

Dual Receiver with Phase and Switched Diversity for Background Processing and Reception Improvement

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ABSTRACT

This paper presents a cost-effective receiver system utilizing dual tuner antenna diversity. There are two modes of operation. In mode 1, the system is in phase diversity where two tuners operate harmoniously to minimize severe multipath distortion using beam pointing. In mode 2, the two tuners operate independently while still achieving reception improvement through intelligent antenna switching. This mode uses one tuner with two antenna switched diversity while the second tuner performs background processing. An advantage of this dual tuner architecture is the ability to provide concurrent multipath distortion reduction and background processing. An example of a digital FM receiver which embodies these functions is described.

INTRODUCTION

The first objective of a radio receiver is to receive and convey desired audio programming. It is also desirable for a mobile receiver to acquire other data in the background to enhance listener experience. Two examples follow:

- All Hazards Public Alert such as the Specific Area Message Encoding (SAME) encoded weather alerts issued by the National Weather Service.
- Radio Data System (RDS). In Europe, this service is used to promote seamless switching of simulcast audio programming to cover broad geographical areas. RDS is also used for the digitally coded Traffic Message Channel (TMC) to transmit real-time traffic data. RDS-TMC technology is also utilized by some US FM broadcasters to provide local traffic information.

In order to support this additional functionality, a second tuner is desirable. The economic question is whether this second tuner can also be used to enhance reception of the desired signal (audio signal) by using novel techniques such as phase and switch diversity algorithms. Certainly, a third tuner could be added to provide this functionality in a brute force way, but a more elegant approach is possible by the judicious use of a two-tuner architecture.

The primary purpose of a diversity system is to improve reception performance under multipath conditions. A diversity system employs two or more uncorrelated receiving antennas. Diversity reception in mobile communication systems has been reported in the literature [1,5-7] to reduce audio distortion due to fading. In a conventional diversity application, when background processing is required, the diversity system must relinquish one of the tuners to the background data processing function at the cost of degraded audio reception. Certainly, the radio can include a third tuner for background processing, leaving two tuners dedicated for diversity reception, but this solution carries a significant cost penalty. This paper presents a dual tuner design that maintains diversity reception during background processing.

MULTIPLE TUNER REVIEW

Multiple tuner designs have been implemented in the past to reduce multipath fading distortion by using algorithms such as Maximal Ratio Combiner (MRC), Equal Gain Combiner (EGC) or selection diversity as described in [1], or a system called Phase Aligning System (PAS) which is described in [5]. Another powerful algorithm called the Constant Modulus Algorithm (CMA) [2,3] continues to be implemented in many communication receivers due to its simplicity as it requires no cooperation from the transmitter (blind algorithm). The CMA can be implemented in a single channel equalizer (filter) or multiple channel (tuner) designs. In many applications, a dual tuner design can improve reception by using one or more of the above mentioned algorithm techniques with two or more uncorrelated antennas. In addition, many broadcast service receivers require background processing for long periods of time to acquire vital data. In these cases, the system must drop out of diversity mode completely to do background data service monitoring. This degrades the reception performance due to the halting of the diversity algorithm by giving up the secondary tuner. Each tuner then has one antenna-and no antenna diversity. Fig. 1 is a simplified block diagram of such a system. Note that the

the Front End consists of impedance matched low noise amplifiers, an image reject filter, automatic gain control (AGC), down convert mixer and local oscillator.

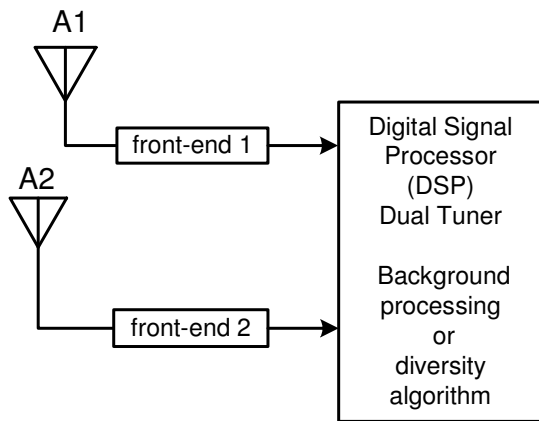


Fig. 1: Dual tuner utilizing diversity for reception improvement or no diversity where the secondary tuner is used for background processing

Some other designs have one antenna and two tuners without diversity as shown in Fig. 2. As an example, one tuner demodulates audio and the other performs background processing such as data acquisition. This architecture can have performance degradation due to the splitting of signal power that supplies both tuners.

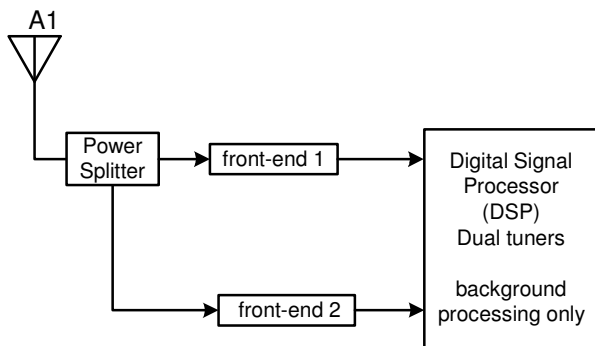


Fig. 2: Single antenna with two tuners, the second tuner is only used for background processing

DUAL TUNER WITH PHASE AND SWITCHED DIVERSITY

The general block diagram of the proposed system is shown in Fig. 3. The advantage of this dual tuner architecture is the ability to provide background processing while switched diversity simultaneously reduces multipath distortion. When not in background processing, it provides full dual tuner phased array diversity performance. A brief description of the block diagram is follows. Switch SW1 is connected to antenna A1 directly and SW2 is connected to antenna A2 via the antenna buffer block. The buffer provides RF signal isolation between SW2 and front-end 2 which is

connected to the Analog-to-Digital Converter 2 (ADC2). A well-designed buffer circuit will minimize signal loss with careful consideration of the required gain, noise figure, proper impedance input, and matching the output impedance to the front-end block. The buffer block is best when integrated into the front-end IC to reduce cost and to improve performance.

In normal operation, the system utilizes a diversity algorithm such as MRC to improve reception where both ADC1 and ADC2 signals implement the diversity algorithm. In this case, SW1 is set to the closed position and SW2 is set open by the diversity algorithm block. This configuration is required because both tuners need to be tuned to the same frequency in order for the phase diversity algorithm to be adjusted in DSP accordingly. When background processing is required for a long period of time, at a frequency other than the frequency of the extracted audio channel, the signal from antenna A2 will be dedicated to the task via the Tuner2 DSP. In this case, front-end2 can be tuned independently from front-end1. Simultaneously, a switched diversity algorithm is utilized to select the least distorted antenna signal via front-end1 and one of the switches.

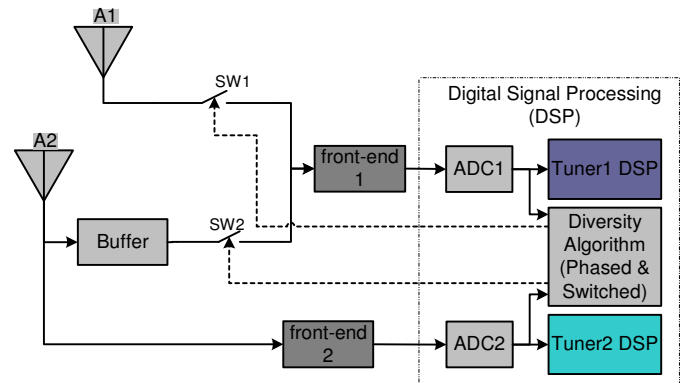


Fig. 3: Dual tuner design for phased diversity and switched diversity with background processing

The proposed system can be expanded to include a switching network for the secondary tuner as shown in Fig. 4.

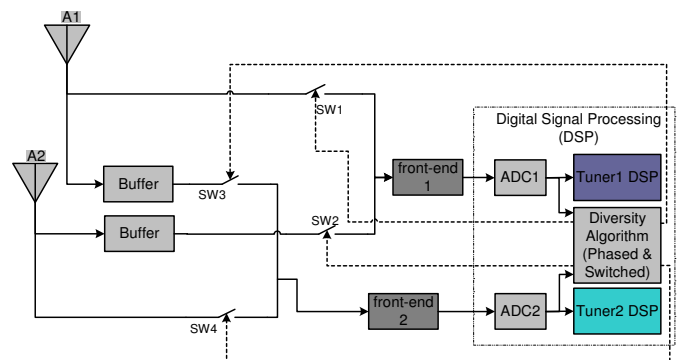


Fig. 4: Dual tuner design which includes switched diversity for both the main and background tuners when the system is in background processing mode.

In normal operation, the system utilizes a diversity algorithm such as MRC as described above. In this case, SW1 and SW4 are set to the closed position. SW2 and SW3 are set open by the diversity algorithm block.

When background processing is required for a long period of time, a switched diversity algorithm is utilized to select the least distorted antenna signal via front-end1 and one of the switches, SW1 or SW2. Another switched diversity algorithm is utilized to select the least distorted antenna signal via front-end2 and one of the switches, SW3 or SW4. It is important to realize that the switched diversity metrics for the main tuner are different from the switched diversity metrics for the background tuner due to the data type needed to be extracted with the background tuner. We assume the main tuner receives and conveys desired audio programming.

This paper will only concentrate on the architecture of Fig.3 to simplify the analysis and discussion.

FM RECEIVER EXAMPLE

An example of the above mentioned concept architecture is shown in the detailed block diagram in Fig. 5. The diversity update block, the multipliers and the summing block are utilized when the system is in full combining diversity mode where both antenna signals are added to optimize certain reception conditions. Refer to Appendix A for a description of the CMA and MRC algorithms that are used to update the weights for optimized reception. In this case, SW1 is closed and SW2 is opened. The FM demodulator1 block then demodulates the sum output. When background processing is required, the diversity update block sets $W1 = 1$ and $W2 = 0$. Front-end 2 is then tuned independently and FM demodulator2 is used to gather the required information in the background. An example is the Radio Data System (RDS) in Europe where the background receiver gathers the available Alternate Frequency (AF) list. AF involves scanning the band for suitable alternate simulcast frequencies or just scanning the band for available stations in the region. Simultaneously, the switched diversity algorithm block controls SW1 and SW2 dynamically based

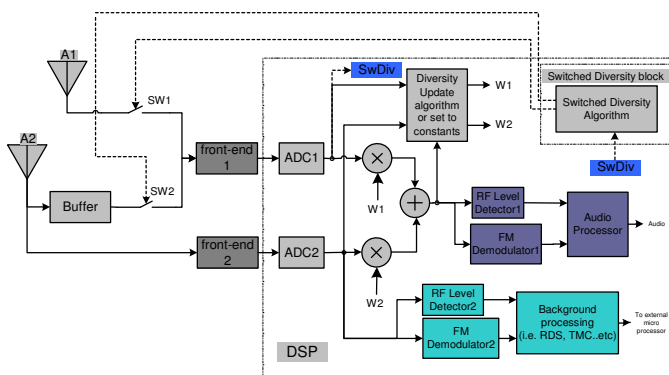


Fig. 5: FM dual tuner system utilizing combined and switched diversity with background processing

on signal conditions. The switched algorithm selects the least distorted antenna signal. Refer to Appendix B for a description of the algorithm.

Hybrid CMA and MRC diversity algorithm with Dual Tuner

In this mode (refer to Fig. 5), SW1 is set to the closed position and SW2 is set open, and both front ends are tuned to the same frequency. The MRC/CMA algorithm is shown in Fig. 6. The hybrid technique optimizes diversity reception over a greater dynamic range of signal levels. While the CMA assumption becomes poor for weak signals, the maximum ratio combiner (MRC) algorithm assumptions remain valid for all signal levels. Furthermore, while the CMA is generally superior to the MRC at high signal-to-noise ratios (SNRs), the MRC algorithm outperforms the CMA for weak signals. An adaptation strategy is implemented that is substantially controlled by the CMA for strong signals and substantially controlled by the MRC algorithm for weak signals. The transition between the two algorithms is accomplished by controlling the weight of each algorithm's contribution to according to the received signal strength.

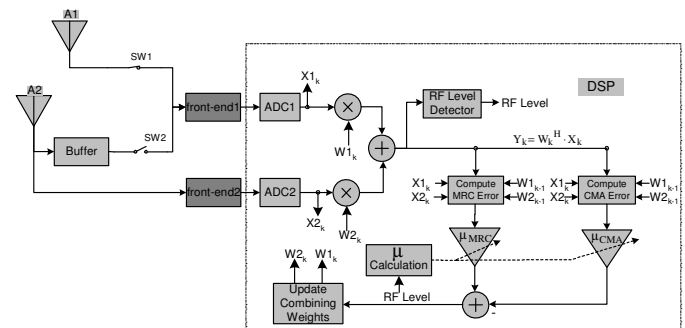


Fig. 6: Hybrid MRC/CMA algorithm

For strong signals, $\mu_{CMA} \gg \mu_{MRC}$, the adaptation is substantially controlled by the CMA. For weak signals, $\mu_{MRC} \gg \mu_{CMA}$, the adaptation is substantially controlled by the MRC algorithm as shown in Fig. 7.

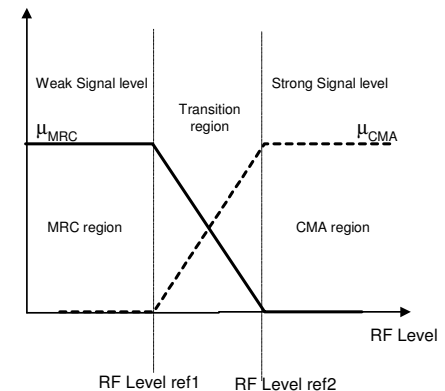


Fig. 7: Adaptation strategy between MRC and CMA based on received RF level

The output Y is given by

$$Y_k = W_k^H \cdot X_k$$

and the equation to update the weight vector W is