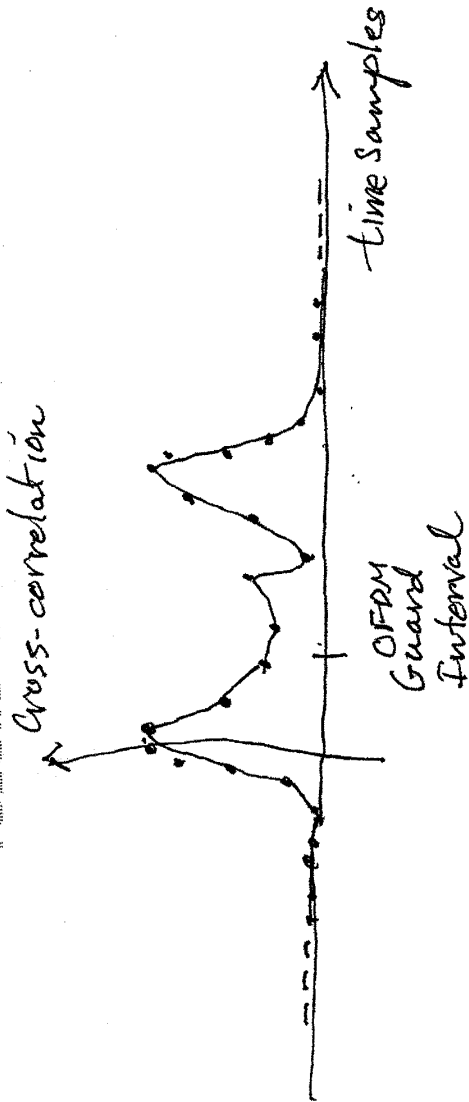
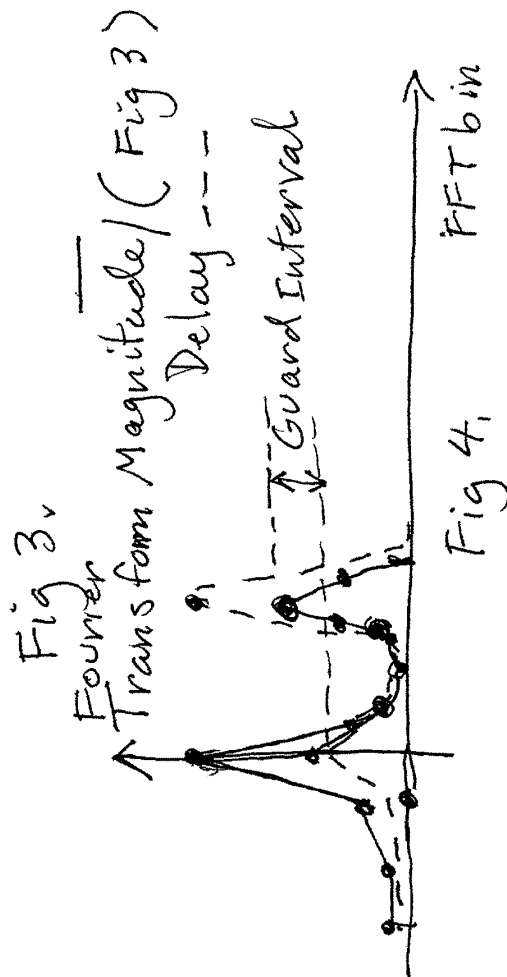


Fig 2.

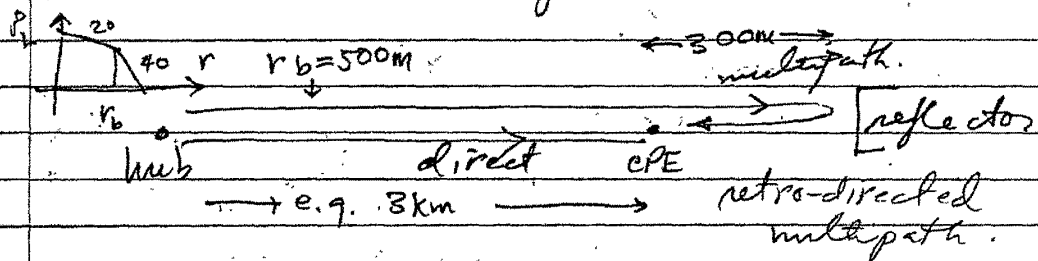
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Multipath in hot spots

Assume a directive antenna illuminates a region as described on page 45. Multipath delay spread will maximize as shown in the calculations, with an exception for retro-directed multipath.



This multipath may exceed the requirements of a particular PHY, e.g. Guard Interval of 800ns in 802.11a.

In these cases, antenna directivity cannot combat the multipath, and only propagation path loss helps.

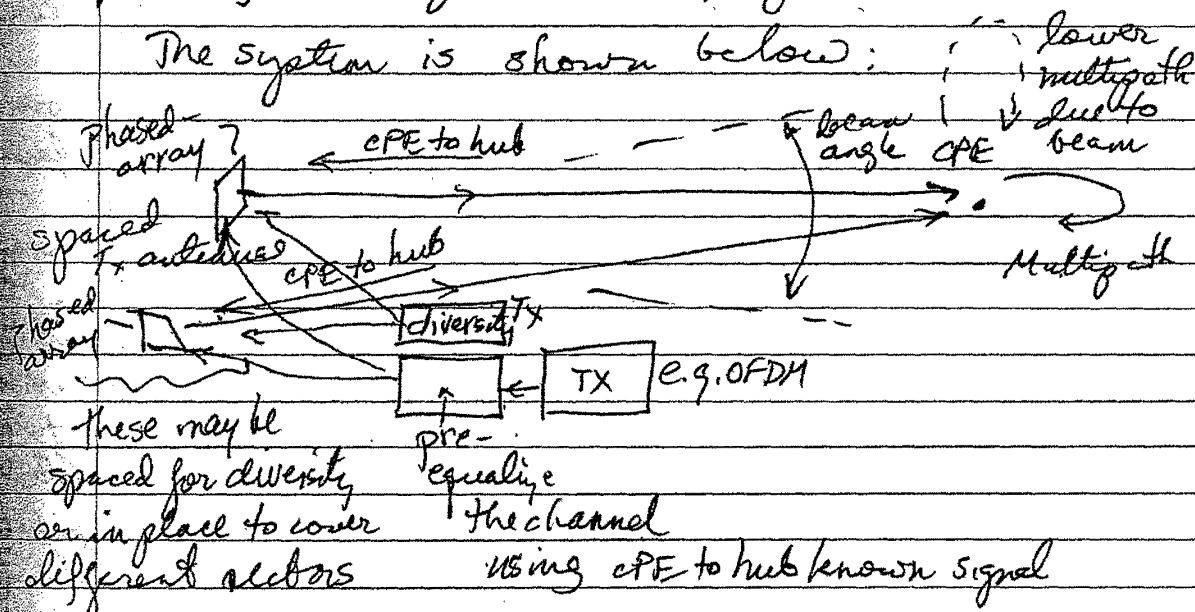
Using a 2-4 Power law w/ $r_b = 500m$ (breakpoint 2-4 power on propagation) The path loss to the reflector (located 300m past desired CPE) is only 1dB higher than P.L. to CPE. If the reflector is larger than one Fresnel zone and adequately illuminated, resulting in near specular reflection, only a few dB in signal level difference exists. Therefore, multipath delay beyond the specified level occurs.

To combat this effect, some channel equalization is required. A combination of narrow beamwidth, TX diversity and

channel equalization (on the TX side) produces a robust channel capable of providing a reliable link to nonadmic CPE.

The assumption is made that the CPE contains a single antenna, and that moving the CPE to optimize the signal is not preferred.

The system is shown below:



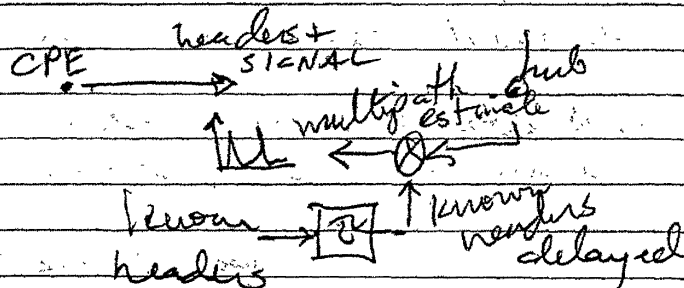
The means to combat overall multipath are as follows:

- 1) flat fade due to local diffraction, etc. - T_x Diversity
- 2) retro-directed multipath - pre-equalize
- 3) side-multipath - narrow beam angle.

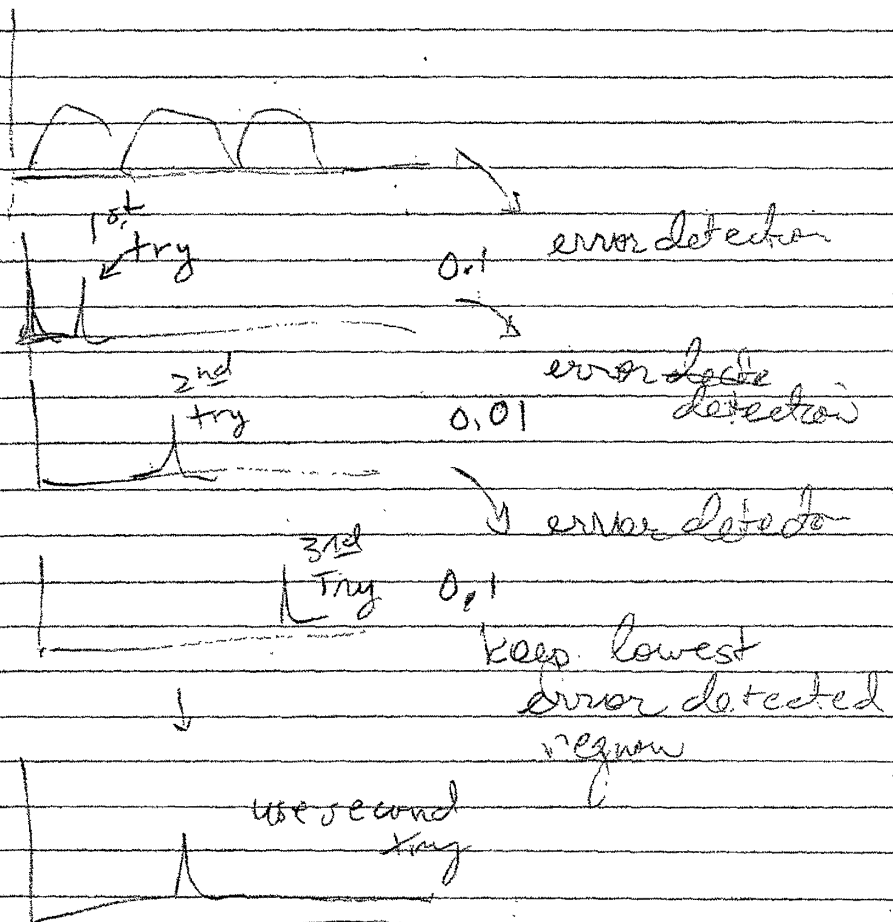
The combination of all three techniques provides robust performance to a single antenna CPE.

Equalization Technique for System on pages 46-47

It is likely that reverse link bursts transmitted to the hub will be below the noise level in the full bandwidth of the system. However, header signals e.g. SIGNAL and pre-SIGNAL header in 802.11a will be detectable at lower levels. The cross-correlation of the known header with ~~known~~ signals received on the two sub channels allow a lower sensitivity detection. This detection is necessary so equalization of the channel and diversity combining may take place. An OFDM signal for example 802.11a may be detected at a lower level by searching cross-correlation with a known PLOT tone sequence. If fewer pilots are transmitted power may be concentrated in the pilots if regulatory limits are not exceeded. The benefit of the cross-correlation of known headers is to reduce the effective bandwidth essentially establishing an effect similar to a rake receiver receiving a direct sequence waveform.

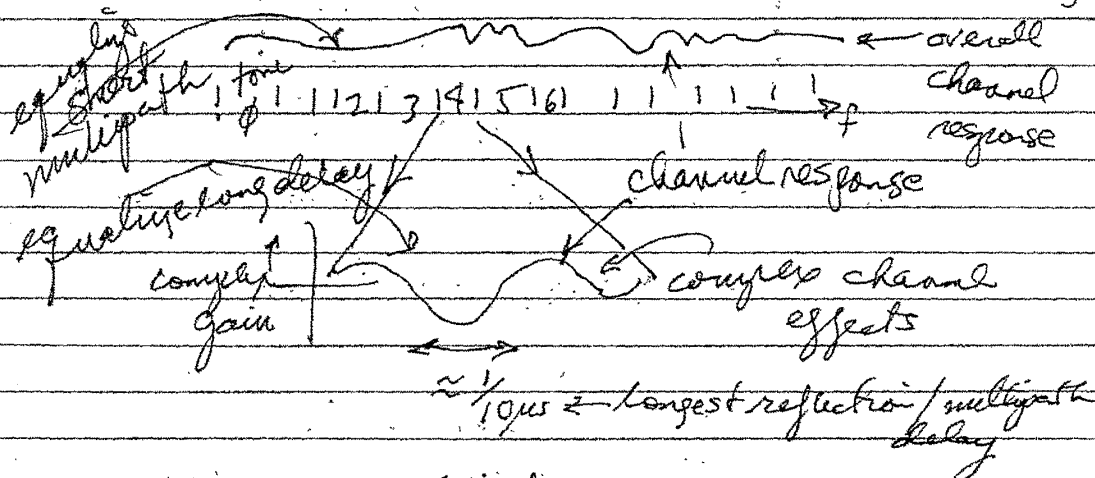


This aliasing may be dealt with by estimating on which aliased set signal set the delay potentially exists, and transmitting pre-equalized signals to combat that multipath. Subsequent attempts on other aliased signal sets (or regions) with error detection can establish the correct aliased region to apply the pre-equalized signal.



Pre-equalization Example

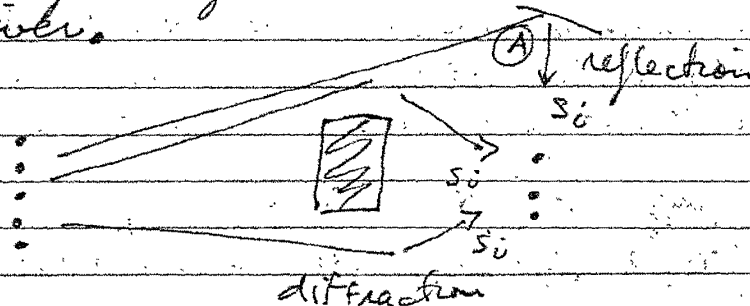
As an example of the "known headers" described on page 48, the 802.11a short & long sequences totalling a duration of 8 μ s may be used to ascertain delay spread to approximately 8 μ s delay. The known sequences have sufficient low frequency energy per burst (low $\approx$ 100 kHz $\sim$ 125 kHz $\sim$ 1/8 μ s resolution) to determine fine variations in the complex channel response. Graphically,



Normally, conventional OFDM systems rely on the guard interval to eliminate multipath effects during the transmission of the tone in the OFDM signal. Longer delay requires longer guard interval. The technique shown here uses the long & short sequences to perform channel estimation, and decision feedback equalization following the header, to equalize the channel for delays much greater than $1/\Delta f$, where Δf is the subcarrier (in OFDM) spacing. Reciprocity allows the TX to use the channel values determined on the reverse link.

Bandwidth allocation per multipath

Generally spatial or scatter multiplexing techniques re-use a band of frequencies and establish separate concentrated paths for signals from the transmitter to the receiver.



Shannon's Capacity Theorem states:

$$C = W_i \left(\log_2 \left(1 + \frac{S_i}{N_0 W_i} \right) \right)$$

where W = channel bandwidth

S = average power

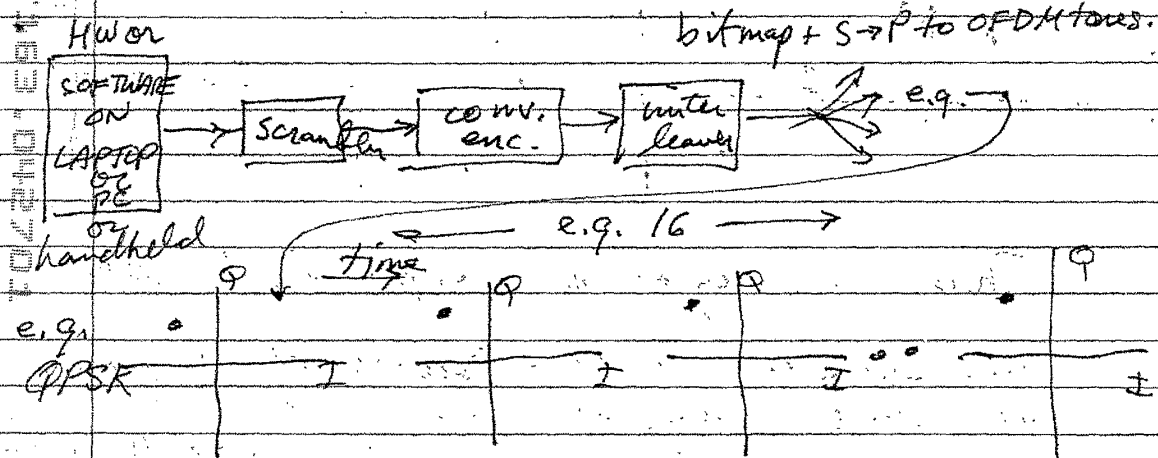
N_0 = spectral power density of the noise

In some cases it is preferable to use a different W for each multipath shown above. For example, A is capable of potentially high bit rate due to $S_i/N_0 W_i$ being large. As S_i increases, the advantage gained by using higher-order modulation does not increase capacity as much as by increasing W_i to establish a constant $S_i/N_0 W_i$. Therefore W_i should be chosen to equalize $S_i/N_0 W_i$ for each path, or approximately so.

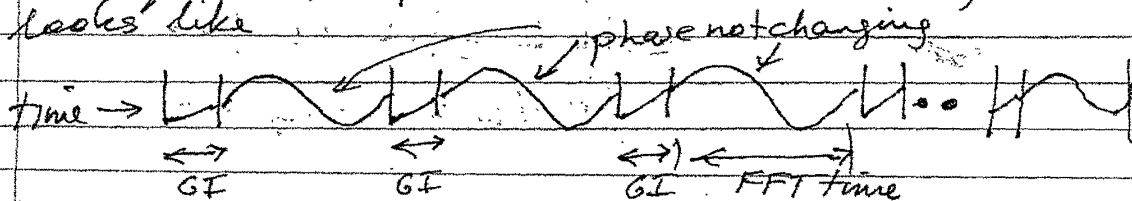
Low Bandwidth reverse link w/ existing 802.11a client devices.

It is possible to use an 802.11a on reverse link to the base station at a bit rate much less than the minimum 6 M bps in the standard. This is useful due to the low power of the CPE (compared to forward link 1 Watt), and allows a slower speed reverse link to work, when a 6 M bps link would not work, due to shadow fading or otherwise poor link budget.

The system works by "backing out" the effect of the interleaver, FEC convolutional coder, and scrambler, as shown below:



Set the software on laptop etc. to force a constant phase shift, e.g. QPSK symbol over a long number of OFDM symbols, e.g. 16. In the time domain, this looks like



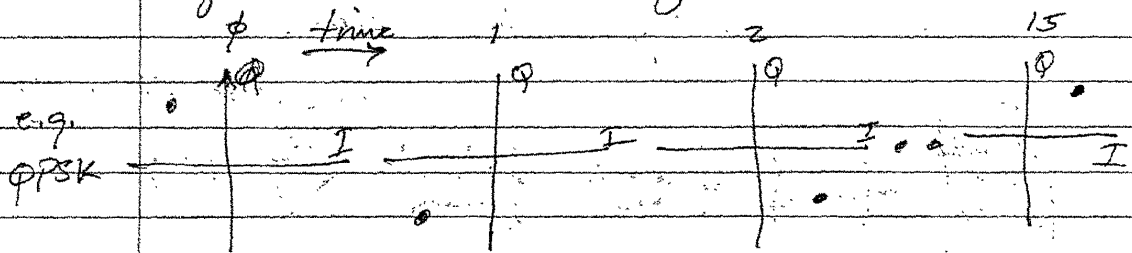
In the receiver, the guard interval is removed, and a long FFT is performed on the compressed time (6T removed) interval.

FFT length e.g. maybe $16 \times 64 = 1024$ pt. the bandwidth per bin is $1/16$ of the 64 pt FFT, resulting in an

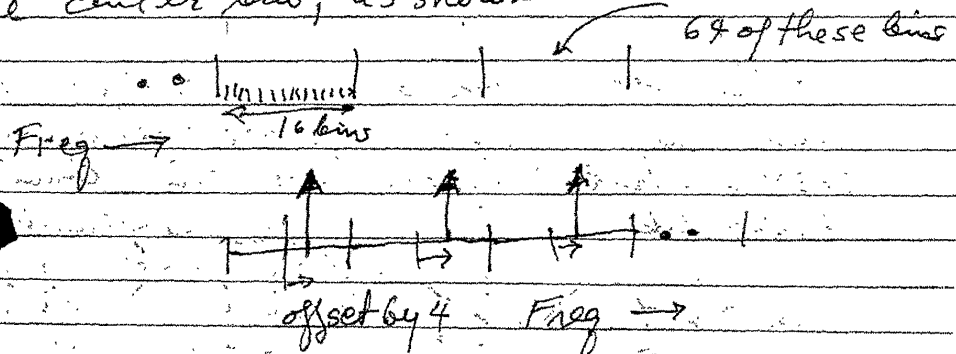
SNR improvement of 16, $10 \log 16 = 12.04 \text{ dB}$.

The system maybe used with any OFDM modulated client device.

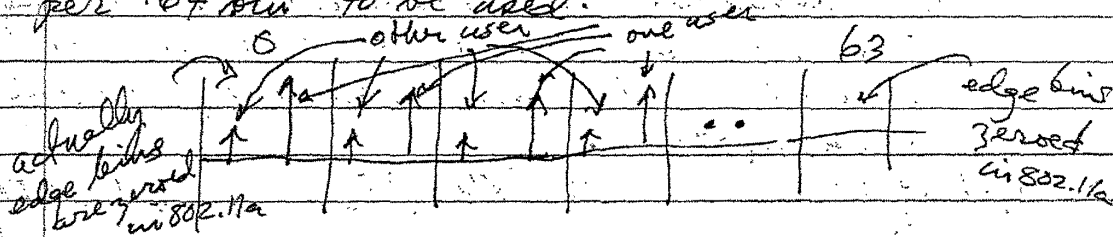
By allowing a slow phase rotation during the 16 symbol interval, OFDMA may be implemented. For example:



Thus, this signal will appear in the bin corresponding to one-fourth offset from the "center bin, as shown



Thus more than one reverse link may be present at a time, improving reverse link capacity. If QAM modulation is used, as opposed to QPSK, slower phase rotation may be made, allowing more of the ± 16 bins per "64 bin" to be used.



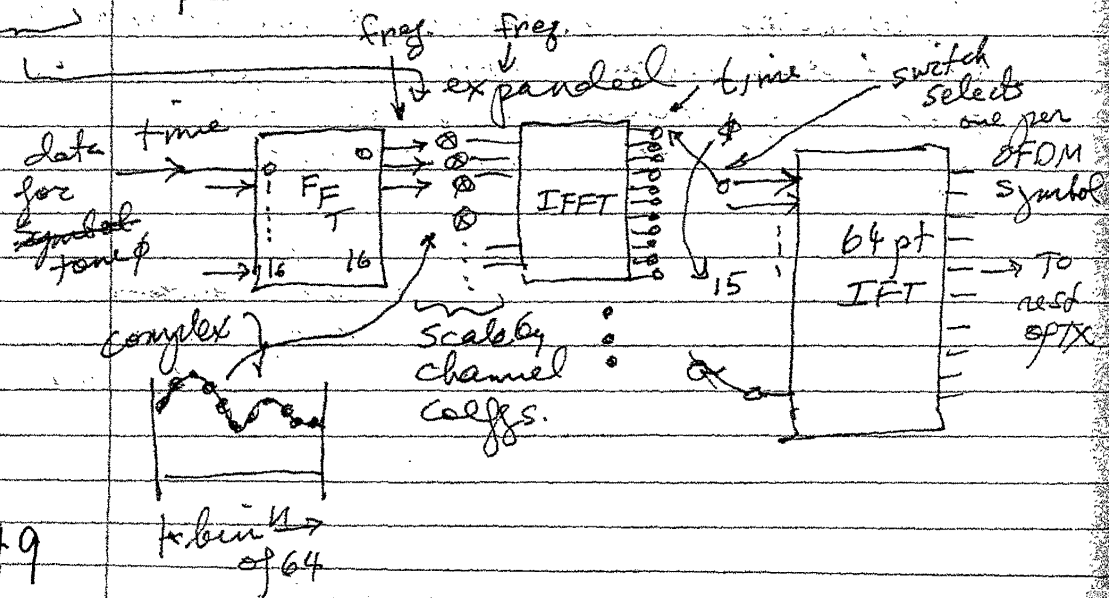
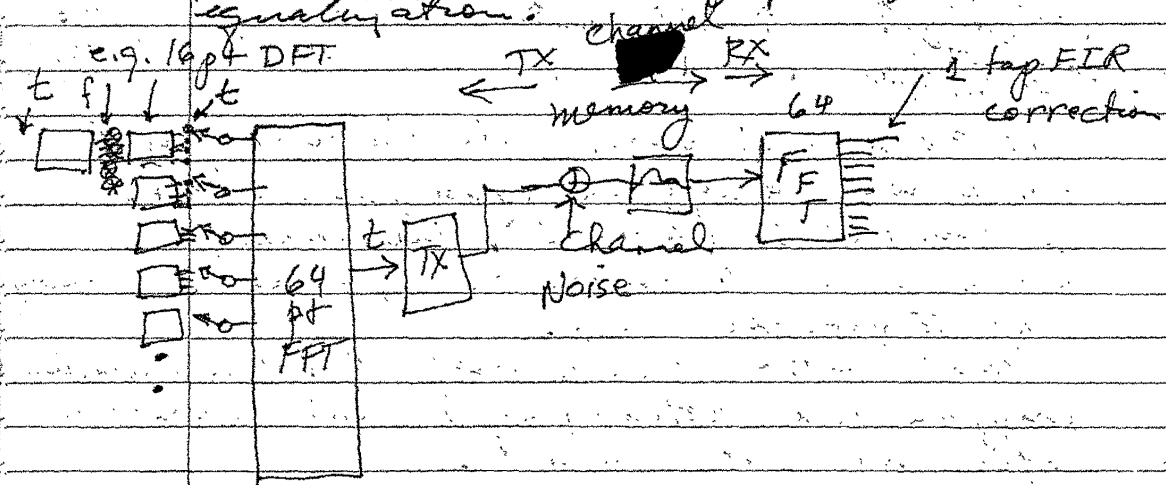
The data is encoded onto the tones, in the usual way, a different phase, angle, (QAM) per tone (of the 64 tones). This coding is performed in the laptop SW, preferably assembly code to provide speed.

Power control of each user, QAM modulation mapping and virtually all "normal" operation of the modulation results.

This allows us to deploy 802.11a client devices and subsequently provide infrastructure capable of receiving the weak reverse link signals from the client devices.

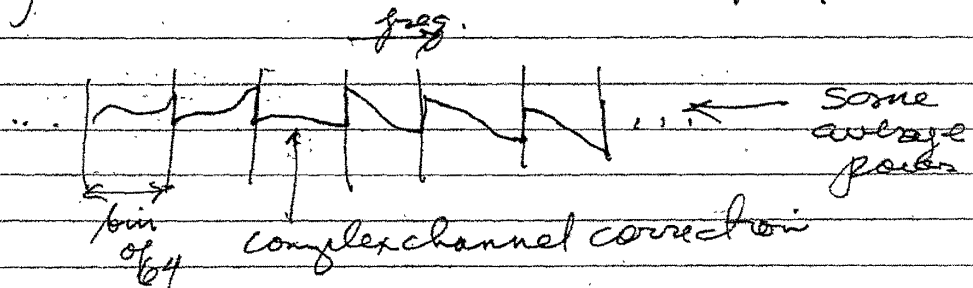
Equalization Techniques

The system shown on page 48-50 may be improved using a freq domain equalizer as described in IEEE Jan 2001 Issue of Transactions on Communications. A longer than 64 (for 802.11g) FFT is used to provide sub-band frequency domain equalization.

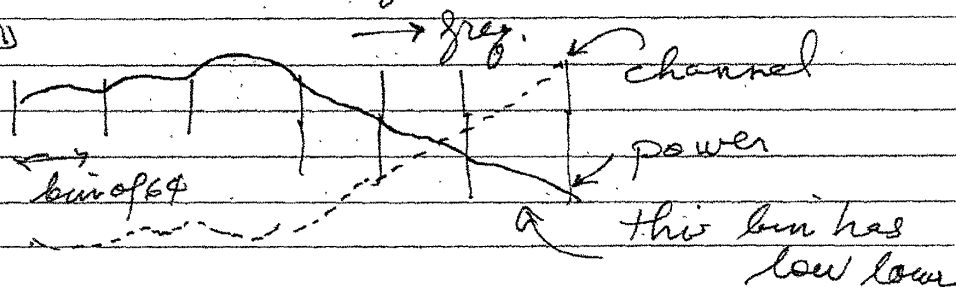


In the article, the freq. domain processing for the sub-band equalizer is performed in the receiver. In the system shown lower page 56, the sub-band processing is performed in the transmitter, with Guard interval and other 1st FIR correction performed in the Rx.

Another aspect of the system is that power may be set to be equal in each of the sub-bands, allowing FCC rules and other spectral specifications to be met. For example:



In other overall Tx pre-equalization schemes, the power will not be flat over the spectrum. E.g.

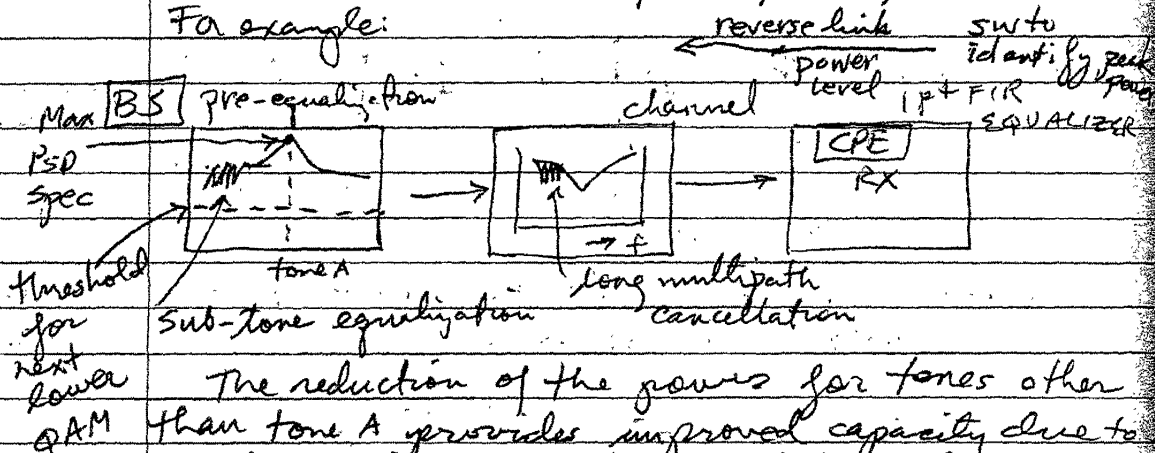


So separation of equalization to Tx from Rx is important.

Addition to provide minimum power (spectral power density) transmission

On page 57, the power in each sub carrier is held constant. A modification to the system involves the determination of a worst case path loss over the OFDM ~~tones~~ ^{tones type} and the use of the highest allowed power spectral density for that ~~some~~ sub-channel, then reducing the PSD for other tones, allowing the other tones to sustain the same level of QAM, QPSK, BPSK.

For example:



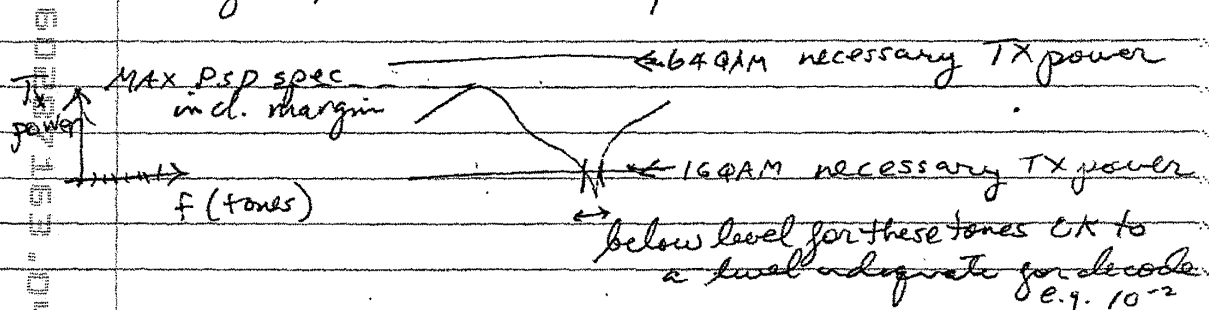
The reduction of the power for tones other than tone A provides improved capacity due to the lower interference generated, and allows the power amp to carry additional channels for the same PEP level.

The channel is determined through reciprocal measurement.

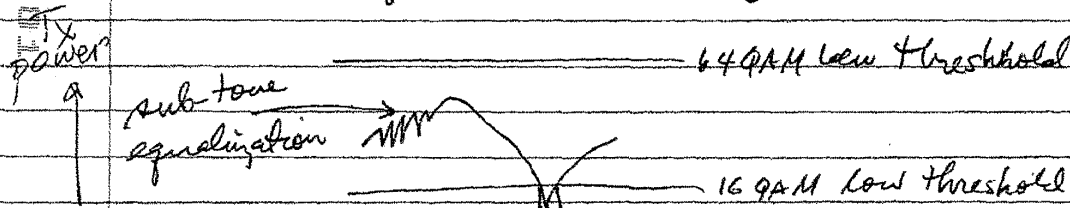
The determination of the necessary PSD to establish a level of QAM is determined by a path loss estimation and the knowledge of the reverse link power level transmitted on the reverse link by software running on the CPE or transceiver interfaced computer.

The system works as follows:

- Reverse link established
- info. regarding reverse link power level is sent to B.S. (RX NF may also be included)
- reciprocal path loss measurement is made at BS
- link budget for a particular QAM level is determined.
- Variation in channel path loss used to set min-max power levels for a particular single QAM level - e.g. 16 QAM



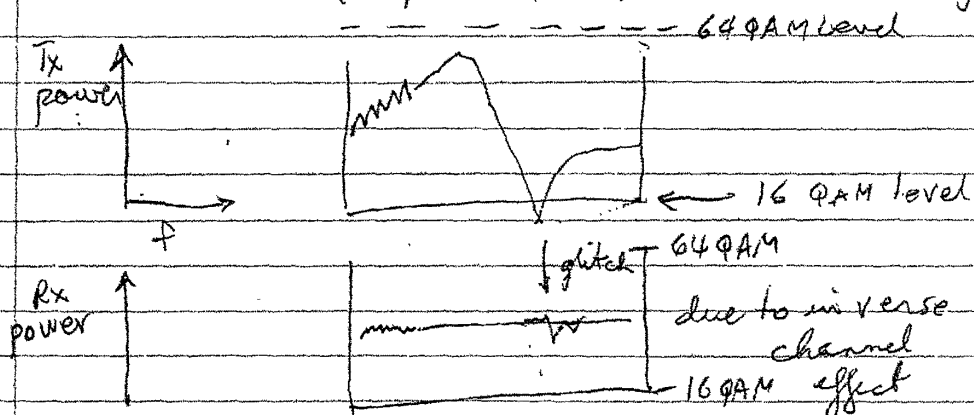
- sub-tone equalization is performed at TX



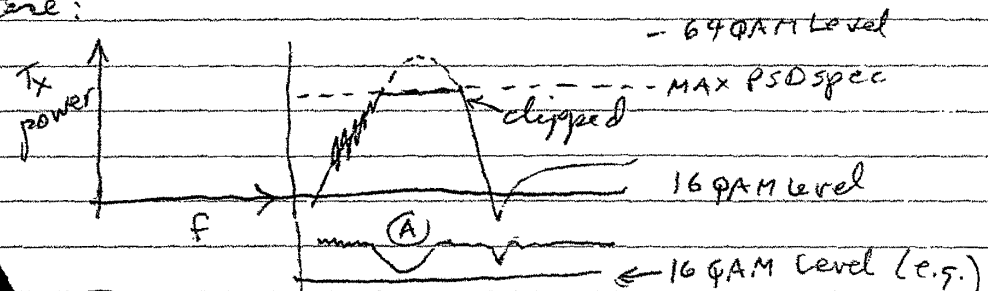
- signal is transmitted to CPE.
- CPE performs single point FIR equalization to decode 16-QAM tones
- decoder corrects the errors caused by the tones below the 16 QAM threshold.

Tx power below level required
What to do in this case

As shown on the previous page, some channel conditions will result in less power required than a minimum (e.g. 16 QAM) level. For example:



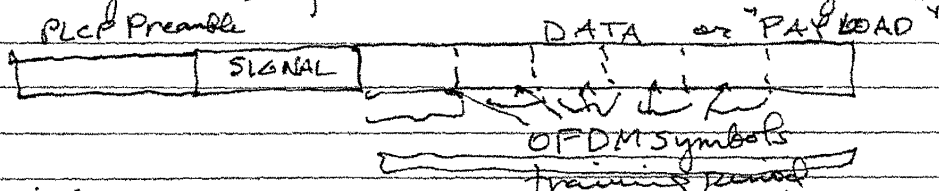
Therefore the 10^{-2} error rate discussed on page 59 is irrelevant. What is relevant is the following case:



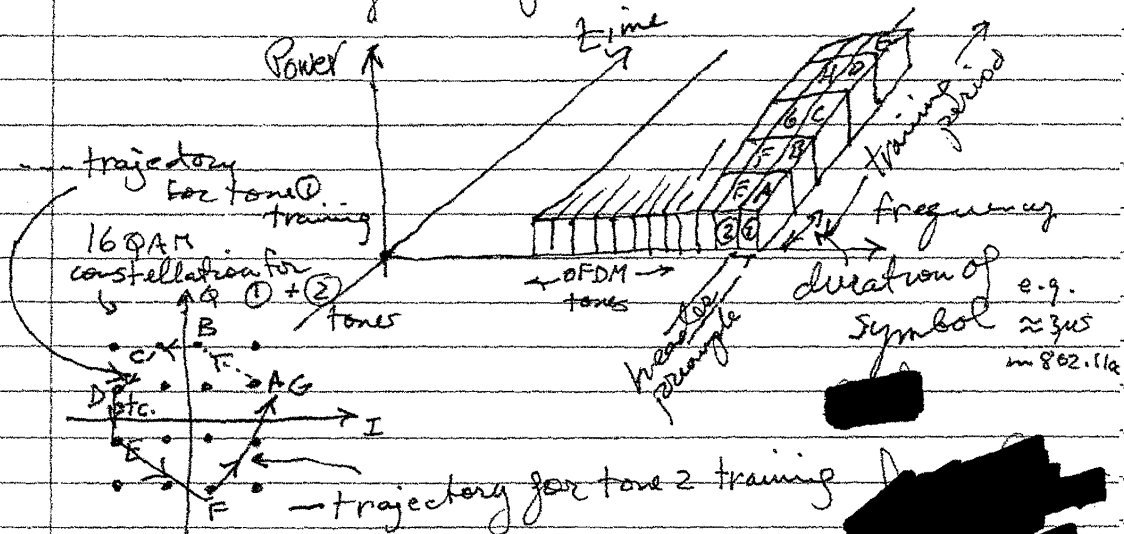
Power needs to be clipped at MAX PSD spec. The 1pt FIR in the Rx removes the clip @ (A), and 16 QAM is supported if the clip does not reach the 16 QAM minimum threshold. If the threshold is passed, then FEC must be used to reduce errors.

Data or Payload contained training sequence

The reverse-link training sequences needed to calculate equalization parameters in the pre-equalized transmitter are contained in the data or payload portion of the physical layer protocol data unit. For example: in 802.11a the Physical layer PDU contains the following



Training sequences are contained in the DATA portion of the frame, and generally will span more than one OFDM symbol without repetition. Looking in the time domain at a waterfall representation:



Problem

We are trying to increase capacity while simultaneously reducing interference. How can antennas help us?

Key to items:

- blue Customer Premises Equipment
- red CPE
- Red Interfered by blue TX antenna

Improving U-NII band point-to-point performance

Mobility Networks Confidential

CPE Received Level

$P_{R\>B} = \frac{P_{T\>B}}{A_R} \cdot \frac{A_R}{4\pi R^2}$

$A_R = \frac{\lambda^2}{4\pi}$

2. in what area?

$A_R = \frac{4\pi R^2}{\lambda^2}$

$A_R = \frac{4\pi \cdot 2500}{\lambda^2}$

$A_R = \frac{4\pi \cdot 2500}{(0.3)^2}$

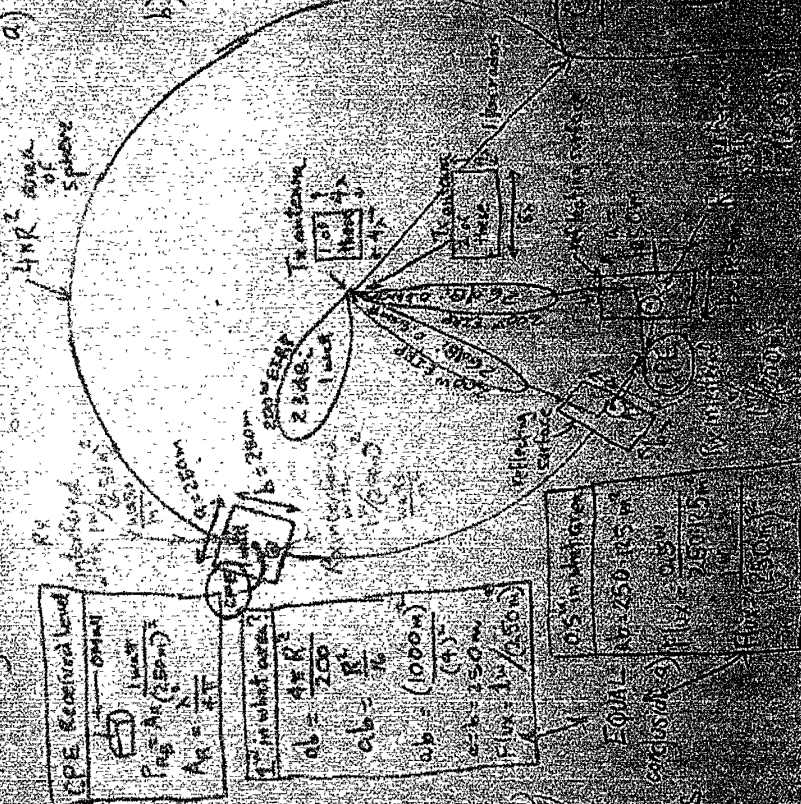
$A_R = 10000$

$A_R = 10000$

$A_R = 10000$

$A_R = 10000$

$A_R = 10000$



Conclusions

- The pairs of (two each) GREEN Receivers are interfered equally by Blue TX and Red dual-beam TX.
- The Red CPE receives 4x power level as compared to the Blue CPE.

c) Due to b), the Red dual-beam TX transmits for less time than Blue TX.

$P_{R\>B} = \frac{P_{T\>B}}{A_R} \cdot \frac{A_R}{4\pi R^2}$

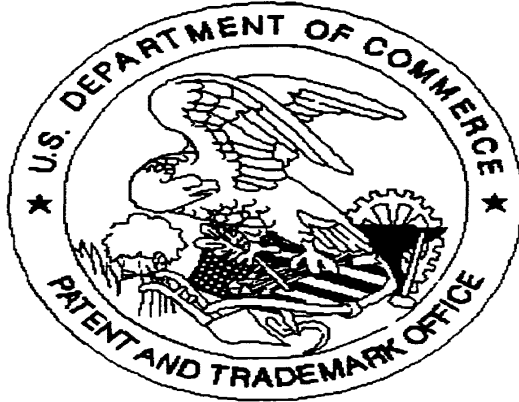
$P_{R\>B} = \frac{P_{T\>B}}{A_R} \cdot \frac{A_R}{4\pi R^2}$

$P_{R\>B} = \frac{P_{T\>B}}{A_R} \cdot \frac{A_R}{4\pi R^2}$

$P_{R\>B} = \frac{P_{T\>B}}{A_R} \cdot \frac{A_R}{4\pi R^2}$

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☒ Page(s) 42 of Miscellaneous were not present
for scanning. (Document title)

☒ Scanned copy is best available. *Drawings.*