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Superposition Coding for Multirate Broadcast of Digital Data

S.Udhayakumar[1], R.RajaKumar[2], P.Indumathi[3]

[1]Department of Electronics Engineering
Madras Institute of Technology, Chennai, (India)
[2]Professor, Department of Mathematics,
Sathyabama Institute of Science and Technology, Chennai, (India)
[3]Associate Professor, Department of Electronics Engineering
Madras Institute of Technology, Chennai, (India)

ABSTRACT

Superposition codes are used for reliable communication over the additive white Gaussian noise (AWGN) channel at rates approaching the channel capacity. In this paper, we develop a communication scheme that code data using superposition coding scheme in such a way users in noisy channels can recover a port of the data while users with sufficient signal to noise ratio (SNR) can recover the entire data using subtractive decoding process. Simulation results show that between the complexity of dependencies in auxiliary codeword generation and that of the function, maps them into transmitted codeword.

Keywords - Superposition code, Broadcast channel, Noisy channel, AWGN, SNR, and Codeword.

I. INTRODUCTION

Superposition coding proposed by T.M. Cover is used to send individual information to multiple receivers within a single broadcast signal [1].

A broadcast channel has one transmitter and multiple receivers. The main object is to transmit information to multiple users. The transmitted information may be independent or nested. The transmitted input x to the channel and the output y_1 and y_2 at receiver terminal1 and terminal2 are shown in Fig. 1.

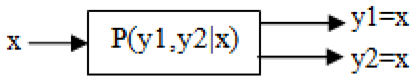

Figure 1: Broadcast channel

The aim of the problem is to communicate simultaneously receivers 1 and receiver 2 [2]. The broadcast channel is said to be

$$p(y_1, y_2|x) = \prod_{j=1}^{n} p(y_{1j}, y_{2j}|x_j) \qquad (1)$$

An $((N_{11},N_{22}),n)$ code for a broadcast channel consists of two sets of messages encoding function

$$x^n = M_{11} \times M_{12} \times M_{22} \qquad (2)$$

an received decoding function is

$$y_{1j} = M_{11} \times M_{12} = (j, l)$$

$$y_{2j} = M_{12} \times M_{22} = (l, k) \qquad (3)$$

The set of input x(j,l,k) is called set of codewords. The messages j and k as arbitrarily chosen by transmitter to receiver1 and receiver 2. The message l is common part of both receivers [3].

The paper is organized as following: Section 2 presents the work related to Superposition coding and broadcast channel, Section 3 deals with System model and proposed method for superposition coding, Section 4 deals with simulation results of the superposition coding and the conclusion are described in section 5.

II. RELATED WORK

Superposition code for reliable communication over the AWGN channel at rates approaching the channel capacity and the decoding complexity can be significantly reduced [4]. To generating secrecy from a publicly available superposition codebook used to confidential message is sent to one receiver and kept secret from the other receivers [5-9]. The two user causal cognitive interference channel, where two transmitters aim to communicate independent messages to two different receivers via a common channel [10]. The multiple access channels with general message sets [11]. As long as a transmitter must transmit more than one message, the technique applies, as has been recently demonstrated for any one-hop discrete memoryless channel network [12], [13]. This also includes settings where a transmitter splits its message(s) into multiple sub-messages via message-splitting [14].

Superposition coding, messages are mapped to auxiliary codewords, and the codeword to be transmitted is selected as a symbol-by-symbol function of those auxiliary codewords [10]. Approximate message passing refers to a class of algorithms that are Gaussian or quadratic approximations of loopy belief propagation algorithms on dense factor graphs [15-18].

Approximate message passing has proved particularly effective for the problem of reconstructing sparse signals from a small number of noisy linear measurements [19].

III. SYSTEM MODEL AND PROPOSED METHOD

The transmitter design scheme is lossely based on the already existing framework for QPSK modulation. In this problem, we proposed superposition coding for broadcast channel. The transmission of an 'n' bit codeword will result in the reception of a vector of power n(P+N).The space of received vectors can be encompassed in a sphere of radius $\sqrt{n(P+N)}$, and it is within this sphere that any possible codeword will be mapped.

The received vectors are normally distributed with mean equal to the true codeword and variance equal to the noise variance, which means that they will very rarely be mapped as the exact transmitted word but have a high probability of being mapped inside a sphere of radius $\sqrt{n(N+\epsilon)}$ around the true codeword. These decoding spheres denote the limits of error the decoder can tolerate, any transmitted vector will only result in an error if it is plotted outside of it is decoding sphere. The number of decoding spheres of radius $\sqrt{n(N)}$ that can be packed in a sphere of the radius $\sqrt{n(P+N)}$ is

$$(1+\frac{P}{N})^{n/2} = 2^{n\times\frac{1}{2}\log(1+\frac{P}{N})} \quad (4)$$

Efficient transmission over a channel of capacity C can be achieved using a $(2^{(nC)}, n)$ codebook because we need a codeword to represent each decoding sphere, and there are $2^{(nC)}$ decoding spheres in a larger sphere of plausible received vectors.

In superposition coding we construct a code of this type for a channel x and pack in extra information for y_1 that will still keep the codeword within the hamming distance of the intended word in the codebook of channel x.

The number of such points will be $2^{nH(\alpha)}$. This is because the number of probable errors for each codeword/cloudcenter is $2^{nH(\alpha)}$. In our case they are not really errors, but information bits meant for y_1.Hence the extra information we can transmit to y_1, with each codeword sent to y_2, is $H(\alpha)$. Resulting in the rates:

$$R1 = C(\alpha P' + \alpha' P) + H(\alpha)$$

$$R2 = C(\alpha P' + \alpha' P) \quad (5)$$

First generate 2^{nR2} codewords of length n to give the cloud centers, $u^n(w_2)$. Then for each of these 2^{nR2} codewords generate an additional 2^{nR1} code words $x^n(w_1,w_2)$. To transmit the pair (w_1,w_2) send the codeword $x^n(w_1,w_2)$. The cloudcenter $u^n(w_2)$ is never actually sent.

The α is the controls power allocation between different points. For practical constellation it decides the Euclidian distance between points in a constellation. The power allocation parameter led us to design a constellation with 4 cloud centers and sixteen superimposed constellation points. To better elucidate this point we make a brief venture into the actual coding schemes used for multi-rate broadcast in figure 2

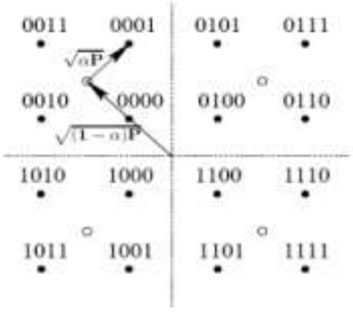

Figure 2: 16QAM Constellation and Cloud center

The first two bits of each word denote the 'cloud centers'. Receivers in noisy channels can only decode empty dots, while receivers in better channels can decode black dots. For a fixed rate code in which the number of points cannot change, α determines the Euclidian distance between constellation points.

As α is increased the oversampled points move away from the nyquist points and as α is decreased more power is given to the Nyquist points. A very noisy environment will require a lower α value because we need to ensure that at least the Nyquist points reach the destination.

IV. SIMULATION RESULTS

The performance of proposed superposition coding has been evaluated as one sender transmitted audio signal to two receivers. The audio signal is shown in figure 3.

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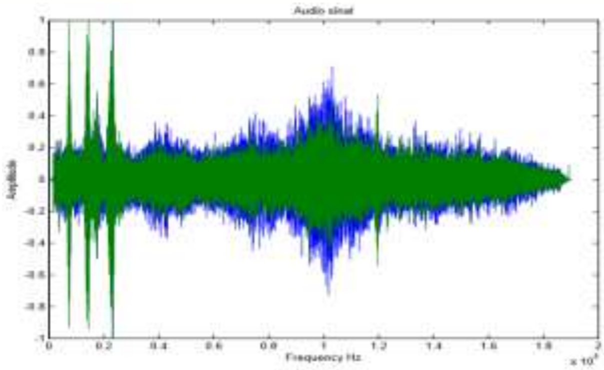

Figure 3: Audio signal

Root raised cosine filter is used as receive filter to minimize inter symbol interference shown in figure 4.

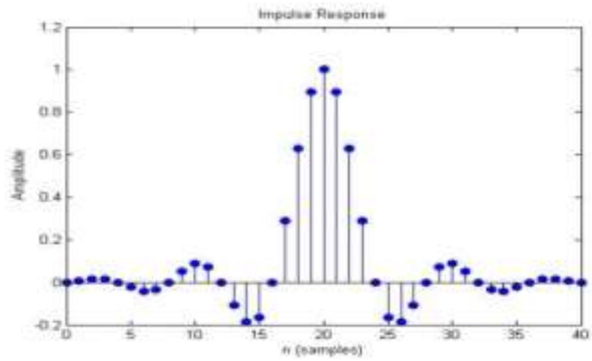

Figure 4: Root raised cosine filter response in AWGN

The receiver will have a less than perfect modulated 16 QAM constellations at the front-end, due to noise, distraction and channel imperfection as shown in figure 5.

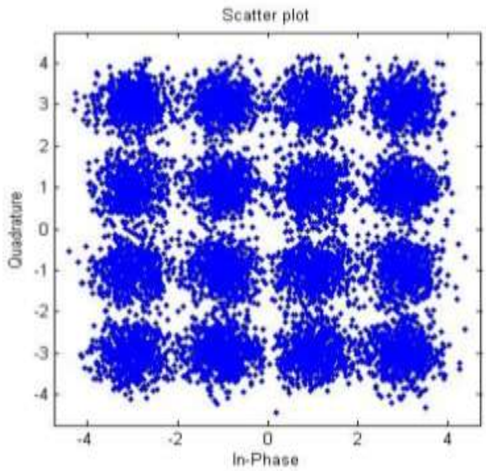

Figure 5: Modulated 16QAM Constellation

The cloud centre around each point represents uncertainty that the decoder must deal with when it attempts to take the received symbol and decide what bit pattern it actually represented in figure 6. Even through weaker signal was user transmitted for the with poor channel, the receiver information at both the users is strong.

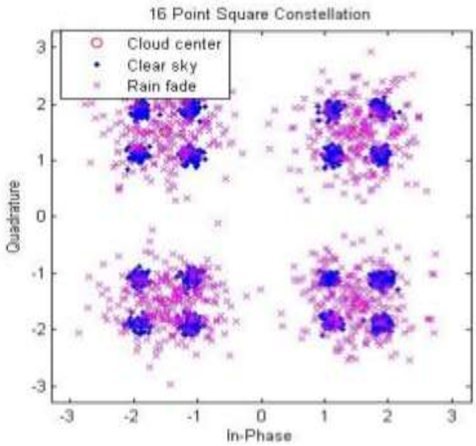

Figure 6: Superposition coding constellation

V. CONCLUSION

This paper proposed Superposition coding for the degraded broadcast channel. It was shown that the proposed transmission achieves rate pairs that are very close to boundary of the constellation constrained capacity. A simulation result shows that the two users, one with good channel and the other with poor channel are treated fairly. Neither good channel user was devoid of his ability to receive finer details of music nor poor channel user was completed “blacked” out. Both of the users have had their fair share of the transmitted signal.

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