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DAYANANDA SAGAR COLLEGE OF ENGINEERING

(An Autonomous Institute Affiliated to VTU, Belagavi)

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Department of Telecommunication Engineering

Online Continuous Internal Assessment Test - III

Course: **MIMO Communication**
Course Code: **TE814**
Semester: **VIII 'A' &'B'**

Date: 21/05/2020
Maximum marks: **50**
Duration: **90 Min**

	Note: Answer 5 full questions.	Marks
1.(a)	Concatenated codes are ---- --- i) Compression Code ii)error-correcting codes iii)Source Code iv) none	1x10
(b)	Concatenated codes are constructed from----------Codes i) 2 or more ii) single code iii) hundreds of iv) none	
(c)	Reed–Solomon (RS) code which is the inner code in the concatenation code has a powerful ______ i) Error correction capability ii) Error detection capability iii) Both A & B iv) none of the these	
(d)	The --------- decoding principles have found widespread applications not only in error control, but in detection, interference suppression and equalization. i) Reed Solomon Code ii) BCH Code iii) Hamming Code iv) Turbo Code	
(e)	--------is the process of removing some of the parity bits after encoding with an error-correction code. i) puncturing ii) equalization iii) Source coding iv) decoding	
(f)	--------- is where the fading process is approximately constant for a number of symbol intervals. i) Block fading ii) Flat fading iii) FS fading iv) Rayleigh Fading	
(g)	The complexity of the STBC decoder is much_____ than that of the TuCM scheme and it is more ______. i) more, unstable ii) Less, stable iii) less, unstable iv) More stable	
(h)	Concatenated Coding for MIMO FS Channels the inner code is ______ i) Convolutional code ii) Reed–Solomon code iii) Frequency channel iv) None of these	
(i)	If we delay the transmitted signal of the first antenna by the number of ISI taps L instead of by a single symbol, if Nt is the number of transmitters, Nr is the number of receivers, then the diversity order is	

	i) NtNrL ii) NtNr(L-1) iii) NtNr iv) None of these	
(j)	The ------ algorithm is an algorithm for maximum a posteriori decoding of error correcting codes defined on trellises i) BCJR ii) Viterbi iii) MAP iv) Priori	
2	Evaluate Concatenated STBC with encoder and decoder with diagrams.	10
3	With tapped delay line model describe MIMO Frequency Selective Channels	10
4a	Design a Simple Full Diversity Code for MIMO FS Channels using the idea of delay diversity for the flat fading scenario	05
4b	Verify structures of SCCC and PCCC with differences.	05
	(OR)	
5a	Investigate on Turbo Space Time Trellis Coding Scheme.	05
5b	Design the encoder structure for Turbo Coded Modulation for MIMO channels, specifically, to simultaneously transmit *Nt* symbols from the available *Nt* transmit antennas, the mapper maps every set of *m* coded bits to one symbol from a signal constellation of size *2m*	05
6	With the input–output relationship of the MIMO FS channel, analyze the virtual antenna interpretation of transmission over MIMO FS channels	10
	(OR)	
7	Use the sub orthogonal carriers and DFT pairs, with block diagram describe the implement process of MIMO OFDM system	10

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Solution Scheme

CIE-III Date: 21-05-2020

Marks: 50 prepared by: Dr. Sayed Abdulhayan

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1. (a) — Error correcting code — (ii)

(b) — 2 or more — (i)

(c) — Both A & B — (iii)

(d) Turbo code — (iv)

(e) — puncturing — (i)

(f) — ~~Black~~ Block Fading — (i)

(g) Less, Stable — (ii)

(h) ~~Convolution~~ Frequency Channel. convolution — (i)

(i) $N_t N_r (L-1)$ — (ii)

(j) BCJR — (i)

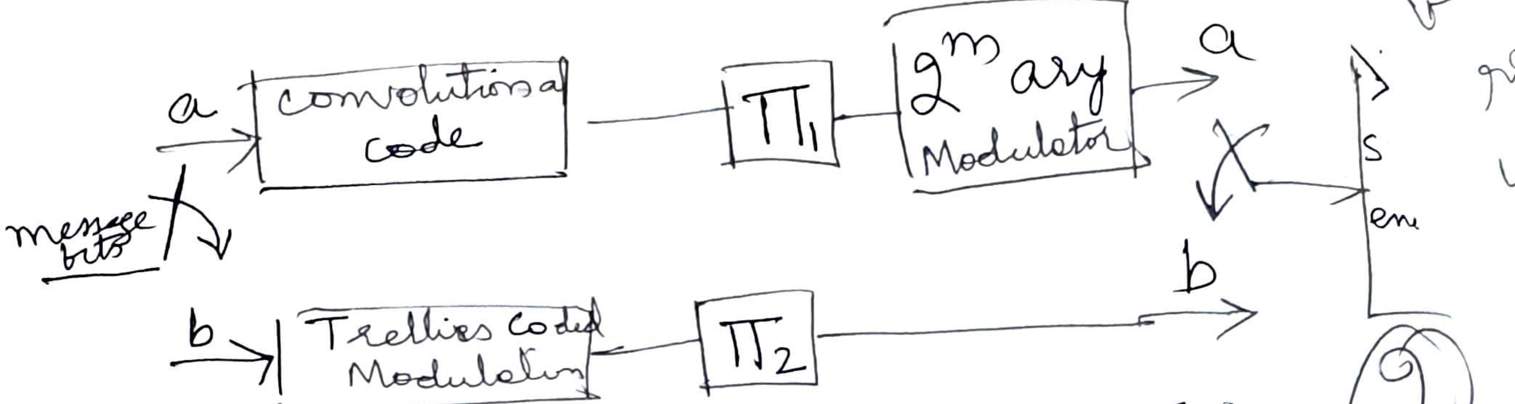
$\boxed{1 \times 10}$

Q2. Concatenated STBC Encoder/Decoder

Here we are concatenating an outer channel code and inner orthogonal STBC, hence STBC (inner code) will replace the Mapper.

(a) STBC Encoder

Primitive data stream is first encoded by an outer channel encoder.



encoder of concatenated STBC 2

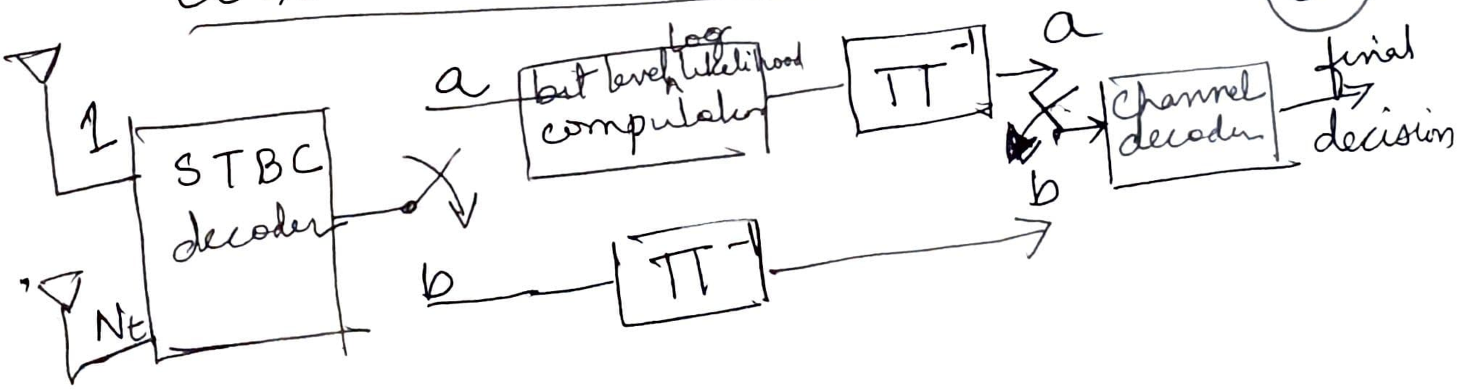
There is no restriction on type of channel code employed for outer coder.

The coded sequence is interleaved and Multiplexed. Each set of m bits at the output of the demultiplexer is mapped onto a symbol of 2^m ary signal constellation.

The output of modulator is ~~feed~~ then fed into STBC encoder which groups every Nt consecutive symbols and transmits them from the available Nt antennas. Transmission Rate acheived is $R = mR_c \Rightarrow m = m$ bits mapped into symbol

$R_c \Rightarrow$ rate of outer channel code 3

Concatenated STBC decoder 2



STBC

x]. When switch is in position 'a' the resulting decoder corresponds to convolution coded system. For this case output of STBC decoder is fed into the bit loglikelihood computation module. The output of this is then deinterleaved and passed to the channel decoder.

When switch is in 'b' position the resulting decoder corresponds to the TCM coded system. Here decoupled symbols at output of STBC decoder is deinterleaved and passed to channel decoder which is Viterbi decoder.

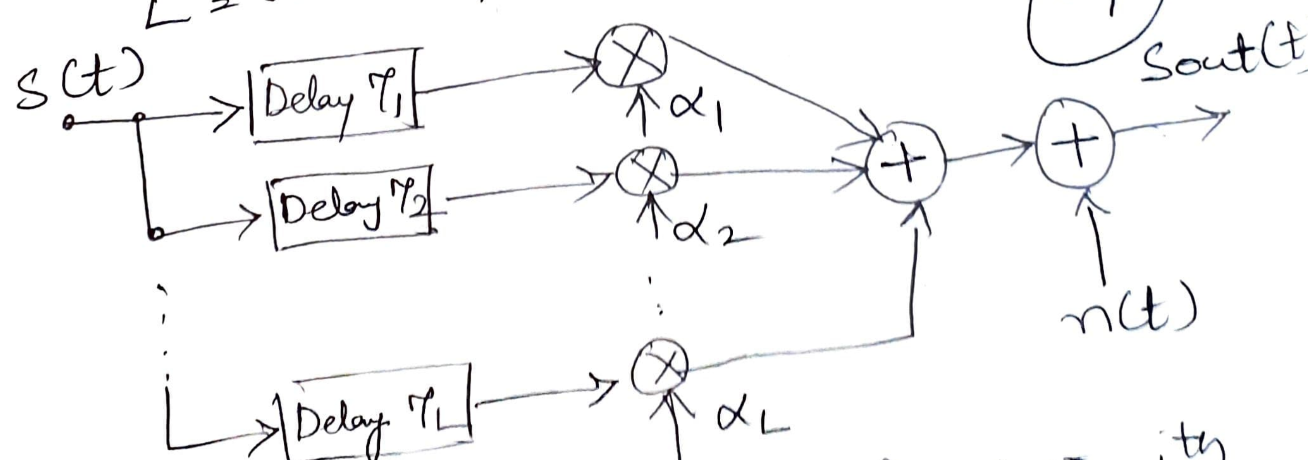
3

Q3. Tapped delay Line Model for MIMO FS Channel

N_t = transmit antenna Num N_r = Receive antenna number

L = ISI tap.

4



y) The Received signal at the j^{th} receive antenna at time k is given by

3

$$y_j(k) = \sqrt{\rho} \sum_{l=0}^{L-1} \sum_{i=1}^{N_t} h_{ij}^{(l)}(k)\, x_i(k-l) + n_j(k)$$

l = number of paths between Tx & Rx

$x_i(k) \rightarrow$ transmitted signal from i^{th} antenna at time (k)

$h(l)_{i,j}(k) \rightarrow$ channel coefficient for l^{th} path from transmit antenna i^{th} receive antenna j at time (k)

$n_j(k)$ — AWGN with variance $1/2$

Different channel taps are usually assumed to be independent. The average channel gains for different paths are determined from the power delay profile of wireless channel.

3

For uniform power delay profile all channel gains for different paths have equal average channel power. For exponential power delay profile the channel tap powers decay exponentially

Q4. Simple full diversity code for MIMO FS of delay diversity for flat fading.

1

N_t = transmit antenna numbers

For N_t, a delay diversity code is obtained by simply transmitting delayed versions of the sequence on the first transmit antenna from the other antennas. i.e

For this method space time codewords are of the forms.

$$
\begin{bmatrix}
x(1) & 0 & 0 & \cdots & 0 \\
x(2) & x(1) & & & \\
x(3) & x(2) & x(1) & & \\
x(N_t) & x(N_t-1) & x(N_t-2) & \cdots & x(1) \\
x(N_t+1) & x(N_t) & x(N_t-1) & \cdots & x(2) \\
\vdots & & \vdots & & \\
x(N) & x(N-1) & x(N-2) & & x(N-N_t+1)
\end{bmatrix}
$$

Therefore the codeword difference matrices will ~~be~~ clearly be full column rank if a distinct pair of codewords are considered. Hence delay diversity will achieve a full rank of $N_t N_r$ over flat fading.

2

It is easy to see that delaying by single symbol for each transmit antenna will not work, because some columns of the equivalent ST codeword matrix will be identicals, hence the code will ~~be~~ not be of full rank.

1

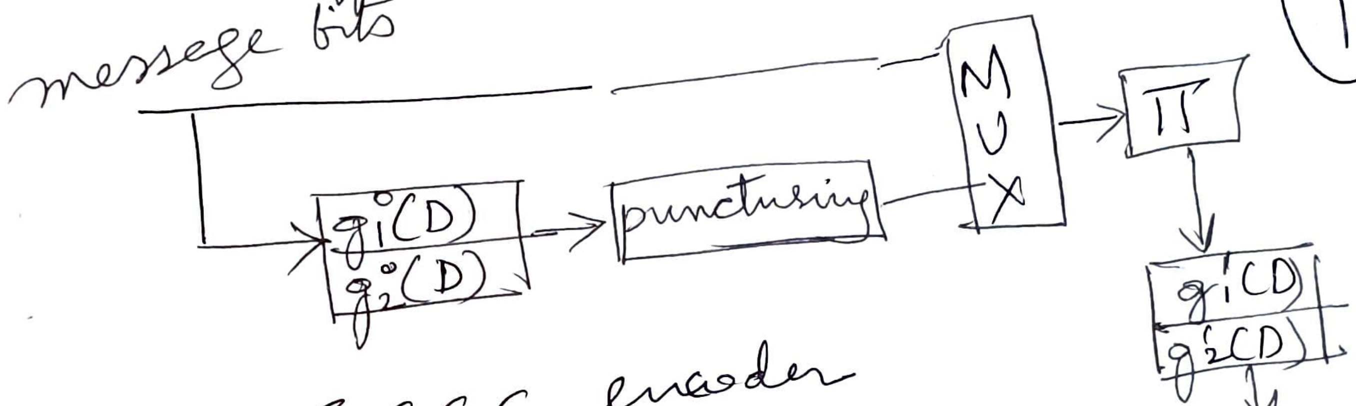
We obtain equivalent Space time codeword

$$
\begin{bmatrix}
x(1) & 0 & 0 & \cdots & 0 \\
x(2) & x(1) & 0 & \cdots & 0 \\
x(3) & x(2) & x(1) & \cdots & 0 \\
\vdots & & & & \\
x(N_tL) & x(N_tL-1) & x(N_tL-2) & \cdots & x(1) \\
x(N_tL+1) & x(N_tL) & x(N_tL-1) & \cdots & x(2) \\
 & & & & \\
x(N) & x(N-1) & x(N-2 & \cdots & x(N-N_tL+1)
\end{bmatrix}
$$

if we delay the transmitted signal of the first antenna by the number of ISI taps L instead of by a single symbol. Hence it provides diversity model order of $N_t N_r L$

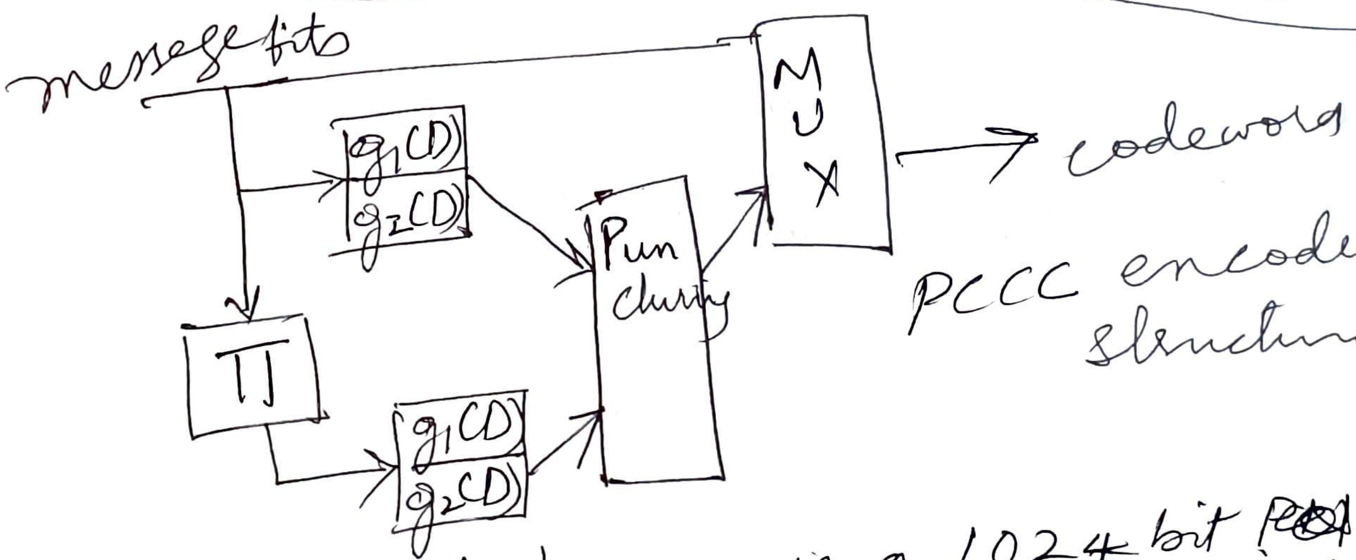
1

Q4b Structure of SCCC & PCCC with differences



1

SCCC encoder



1

PCCC encoder structure

PCCC interleaver is a 1024 bit ~~PRN~~ PRN interleaver with no constraints added.

SCCC interleaver is a 1152 bit PRN interleaver with no constraints added.

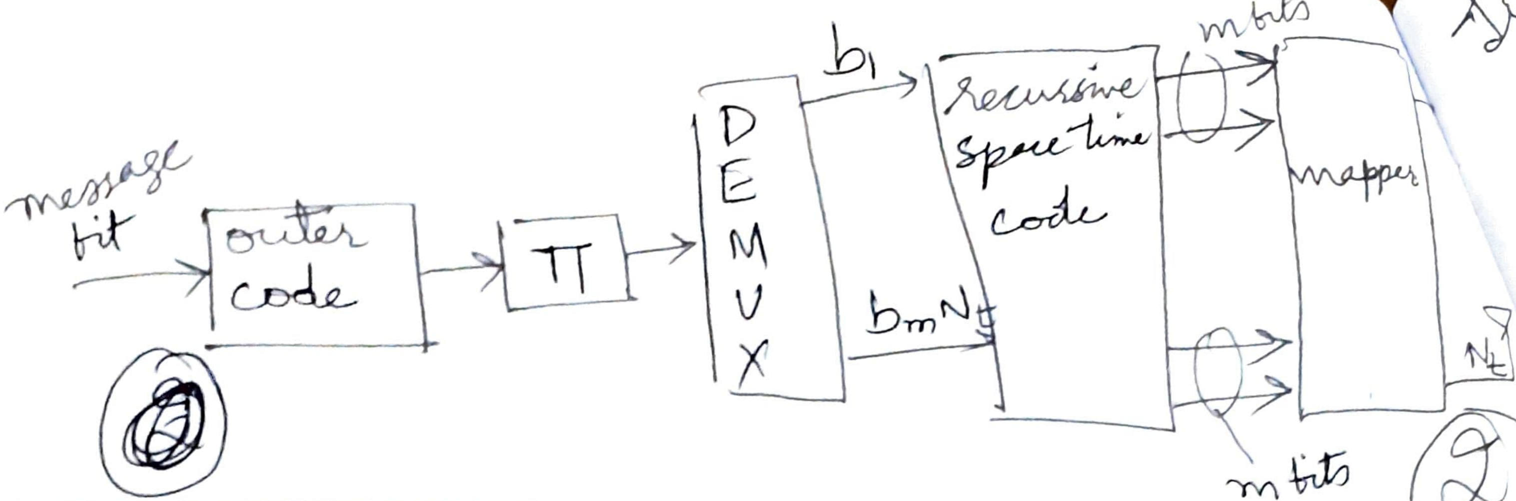
→ PCCC design consist of two convolution encoders which are joined in parallel but one of them accepts the same primary data through an interleaver
→ PCCC is complex
→ SCCC are a class of FEC highly suitable for turbo decoding. The recursive inner code provides the interleaver gain
→ SCCC is simple than PCCC.

3

Q 5 (a). Turbo Space time Trellis Coding Scheme

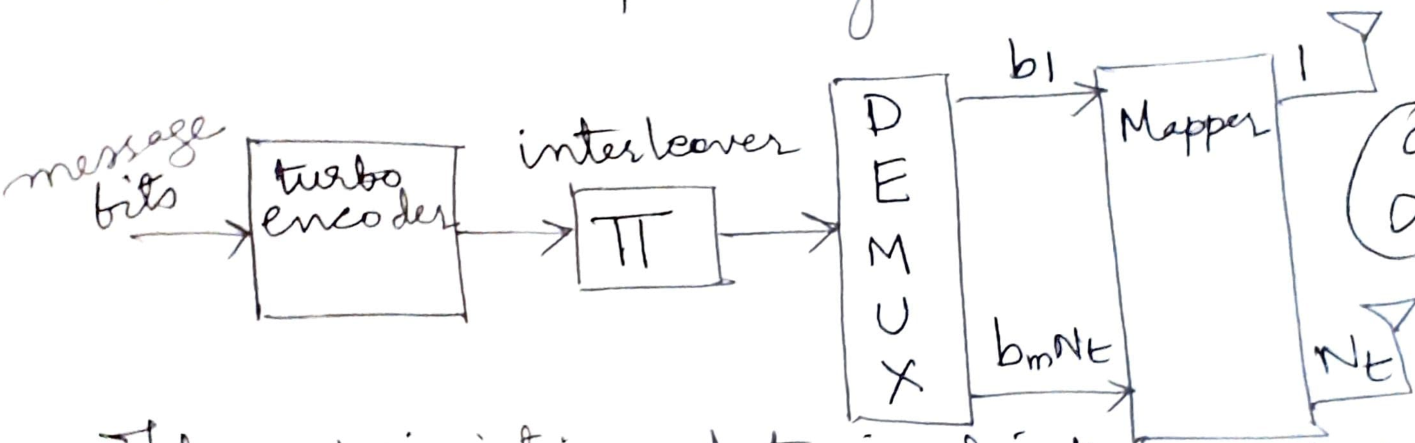
The outer code is a binary code whereas the inner code is a recursive STTC. The recursive nature of the inner code enhances the overall minimum Hamming distance of the combined code, thereby improving the available diversity. It is easy to design full diversity (Full Rank) Non recursive full diversity can be easily transformed into a recursive full Rank Code. However this does not achieve full rank because of presence of outer code. This concatenated scheme is decoded iteratively where the front end generates log likelihoods for the mN_t bits which are deinterleaved and passed to the outer decoder.

3



5b. Encoder for Turbo Coded Modulation for MIMO

Here involves the serial concatenation of a turbo code and a mapper with an interleaver separating them.



The primitive data is first encoded by a turbo encoder. The turbo coded ~~encoder~~ sequence is interleaved so that the bursts of errors resulting from deep fades are distributed. The interleaved sequence is demultiplexed into number of parallel substreams. We assume there are mN_t substreams. The mN_t substreams are fed into a mapper. The function of mapper is to map the incoming bits to a particular signal constellation.

To simultaneously transmit N_t symbols from available N_t transmit antennas the mapper, maps every set of m coded bits to one symbol from a signal constellation of size 2m.

Q6 Virtual antenna Interpretation of transmission over MIMO FS channel.

Assume Space time codeword length is N and additional L−1 zeros are appended ~~and~~ at the end of each codeword. to clear the channel. The input-output relationship of the MIMO FS channel can be written as

2

$$Y = \sqrt{P}\, X_{eq} H_{eq} + N$$

where the equivalent space time codeword transmitted is an $(N+L-1) \times N_t$

3

→ $Y = (N+L-1) \times N_r$ } matrices
→ $N = (N+L-1) \times N_r$
→ $X = (N+L-1) \times N_t$ → matrix
→ X_{eq} = equivalent space time code matrix

1.5

$$X_{eq} = \begin{bmatrix} x_1(1) & 0 & 0 \cdots x_{N_t}(1) & 0 & 0 & \cdots 0 \\ x_1(2) & x_1(1) & 0 \cdots x_{N_t}(2) & x_{N_t}(1) & & \\ \vdots & & & & & \\ x_1(N) & x_1(N-1) & 0 \cdots x_{N_t}(N) & x_{N_t}(N-1) & \cdots & 0 \\ \vdots & \vdots & \vdots & & & \\ & & & & & x_{N_t}(1) \\ 0 & 0 & \cdots x_1(1) & & & \end{bmatrix}$$

$$H_{eq} = \begin{bmatrix} h^0_{11} & h^0_{12} \cdots & h^0_{1N_r} \\ h^1_{11} & h^1_{12} & h^1_{1N_r} \\ \vdots & & \\ h^{L-1}_{11} & h^{L-1}_{12} & h^{L-1}_{1N_r} \\ h^0_{21} & h^0_{22} & h^0_{2N_r} \\ h^1_{21} & h^1_{22} & h^1_{2N_r} \\ \vdots & & \\ h^{L-1}_{N_t,1} & h^{L-1}_{N_t,1} & h^{L-1}_{N_t,1} \end{bmatrix}$$

1.5

By examing X_{eq} we have $L-1$ additional virtual antennas corresponding to each actual transmit antenna that emits delayed versions of transmitted sequence

2

Q7. MIMO OFDM System using sub orthogonal carriers and DFT pairs.

To avoid complex signal processing algorithms we employ multi carrier transmission used in same frequency band. The overall available bandwidth W is split into N frequency subbands (W/N = Bandwidth) so that each subband experiences flat fading

1

The symbol duration on each multicarrier component is $\simeq N/W$ which can be made much larger than the multipath spread of the channel, hence the subchannels do not experience ISI.

The overall transmission rate is still $\sim N \cdot W/N = W$ symbols per second i.e. the same as the original single carrier system..

~~A~~ scan To achieve multi carrier modulation we employ orthogonal sub-carriers that are seperated by $1/T_s$ Hz where T_s is the symbol duration. and use DFT pair for implementation. The idea is to obtain N-point inverse DFT or IFFT of data sequence of N sub carriers.

At receiver the DFT/FFT is applied and standard receiver algorithms are used.

2

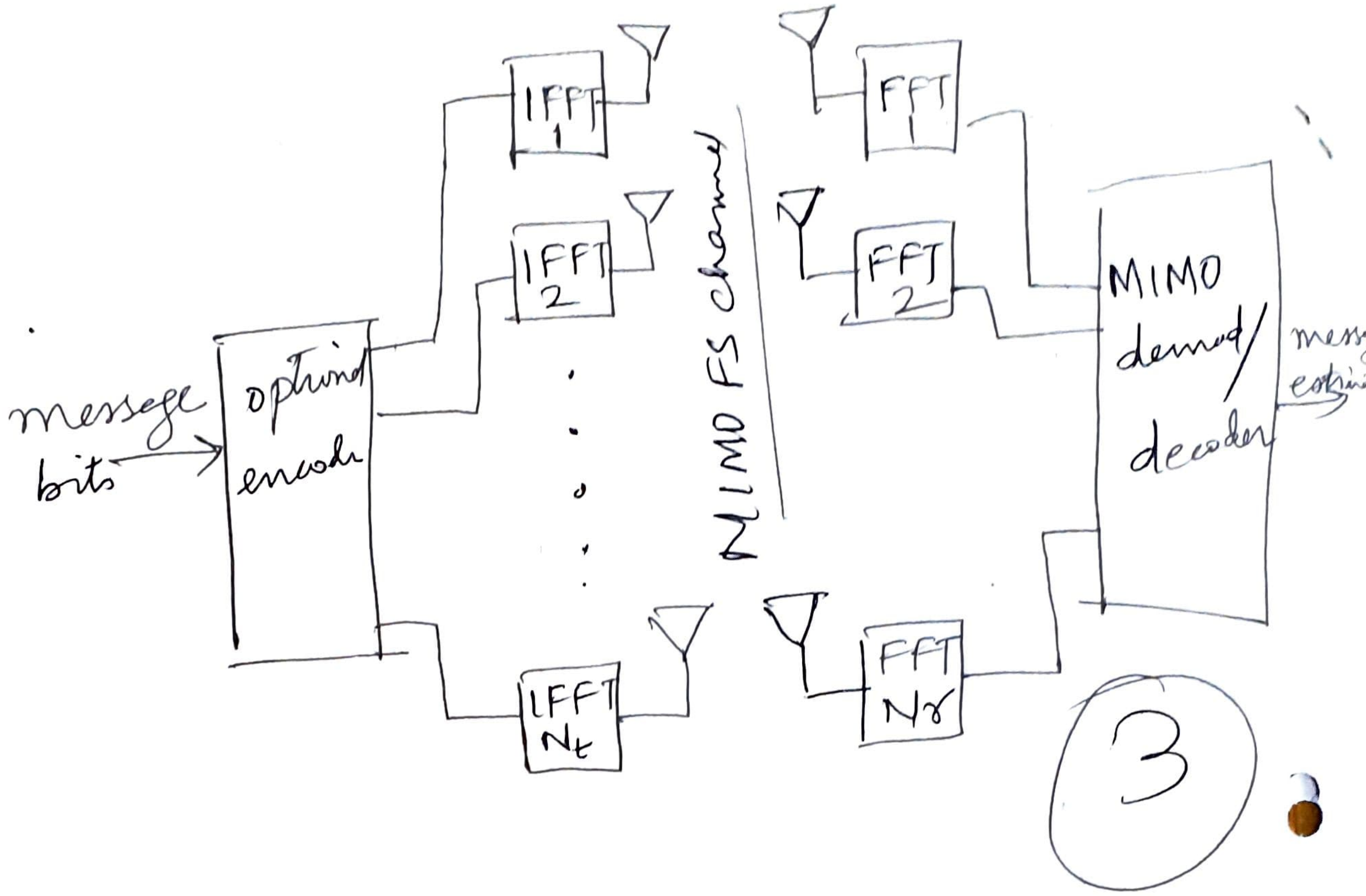
For MIMO FS channels, for each transmit antenna element, the IDFT/IFFT of N M-ary symbols denoted by $X_i(0), X_i(1), X_i(2) \ldots X_i(N-1)$ is first computed, Then cyclic prefix is appended to each of these sequences and resulting signal is transmitted to avoid interference between consecutive symbols

2

For each of received signals at Nr antennas the DFT/FFT of the aggregate received signal is calculated and cyclic prefix is removed. The resulting set of signals is then used for demodulation/decoding.

2

(P. T. O)



message bits
optimal encoder
IFFT 1
IFFT 2
IFFT N_t
MIMO FS channel
FFT 1
FFT 2
FFT N_r
MIMO demod/ decoder

END