A Review of Diversity Techniques in Wireless Communication system

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Abstract—It is the technique used to compensate for fading channel impairments. It is implemented by using two or more receiving antennas. While Equalization is used to counter the effects of ISI, Diversity is usually employed to reduce the depth and duration of the fades experienced by a receiver in a flat fading channel. These techniques can be employed at both base station and mobile receivers. Spatial Diversity is the most widely used diversity technique. In this technique multiple antennas are strategically spaced and connected to common receiving system. While one antenna sees a signal null, one of the other antennas may see a signal peak, and the receiver is able to select the antenna with the best signal at any time. The CDMA systems use Rake receivers which provide improvement through time diversity.

Keywords: Equalizers, diversity, ISI (Inter-Symbol Interference), Fading.

I. INTRODUCTION

Diversity [2] is a technique, which is used to diminish the channel fading & is often implemented by using two or more receiving antennas. In 3G transmit diversity is used where base-stations may transmit replicas of the signal on spatially alienated antennas or frequencies. With an equalizer, diversity improves the quality of a wireless communication link without alerting the common air interface & devoid of increasing the transmitted power or bandwidth. The difference in equalization & diversity is that equalizer technique [4] is used to reduce ISI, whereas diversity technique is used to diminish the effect of fading on wireless communication.

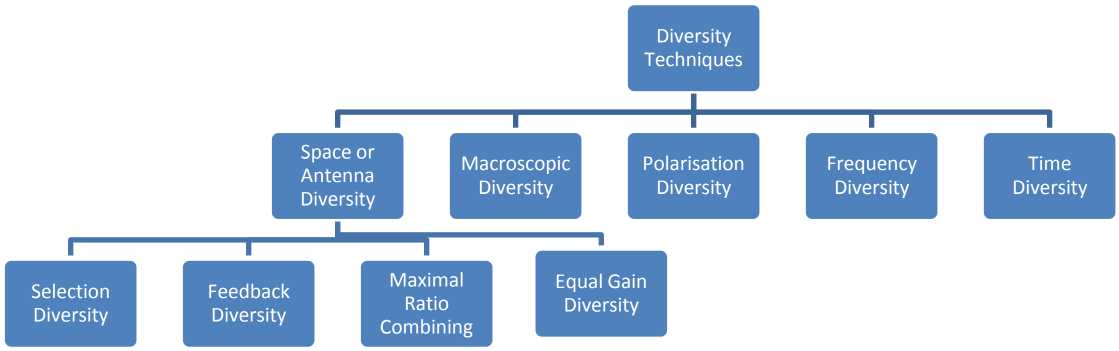
Diversity exploits the random nature of radio propagation by finding independent signal paths for communication. Diversity technique is mainly applied on the receiver, & unknown to the transmitter. By this technique the strongest or the best signal is received at the receiver. According to the types of fading i.e. small & large scale, diversity techniques may be classified as:

(1). Small- scale fading: Small scale fades are characterized by deep & rapid amplitude fluctuations which arise as the mobile moves just few wavelengths. These fades are caused by multiple reflections from the surrounding object. To alleviate this, microscopic diversity technique, space diversity or antenna diversity techniques may be used.

(2). Large-scale fading: Large scale fading [5] is caused by shadowing due to variations in the terrain profile & surrounding also. It occurs at large distance from the base-station. To alleviate this, macroscopic diversity may be used.

II. CLASSIFICATION OF DIVERSITY TECHNIQUES

According to way the fading of the incoming signal is mitigate in wireless communication diversity techniques are classification as:



- *Space Diversity or Antenna diversity:* It is one of the most popular diversity technique used in wireless systems. The direct path between the transmitter (BS) & receiver (MS) is not guaranteed & the possibility of a number of scatters in the mobile environment suggests a Rayleigh fading signal (small-scale fading). Multiple signals from spatially separated antenna (BS) is received on the mobile, the best signal is picked by the mobile using the diversity technique as shown in Figure 1.. It is also used in the base station (BS) design. At each cell site, multiple BS receiving antennas are used to provide diversity reception as shown in Figure 1. The Space or Antenna diversity [6] can be categorize as:

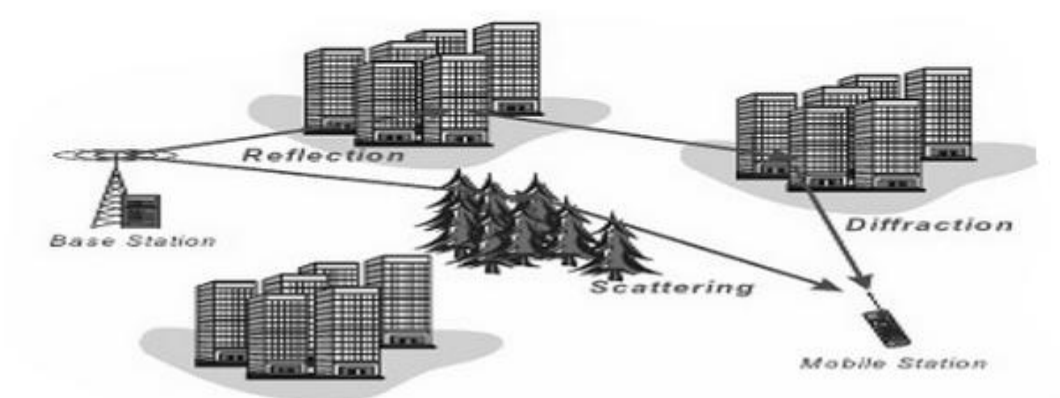


Figure 1: Multipath Signal Environment and Selection of strongest signal

(1) *Selection Diversity:* This is simplest diversity technique where demodulators are used to give diversity branches whose gains are adjusted to provide the same average SNR for each branch. The receiver branch having the highest instantaneous SNR is connected to the demodulator. In practice the branch with the largest (S+N)/N is used, as it is difficult to measure SNR alone. Figure 1 shown the block diagram of selection diversity in communication systems.

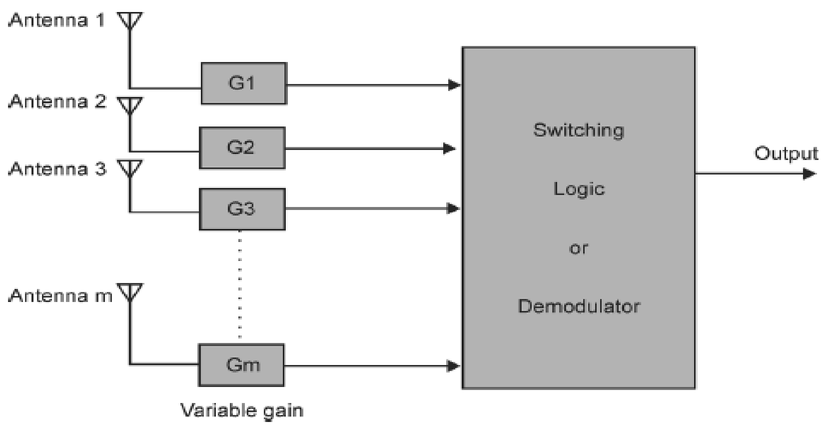


Figure 1. Shown the block diagram of selection diversity in communication systems.

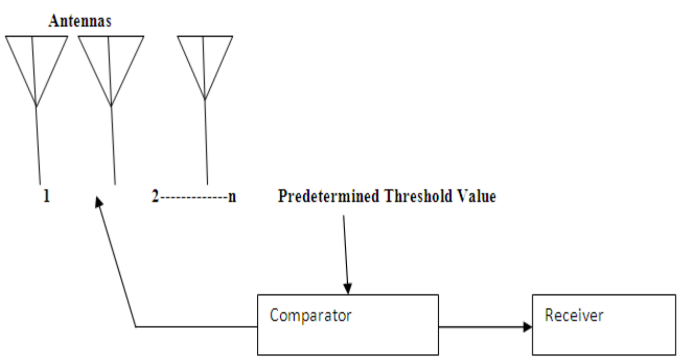


Figure 2. Block Diagram Of Feedback/Scanning Diversity

(2). *Feedback or Scanning Diversity:* This technique is very similar to selection diversity except that instead of always using the best 'n' signals, the 'n' signals are scanned in a fixed sequence until one s found above a predetermined threshold value. Now, this signal is then continuously received until it falls below threshold value & if falls, the scanning process is again initiated. The block diagram of feedback or scanning diversity is shown in figure 2.

(3). Maximal Ratio Combining (MRC): In this method, the signal from the all branches are weighted according to their voltage to noise power ratios & then summed (unlike selection diversity, where individual receiver is used). MRC [1] produces an output SNR equal to the sum of the individual SNR.

This technique has a merit of producing an output with an acceptable SNR even when none of the individual signals are themselves good enough. It is used in modern DSP techniques & digital receivers. Here the individual signals must be co-phased before summation.

Maximal Ratio Combining (MRC): On the i^{th} receive antenna, the received signal is, $y_i = h_i x + n_i$
where

y_i is the received symbol on the i^{th} receive antenna,
h_i is the channel on the i^{th} receive antenna,
x is the transmitted symbol and
n_i is the noise on i^{th} receive antenna.

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(4). *Equal Gain Diversity:* In certain cases, it is impossible to provide variable weighting capability like MRC. In such cases, the branch weights are set to unity, but the signals from each branch are co-phased to provide equal gain combining diversity'. This allows the receiver to exploit signals that are simultaneously received on each branch. This is superior than selection diversity but inferior than MRC technique. The block diagram of the Equal Gain Diversity is shown in figure 3.

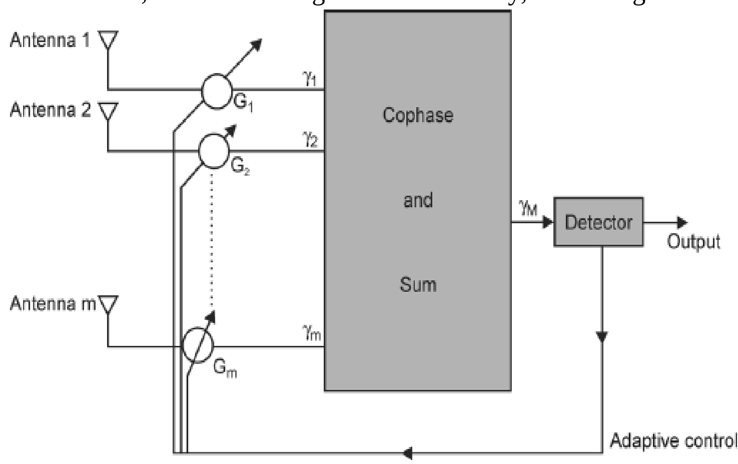

Figure 3: Block diagram of the Equal Gain Diversity

- *Macroscopic Diversity:* Macroscopic diversity [3] is a technique that can facilitate high quality and ubiquitous communications between low-power portable radiotelephones and data terminals, and radio base stations (ports) that are connected to the local network. It uses radio signals from several base stations to alleviate the effect of shadow fading, a variation of signal strength over space created by the presence of buildings, foliage, and terrain variations. With a path loss exponent of four and a shadow fading standard deviation of 10 dB, four-branch macroscopic diversity results in a 13 dB improvement in signal strength and a 15 dB improvement in signal to co-channel interference ratio for high user capacity interference-limited operation. (Both figures are for 99 percent statistical coverage of the service area.) The improvement in signal to co-phased channel interference ratio is equivalent to a factor-of-five savings of spectrum.

- *Polarization diversity:* It relies on the de-correlation of the two receive ports to achieve diversity gain. The two receiver ports must remain cross-polarized. Effective Diversity is obtained with a Correlation Coefficient below 0.7. In order to keep the correlation at this level -space diversity at a base station requires antenna spacing of up to 20 wavelengths for the broadside case, and even more for the inline case.

  Polarization diversity [6] at a base station does not require antenna spacing. At the base station, space diversity is considerably less practical than at the mobile because the narrow angle of incident fields requires large antenna spacing. The comparatively high cost of using space diversity at the base station prompts the consideration of using orthogonal polarization. Polarization diversity provides two diversity branches and allows the antenna elements to be considered

- *Frequency diversity:* The signal is transmitted using several frequency channels or spread over a broad spectrum that is exaggerated by frequency-selective fading [4]. Middle-late 20th century microwave radio relay lines often used numerous regular wideband radio channels, and one protection channel for automatic use by any faded channel. Later examples include: (1). OFDM (orthogonal frequency division multiplexing) modulation in combination with subcarrier interleaving and forward error correction and (2). Spread spectrum, for example frequency hopping or DS-CDMA.

- *Time diversity:* Multiple versions of the same signal are transmitted at different time instants. Time Diversity repeatedly transmits information at time spacing that exceeds the coherence time of the channel. A modern implementation of time diversity involves the use of RAKE receiver for spread spectrum CDMA, where multipath channel provides redundancy in the transmitted message. Multiple repetitions of the signal will be received with multiple fading conditions, thereby providing for diversity.

III. ADVANTAGES AND DISADVANTAGES

Diversity is a powerful communication technique that provides wireless link improvements at relatively low cost. Diversity exploits the random nature of radio propagation by finding the best version of multiple independent incoming signals at the receiver. In diversity technique the multiple independent paths signal are highly uncorrelated. If one radio path undergoes a deep fade another independent path may have a strong signal. Two criteria are necessary to obtain a high degree of improvement from a diversity from a diversity system are (1). First, the fading in individual branches should have low cross-correlated and (2). Second, the mean power available from each branch should be almost equal.

IV. COMPARISON

Comparison of different diversity techniques is shown in Table 4.

Table 4 comparison between diversity methods, Source [6]

Diversity Scheme	Advantages	Disadvantages
Space diversity	Easy to design. Any number of diversity branches are (*L*) selectable. No extra power nor bandwidth is necessary. Applicable to macroscopic diversity.	Hardware size could be large (depends on device technologies). Large antenna spacing is necessary for microscopic diversity at the base station.
Polarization diversity	No space is necessary. No extra bandwidth is necessary.	Only two-branch diversity schemes are possible. Three decibels more power is necessary.
Frequency diversity	Any number of diversity branches (*L*) are selectable.	*L* times more power and spectrum are necessary.
Time diversity	No space is necessary. Any number of diversity branches (*L*) are selectable. Hardware is very simple.	*L* times more spectrum are necessary. Large buffer memory is necessary when *fd* is small.

V.CONCLUSION

Diversity improves reliability of a message signal by using two or more communication channel with different characteristics. Diversity plays vital role in combating fading and co-channel interference and avoiding error bursts. It is based on the fact that individual channels experience different levels of fading and interference. Multiple versions of the same signal may be transmitted and/or received and combined in the receiver. Alternatively, a redundant forward error correction code may be added and different parts of the message transmitted over different channels. Diversity techniques may exploit the multipath propagation, resulting in a diversity gain, often measured in decibels.

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