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Performance Analysis of BICM and BICM-ID based Co-operative MIMO Network over different Fading Environment

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Abstract-In cooperative networks, the interference reduction techniques depend upon coordination among cells by setting up relays between multiple inputs multiple output (MIMO) configurations. The energy efficient technique, cooperative MIMO (C-MIMO) is employed in this paper. The bit inter-leaved coded modulation (BICM) and bit inter-leaved coded modulation with iterative decoding (BICM-ID) code are used to get the better performance of the system. The ½ coding rate is used over both fading and additive white Gaussian noise (AWGN) channels. The simulation outcomes show that the cooperative communication scheme outstrips the single input single output (SISO) technique for BICM and BICM-ID. The bit error rate (BER) of the system is examined under various statistical distributions like Nakagami-m, Rician-k and Rayleigh.

Keywords-SISO, MIMO, BICM, BICM-ID, Cooperative MIMO Network

I. Introduction

The wireless technology has survived as an essential telecommunication mean after its origination in the late 19th century. With the remarkable innovation of cellular phone, this technology has outnumbered the wired technologies in telecommunication field. Telecommunication industry is at the epoch of a new revolution where, high-speed digital signal processing (DSP) being applied to replace most of the analog circuitry used to modulate and demodulate the radio waves [i]. After this excogitation, many distinct, prosperous and adaptive solutions appeared that have improved the efficiency of wireless communication channels by coordinated multipoint (CoMP) transmission. The co-operative communication is exploited to encounter the multi-path fading by co-operating with each other in a wireless communication system. The major requirement for wireless networks is to improve the performance of cell edge and provide the multiple streams to edge users [ii]. The transmission reliability and network capacity can significantly be improved by the co-operative networking. Most of the current work is restricted to simple 3-node relay design and single antenna system. These limitations can be undone by optimal power allocation structure in MIMO cooperative networks (MIMO-CN) [iii - iv]. The primary prerequisites to apply OFDMA networks involve scheduling, spatial filtering and power control [v]. To meet future requirement and reducing past issues, different techniques are used to develop the wireless system such as diversity technique [vi] and to resolve the energy problems in wireless communication systems, the cooperative networks are proposed by many research groups. In MIMO cooperation, many users are associated to form virtual communication antenna array. Multi-hop cooperative MIMO network form a co-operation that uses intermediate node to forward the information from sender to receiver [vii].

The bit inter-leaved coded modulation is a combination of bit inter-leaver, channel encoder, and multilevel modulator [viii]. A turbo decoding process is supplemented by offering a feedback loop to the decoder/ demapper in order to increase the performance of this technique. This amended technique is called bit-interleaved coded modulation with iterative decoding [ix]. This approach improves the time diversity of coded modulation, which provides bandwidth-efficiency for fading channels. The decoding performance of BICM can be enhanced as a result of iterative decoding (ID). The BICM with iterative decoding (BICM-ID) takes advantages of iterative information exchanges between the channel decoder and provides excellent performances over both additive white Gaussian noise (AWGN) and Rayleigh fading channels [x]. The error floor can be minimized by applying doping techniques on BICM [xi]. The system performance can also be significantly enhanced due to code diversity. The path loss based on the co-operative MIMO network can be reduced by employing the conventional convolution based codes and bit interleaved coded modulation with iterative decoding (BICM-ID) [xii]. It will considerably improve the reliability and spectral efficiency of MIMO systems [xiii].

The Multiple Input Multiple Output (MIMO) technology is widely used for different wireless access networks primarily for wireless fidelity (WiFi), long term evolution (LTE) and worldwide interoperability for microwave access (WiMax) [xiv]. MIMO system using spatial multiplexing are increasing the number of b/s/Hz of allocated bandwidth, enhancing the performance through space-time coding and formation of beam forming. The performance analysis of BICM and BICM-ID based co-operative communication MIMO network is considered over Rician-K and Nakagami-m multipath fading environment [xv]. The MIMO techniques involve the large power utilizations and complex signal processing. Moreover, it is hard to achieve the real time carrying out of multiple antennas at a small relay node. To resolve these issues, a solution appears in the form of the cooperative MIMO (C-MIMO) [ii]. C-MIMO is a based on multiple inputs and outputs system through the cooperation of multiple relays nodes with better energy utilization. However, the scope of this paper is aimed to introduce the BICM-ID in MIMO cooperative system. The purpose is to increase the spectral efficiency and reliability of the system.

II. SYSTEM MODEL

The system model mainly comprises of a source terminal, a destination terminal and multiple relay nodes. All terminals are equipped with multiple antennas. The relays are operating in AF mode and MRC signal combining technique is used at the destination terminal.

A. Transmission Protocol

A MIMO system normally uses 'm' numbers of transmitting and 'n' receiving antennas. Every antenna receives only the direct path signal during the transmission over the same channel, but also the indirect path signal from the other antennas. The channel assumed to be narrowband. The direct path from antenna given by h_{11}, while the indirect path from antenna given by h_{21}. The transmission matrix H obtained with the dimension's n x m.

$$Y = HX + N \tag{1}$$

$$\text{Where, } H = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \tag{2}$$

$$X = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \tag{3}$$

$$N = \begin{bmatrix} n_1 \\ n_2 \end{bmatrix} \tag{4}$$

$$\begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix} \tag{5}$$

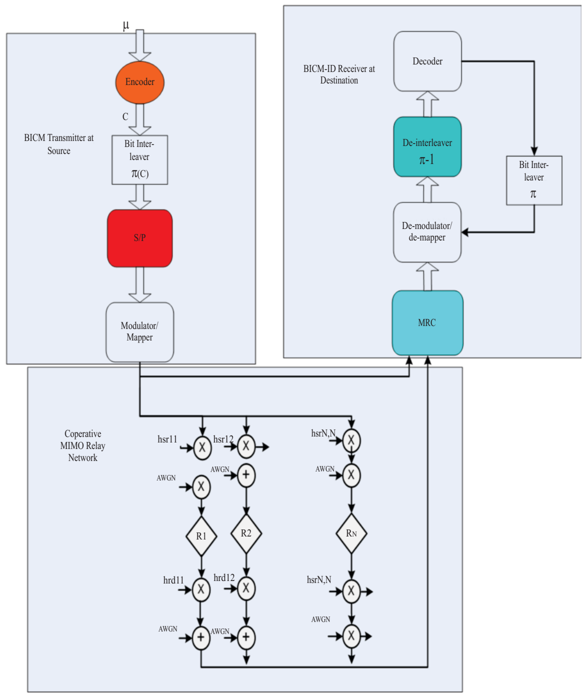

Fig. 1. Schematic diagram of C-MIMO Network

In the wireless channel model *n* numbers of relays nodes are used for cooperation. The transmission protocol used here is two time slot TDMA [v]. In this transmission protocol, the source transmitted signal x_1, x_2 and x_3 in the first time slot to the relay stations R_1 and R_2, respectively. The relay nodes firstly amplified the propagating signal and then forwarded it to the destination terminal. The incoming signals at the relay given by:

$$Y_{sr(i,j)} = h_{sr(i,j)}\sqrt{E_{sr(i,j)}}S_i + n_{sr(i,j)} \tag{6}$$

Where,
i denotes the relay $i = 1,2,3,...,N$ and *j* denotes the relays's antenna $j = 1,2,3,...,N$.

In time slot 1, the source *S* propagates the unit signal *S(t)* to destination terminal *D* and to the relays *R* (*i=1,2,....,N*). The scheme used by relays is first amplify the signal and then forward (AF) it to the destination. The best relay will be chosen on the basis of highest SNR for the received signal.

$$y_{SR_{11}} = h_{SR_{11}}\sqrt{E_{SR_{11}}}S_1 + n_{SR_{11}} \quad (7)$$

$$y_{SR_{12}} = h_{SR_{12}}\sqrt{E_{SR_{12}}}S_1 + n_{SR_{12}} \quad (8)$$

$$y_{sd} = h_{sd}\sqrt{E_{sr}}S_2 + n_{sd} \quad (9)$$

$$y_{SR_{21}} = h_{SR_{21}}\sqrt{E_{SR_{21}}}S_3 + n_{SR_{21}} \quad (10)$$

$$y_{SR_{22}} = h_{SR_{22}}\sqrt{E_{SR_{22}}}S_3 + n_{SR_{22}} \quad (11)$$

Where:

h_{sr} = Channel co-efficient between source's' and relay 'r' at time slot 1

E_{sr} = Transmitted energy per bit

S_1 = M-PSK modulated signal-1

S_2 = M-PSK modulated signal-2

n_{sr1} = Gaussian distribution with power spectral density of 'N_0'

At time slot 2, it normalizes and retransmits the received signal to the destination node. The collected signal is elaborated as:

$$y_{r11d} = h_{sr11}\sqrt{E_{sr11}}y_{sr11n} + n_{r11} \quad (12)$$

$$y_{r12d} = h_{sr12}\sqrt{E_{sr12}}y_{sr12n} + n_{r12} \quad (13)$$

$$y_{r21d} = h_{sr21}\sqrt{E_{sr21}}y_{sr21n} + n_{21} \quad (14)$$

$$y_{r22d} = h_{sr22}\sqrt{E_{sr22}}y_{sr22n} + n_{22} \quad (15)$$

The signal is combined at receiver by using maximum ratio by combing (MRC) cooperative diversity.

Where, n_d = AWGN added at destination

A = Amplification factor

$$Y_{MRC} = (E_{sd}|h_{sd}|^2) + \frac{E_r E_{sr11}}{E_{sr11}\|h_{sr11}\|^2++1}\cdot\frac{|h_{sr11}|^2|h_{rd11}|^2}{E_{sr11}+|h_{sr11}|^2+1} + \frac{E_r E_{sr12}}{E_{sr12}|h_{sr12}|^2+1}\cdot\frac{|h_{sr12}|^2|h_{rd12}|^2}{E_{sr12}+|h_{sr12}|^2+1} + \frac{E_r E_{sr21}}{E_{sr21}|h_{sr21}|^2+1}\cdot\frac{|h_{sr21}|^2|h_{rd21}|^2}{E_{sr21}+|h_{sr21}|^2+1} + \frac{E_r E_{sr22}}{E_{sr22}|h_{sr22}|^2+1}\cdot\frac{|h_{sr22}|^2|h_{rd22}|^2}{E_{sr22}+|h_{sr22}|^2+1} \quad (16)$$

In this protocol source S propagates signal $S(t)$ to destination terminal D and relays R at the same time, which is graphically represented in Fig. 2:

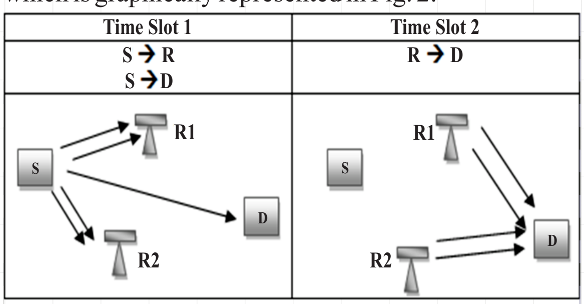

Fig. 2. Conceptual diagram of two-time slot TDMA based protocol.

$$y_{sr} = y_{r_1 r_2}.\frac{g_1^*}{\|g_1\|^2} \quad (17)$$

The signal y_d received at destination from relay 1 in time slot 2 is expressed as:

$$y_d = \frac{\sqrt{Er_1}.h_{sr0}.h_{sr1}\sqrt{E_{sr_1}}s}{\sqrt{E_{sr_1}\|h_{sr_1}\|^2+1}} + \frac{\sqrt{Er_1}.h_{sr1}.n_{r_1}}{\sqrt{E_{sr_1}\|h_{sr_1}\|^2+1}} + n_d \quad (18)$$

B. Path Loss Model

The main objective is to implement the path loss in the MIMO co-operative networks to show the novelty of the research work. Consider the projection of R_i as a straight line from the source to destination. The entire distance between source terminal T_1 and destination terminal T_2 is normalized to unity ($d=1$). The perpendicular distance between T_1 and R_1 is $d/4$ and the distance between T_1 and projection of R_1 on the horizontal line is d_1. The exact distances from T_1 and T_2 to the R_1 denoted by d_{11} and d_{12} respectively and given by Pythagorean theorem as:

$$d_{11} = \sqrt{{d_1}^2 + (0.25)^2} \quad (19)$$

$$d_{12} = \sqrt{(1-d_1)^2 + (0.25)^2} \quad (20)$$

Similarly symmetry is applicable while computing the exact distance from T_1 and T_2 to R_2.

The faded Signal attenuated by a factor $d_{11}^{-\mu}$ and $d_{12}^{-\mu}$ for the first and second time slot influenced by the path loss effect, respectively. The factor of the transmission medium is denoted by the empirical constant μ also known as path loss exponent. It explained the limits for various types of signal propagation depending upon the radio environment.

μ=2 (Empirical constant for free space).

μ=3 (Empirical constant for urban areas).

μ=5 (Empirical constant for outdoor propagation).

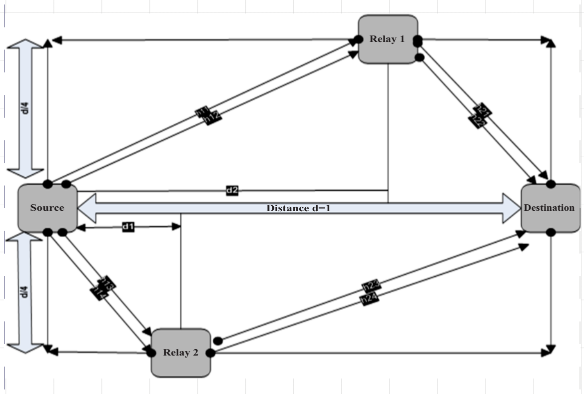

Fig. 3. Path loss Model in MIMO Co-operative Network

For the both terminals T_1, T_2 and the fading distribution of the link to the relay R_i are to be considered as independent and identical distributed (i.i.d) for Nakagami-m and Rician–K fading channels.

The mean channel power is given by $E\{|h_{ij}^2|\} = \Omega_{ij}$ over the path loss model $\Omega_{ij} \propto d_{xy}^{-\mu}$.

Therefore, the performance analysis under path loss effect is considered. Multiple signals which are sent and got naturally mixed in the wireless channel and therefore exploited the multipath phenomena of the wireless channel. Amplification factor (β*j*) at the relay given below:

$$\beta_j = \sqrt{\frac{E_{rj}}{\Omega_{ij}E_1 + \Omega_{2j}E_2 + N_0}} \quad (21)$$

Where, E_{rj} = Average transmitted symbol energy at R_i
$E\{|h_{ij}^2|\} = \Omega_{ij}$ (Mean channel power)
$\Omega_{ij} \propto d_{xy}^{-\mu}$ (Path loss model)

The amplification factor (β*j*) is used in input/output equation model.

III. Simulation Results & Discussions

The BICM, and BICM-ID based co-operative MIMO network over Rician-K fading channels are simulated under Monte Carlo technique. The magnitude of channel coefficients follows K=5, and 10 distributions for uniform phase distribution. Whereas, intermediate nodes (relays) are operating in amplify-and-forward (AF) mode with pre-defined gain value. From figure 4.5, it can be inferred that the cooperative MIMO has better energy conservation ability than SISO transmission. The simulation is taken for code rate r = 1/2.

A. *Bit Error Rate*

The C-MIMO compared with SISO system by using code rate 1/2. The code word length kept fixed and the number of decoder iteration is taken as 5. The bit error rate (BER) analysis is taken as performance factor in this paper. 8-PSK modulation with AWGN is used over Nakagami-m and Rician-K fading environment for the simulation. The cooperative MIMO gave the low bit error rate at the low value SNR by using 8-PSK, The analysis from Fig. 4 to figure 5. and in Fig. 6 to figure 7 gives lower BER value at lower value of SNR. This analysis shows the system is power efficient system.

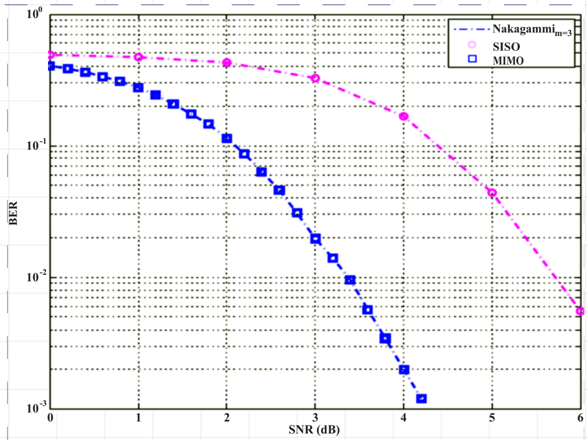

Fig. 4. Performance Comparison of BICM based cooperative MIMO network and SISO over Nakagammi-m channel

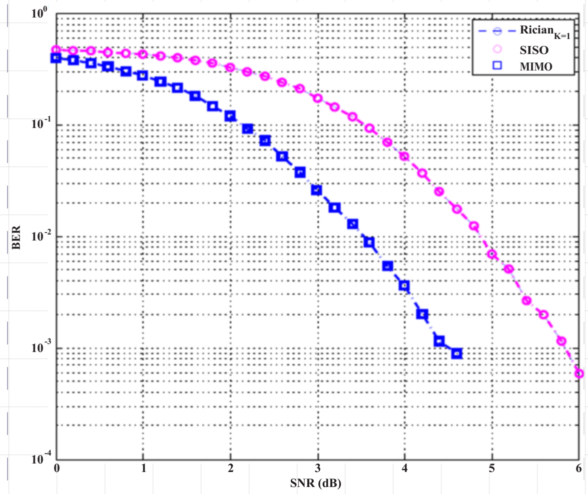

Fig. 5. Performance Comparison of BICM based cooperative MIMO network and SISO over Rician-k channels.

In Fig. 4 and Fig. 5, the comparison of BICM based cooperative MIMO network and SISO system over Nakagammi-m and Rician-k fading channels are analyzed. It can be inferred from the Figures that performance of the system varies by changing the different fading environments. The Nakagami-m fading channel gives the best BER as compare to the Rician-K and Rayleigh Channel. In the start at the 0 dB values are almost same but when we increase the SNR we got better result. In channel wise Nakagami-m fading channel is best among the others, and cooperative MIMO network give better performance as compared to the SISO.

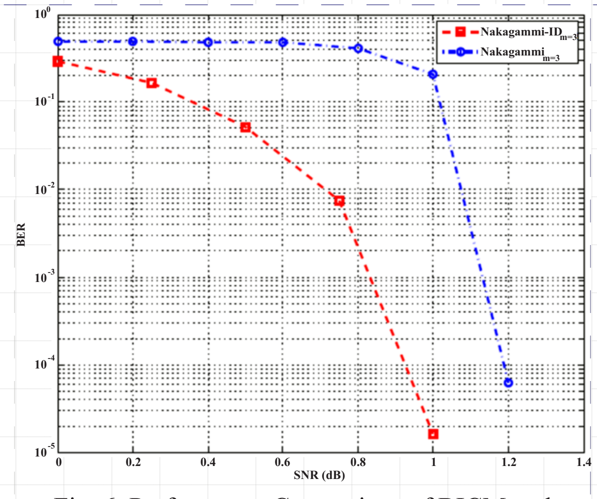

Fig. 6. Performance Comparison of BICM and BICM-ID based cooperative MIMO network over Nakagammi-m channels.

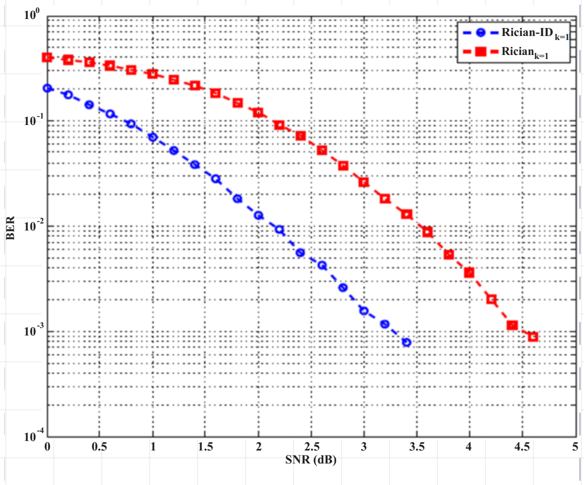

Fig. 7. Performance Comparison of BICM and BICM-ID based cooperative MIMO network over Rician-k channels.

In Fig. 6 and Fig. 7, the performance analysis of BICM and BICM-ID based multiple relay co-operative MIMO network analyzed. The asymptotic bit error rate (BER) bounds of the system using the 8-PSK SP mapped modulations over Nakagami-m, Rician-K and Rayleigh channels are obtained.

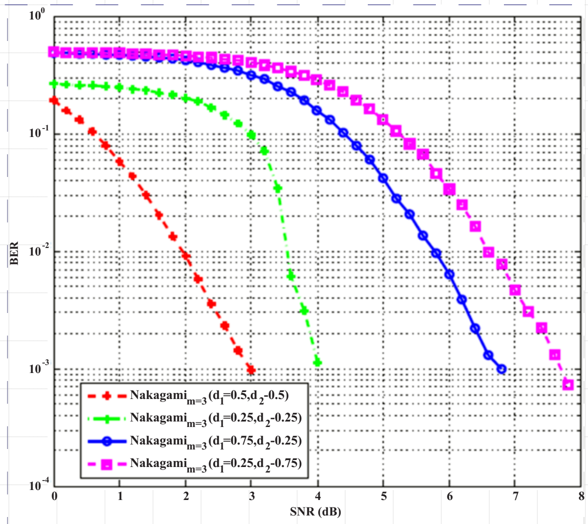

Fig. 8. Performance comparison of BICM based cooperative MIMO network over Nakagammi-k channels.

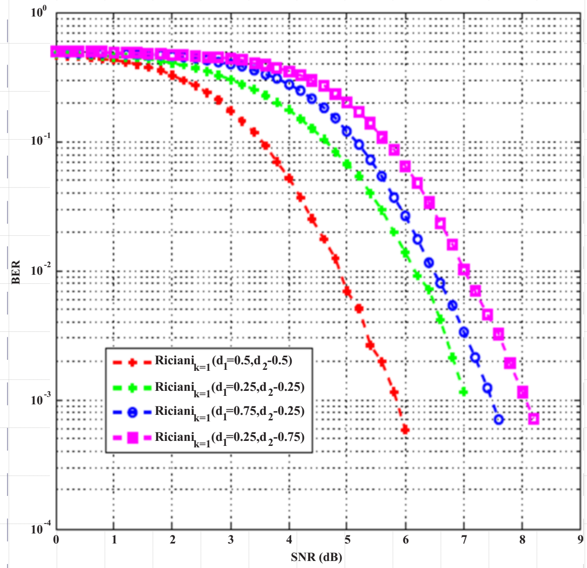

Fig. 9. Performance Comparison of BICM based cooperative MIMO network over Riciani-m channels.

In the analysis of channels with path loss, the proposed relay exactly lied between the source and the destination mean values of the d_1 and d_2 is equal to the 0.5. There are two major ways for placement of relay stations either permanent or any node start working as relay to connect the other portions of network in case of failure of any node. The requirement in such condition is to minimize the number of relay nodes to be deployed.

The proposed relays are moveable and several results are obtained by changing the location of the relays. However, the best result is observed at the center of the source and destination.

This data exchange step carried out during an additional slot exchange to transmit signals from relay to the destination under low power condition. The relays carrying highest SNR are involved in data exchange to reduce the propagation errors. Moreover, distributed transmit beam forming studied to maximize the ratio of coherently combined received signals. The proposed technique has improved outage behavior and data rate than traditional methods at the relay optimal location and for low SNR conditions.

IV. CONCLUSIONS

The simulation results have shown that the cooperative communication system outperforms SISO transmission when we applied error correction codes. By BER analysis of the cooperative MIMO system over different fading environment can be deduced that the cooperative communication system proves to be more energy efficient than SISO transmission system. It offers better BER value at the lower value of SNR. Therefore, the range, reliability and data rate can be increased with a very low transmit power and without increasing the number of antennas both at mobile user end and base station. A low cost and less complex system is achieved by this technique. Moreover, it is also concluded that the cooperative MIMO with BICM-ID is an optimal method for high quality signal reception.

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