

Low Cost Switched Diversity System

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ABSTRACT

This paper presents a low-cost switched diversity receiver system utilizing a single tuner, simple remote antenna unit and one RF cable. The switched diversity algorithm is implemented in the receiver using digital signal processing. The remote unit contains RF switches that select from multiple antenna elements in response to a control signal from the receiver. The control signal is sent from the receiver to the remote unit via the RF cable. Simple logic in the remote unit provides decoding for switch control.

INTRODUCTION

Diversity reception in mobile communication systems has been reported in the literature [1-7] to reduce audio distortion due to fading. The primary purpose of a diversity system is to improve reception performance under both fading and weak signal conditions. A diversity system employs two or more uncorrelated receiving antennas (providing different directionality and delay for the received signal). Phase diversity systems can offer greatly improved reception by coherently combining the antenna signals [6]. However, these systems are more costly because of the additional RF circuitry or the use of a separate tuner for each antenna. Switched-diversity systems are the most cost-effective diversity systems utilized by automobile manufacturers. Classically, these systems include an FM receiver and switched diversity remote unit. The remote unit receives a feedback intermediate frequency (IF) signal from the receiver and it possesses an intelligence block to select the least distorted antenna signal. This paper discusses the current systems that are used in some vehicles and introduces a low-cost switched diversity system that

further reduces the complexity of the remote unit by moving the intelligence to the receiver side. Section I presents currently deployed FM-switched diversity systems utilized in vehicles, section II discusses a new proposed system and section III shows an FM system implementation example.

I. CURRENTLY DEPLOYED FM SWITCHED DIVERSITY SYSTEMS UTILIZED IN VEHICLES

Fig. 1 shows an implementation of a classic FM switched diversity system in vehicles. The system includes a single FM receiver with buffered 10.7MHz intermediate frequency (IF) output to feed the remote diversity module. The remote diversity module contains all the intelligence needed to select the least distorted available antenna signal. The remote module contents are described briefly next. The FM IF demodulator and antenna decision block determines the quality of the selected antenna signal. If the signal quality of the selected antenna falls below a threshold level, the logic block selects a new antenna. Usually the IF demodulator is an analog IC that produces two outputs, an FM demodulator output and a level output. The decision block is another analog IC that determines the quality of the signal based on the demodulator outputs.

This interface between the receiver and remote module requires two expensive RF cables, one for the RF input to the FM receiver and one for the 10.7MHz IF feedback signal. Note that the front-end of the receiver consists of an impedance matched low noise amplifier, an image reject filter, automatic gain control (AGC), down convert mixer and local oscillator.

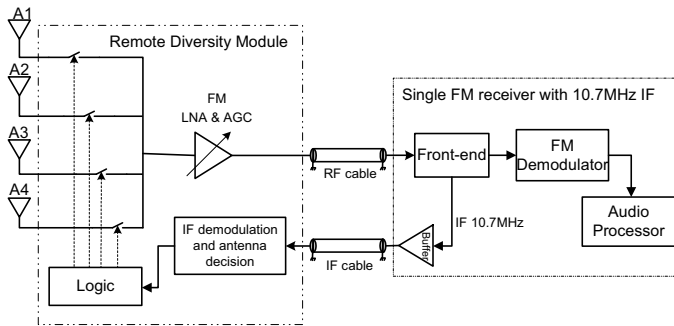


Fig. 1: A classic switched diversity system with two RF cables

To reduce the cost of the above-mentioned system, the RF cable that is used for the 10.7MHz feedback can be eliminated if IF signal is superimposed on the RF cable as shown in Fig. 2. The RF cable carries the RF signal, the IF signal, and a DC control signal (if needed for AM or FM mode indication, not shown in Fig. 2). A crossover network is added in both the FM receiver and the diversity module unit to separate the RF and IF signals at each end. Adequate signal isolation between the RF and IF can be provided by using low cost discrete inductors and capacitors. Less expensive, non-custom passive parts provide sufficient selectivity due to the large frequency difference between RF and IF.

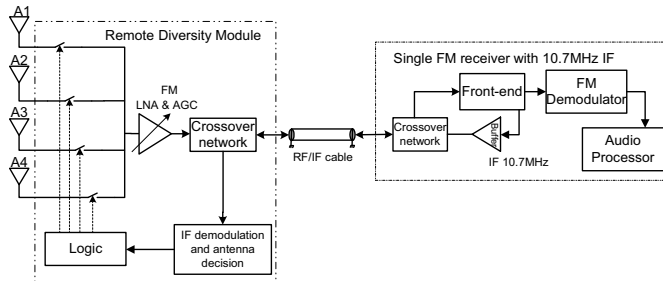


Fig. 2: A classic switched diversity system with one RF cable

A classic switched-diversity system relies on a 10.7MHz IF signal as part of the antenna feedback decision loop. However, modern receiver architectures, such as very low IF (VLIF) and zero IF (ZIF) no longer provide the traditional analog IF signal. It is preferred to implement the switched diversity system in a manner that is compatible with these new receiver architectures.

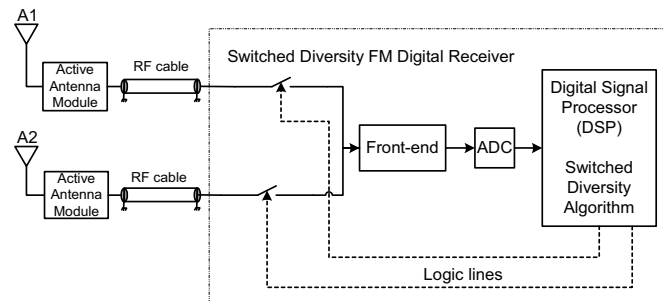


Fig. 3: A two-antenna/cable system with switched diversity implemented in the FM digital receiver.

As new vehicles utilize digital FM receivers with switched diversity algorithms in a digital signal processor

(DSP), some designs utilize two RF cables as shown in Fig. 3, in a two-antenna system. Although the DSP algorithms provide improved performance, this is not a cost-effective design, especially for greater than two antennas, because it requires a separate cable and linear amplifier for each antenna.

II. LOW COST SWITCHED DIVERSITY SYSTEM ARCHITECTURE

The general block diagram of the proposed system is shown in Fig. 4. It utilizes one RF coaxial cable for both the selected RF signal and the logic signal fed back from the digital FM receiver. All the switched diversity algorithms and decision logic are implemented in the DSP. The DSP implementation is more flexible than an analog structure because of the many features that can be included as part of the software. Features include antenna ranking, antenna history, and reduced switching rate in situations where all antenna signals are poor, just to mention a few. The decoder block in the remote diversity module is low cost and simple to implement. This represents a substantial reduction in cost and complexity of the more traditional remote switched diversity module. This is an attractive solution for vehicle manufacturers who wish to improve their current single-antenna on-glass systems at small additional cost. Single antenna on-glass systems usually have an active module which includes a linear amplifier and matching network. The same module can be modified to include low cost RF switches and logic circuitry to implement the low-cost diversity concept. Additional antennas may be printed on the same glass with short wires connecting the antennas to the module. This concept readily extends to greater than two antennas.

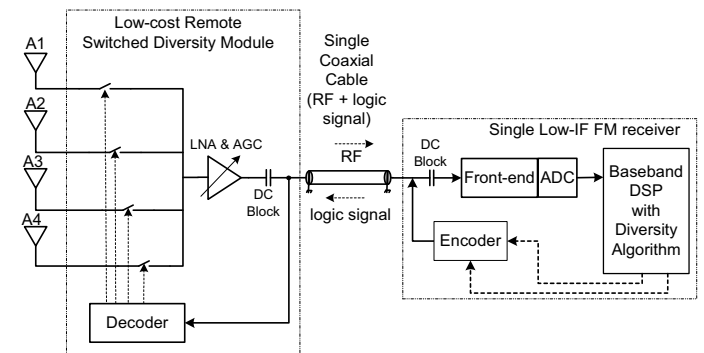


Fig. 4: The proposed low-cost switched diversity system

Referring to Fig. 4, the antennas are most likely to be implemented in the back glass of the vehicle for an FM system to reduce cost. The remote diversity module is mounted near the antenna feed points, as it does today.

III. FM SYSTEM IMPLEMENTATION EXAMPLE

A packaging implementation example in a vehicle is shown in Fig. 5 where two FM antennas are printed on the back glass. The antenna feed points are connected to the diversity module via short wires (called "pigtailed")

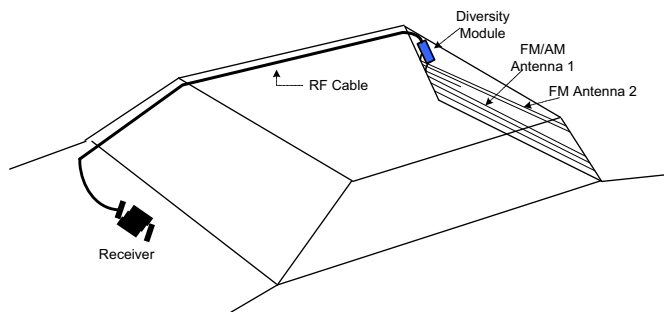


Fig. 5: Vehicle packaging example for a low-cost switched diversity FM system.

Glass antennas tend to be more directional and have lower average gain than a mast antenna. However, with careful design and proper matching techniques, glass antennas can be very effective in receiving RF signals, especially when used in a diversity system. Glass antennas have the advantages of lower cost and higher reliability. Fig. 6 shows the horizontal polarization gain patterns for two FM antennas measured at 100MHz. In the absence of signal impairments, an ideal selection diversity (SD) system will select the antenna signal with maximum instantaneous gain. For example, at azimuth angle 180 degrees, it can be seen that Ant1 experiences a fade while Ant2 has higher gain at the same azimuth angle. Therefore, Ant2 is chosen at this instant.

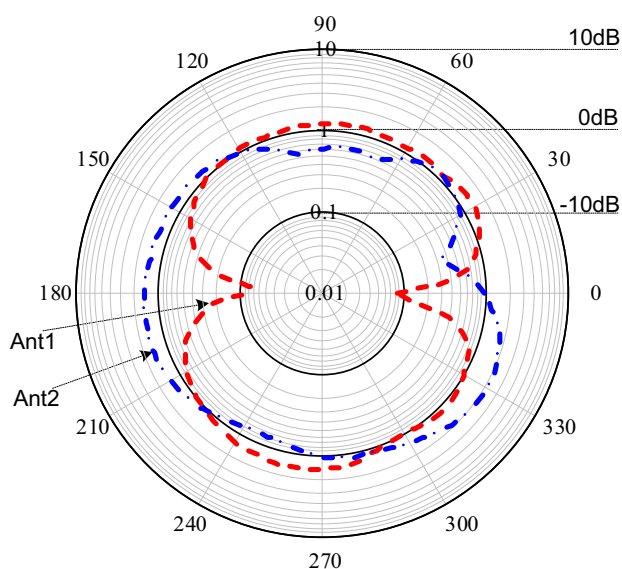


Fig. 6: Azimuthal, horizontal polarization antenna gain patterns for two FM on-glass antennas .

LOGIC IN RECEIVER AND REMOTE DIVERSITY MODULE

The antennas are selected by using a controlled current source in the receiver as shown in the Fig. 7. This current is sent from the receiver on the coaxial cable to the remote diversity module where it is decoded using a comparator ladder (or equivalent circuit). To allow

antennas to be selected in any order and to avoid the need for state memory in the remote module, discrete current levels are used that correspond to the individual antennas. For example, if n antennas are used, then n different current levels are required. By using current, instead of voltage, this method is less sensitive to ground offsets between the receiver and the antenna module. The stateless design simplifies remote module and eliminates potential "confusion" – that is, the DSP is certain which antenna is selected.

The selection of antennas in arbitrary order (vs. sequential) order is advantageous, particularly in digital systems, because of the relatively large transport delay of the signal path. The forward delay fundamentally limits the closed loop bandwidth (selection rate) and direct access can help to address this limitation.

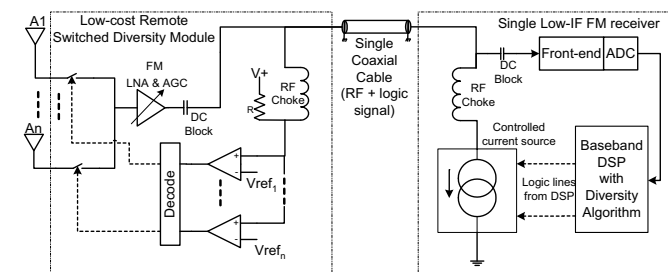


Fig. 7: Block diagram implementation of the control logic signal

SWITCHED DIVERSITY ALGORITHM IN DSP

Fig. 8 shows the input signals to the switched diversity algorithms. They are the RF level signal and FM demodulator output (MPX) signal.

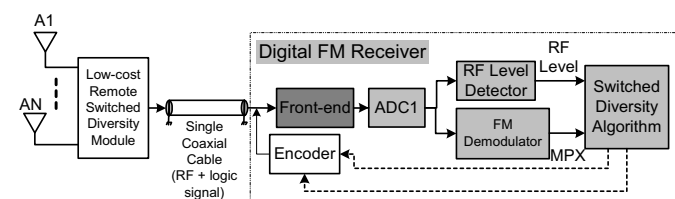


Fig. 8: Detailed block diagram showing the input signals to the switched diversity DSP algorithm.

Under the assumption that switching between antennas does itself not degrade the quality of the final audio output signal, an ideal switched diversity system would select the antenna with the maximum instantaneous quality. However, in a switched diversity system with a single receive path, it is impossible to 'preview' the quality of a particular antenna. That is, there's no way to assess the quality of an antenna without actually listening to it. This is referred to as the "leap before you look" problem - the system must first "leap" (to a different antenna) then "look" (assess the quality). Therefore, it's impossible to realize the ideal algorithm with this fundamental limitation. If the signal quality changes slowly compared to the time it takes to assess the quality and the quality assessment can be 'stealthy' (not noticeable) then a practical system can be designed.