

Multi-Way Diversity Reception for Digital Microwave Systems

White paper



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1. General Information

1.1. About this document

This white paper describes the benefits of multi-way diversity receive systems and details the differences between various implementation methods.

1.2. Acknowledgements

All the best endeavors have been made to acknowledge registered trademarks and trademarks used throughout this document. Any notified omissions will be rectified in the next issue. Registered trademarks and trademarks used are acknowledged below and marked with their respective symbols. However, they are not marked within the text of this document.

2. The Need for Diversity Reception

The significant performance differences between analogue FM and digital COFDM modulation schemes when used in microwave transmission systems, particular under non line of sight or mobile conditions, are well proven. Broadcast Microwave Services, Inc. (BMS) believes significant overall system performance can be gained by the implementation of advanced diversity reception techniques. These techniques overcome the problems of flat fading typically experienced under severe multi-path conditions where basic COFDM implementations cannot survive.

2.1. Flat fading and multi-path

Flat fading is caused by multi-path and occurs when the path difference between two signals arriving at the antenna are small, making the resulting phase differences sufficient for the signals to combine destructively across the entire signal bandwidth. The exact phase relationship and thus the degree of cancellation will vary from position to position, allowing an antenna at location "A" to experience severe destructive cancellation, and an antenna at location "B" to experience constructive addition. The distances involved depend upon the frequencies used for transmission and can be very small.

Diversity techniques aim to improve reception performance by allowing more than one antenna to be used with a common receiver. These antennas are either spatially separated by an appropriate distance or have directionality and be focused in different directions. Typically, a combination of both configurations are used.

2.2. Diversity reception

There are many reasons why it is desirable to utilize multiple antennas in this way. This includes countering flat fading and providing the gain benefits of using multiple directional antennas to replace a single omni-directional type.

It is evident in mobile environments where flat fading can be a particular problem that the selection of the best antenna on a dynamic basis will provide a considerable operational advantage. Another advantage is the ability to use multiple high-gain antennas to replace a single omni. By definition, omni-directional antennas provide very little gain (typically 5 dB). Substituting this scenario with four sector antennas that typical offer 16-18 dB clearly presents an operational advantage. A diversity receiver allows this to happen with the seamless selection of the best antenna, and in mobile environments eliminates the requirement to manually switch between antennas as the position of the mobile transmitter changes.

3. Diversity switching technologies

Receiver diversity is the topic of much discussion within the broadcast industry and is a matter that is often poorly understood. This is largely caused by the numerous methods available to implement diversity, which range from crude designs that offer little or no benefit in mobile applications to the highly sophisticated approach deployed in the BMS DR2000 and DR6000 receivers. These products utilize a purely mathematical process within the FFT to achieve maximum ratio combining within the equalization stage of the demodulator. This optimal performance technique reaches the theoretical limits for diversity and leaves other, less advanced applications far behind.

We have outlined the 3 most commonly used configurations to show how the BMS solution dramatically outperforms other diversity methods.

3.1. Common methods of implementing diversity

The fundamental aim of a diversity receiver is to select the best antenna to automatically and dynamically recover the highest possible signal quality. The following three methods, which are all used on commercially available receivers, achieve this in very different ways and achieve differing levels of performance and technical complexity in the process.

These methods are:

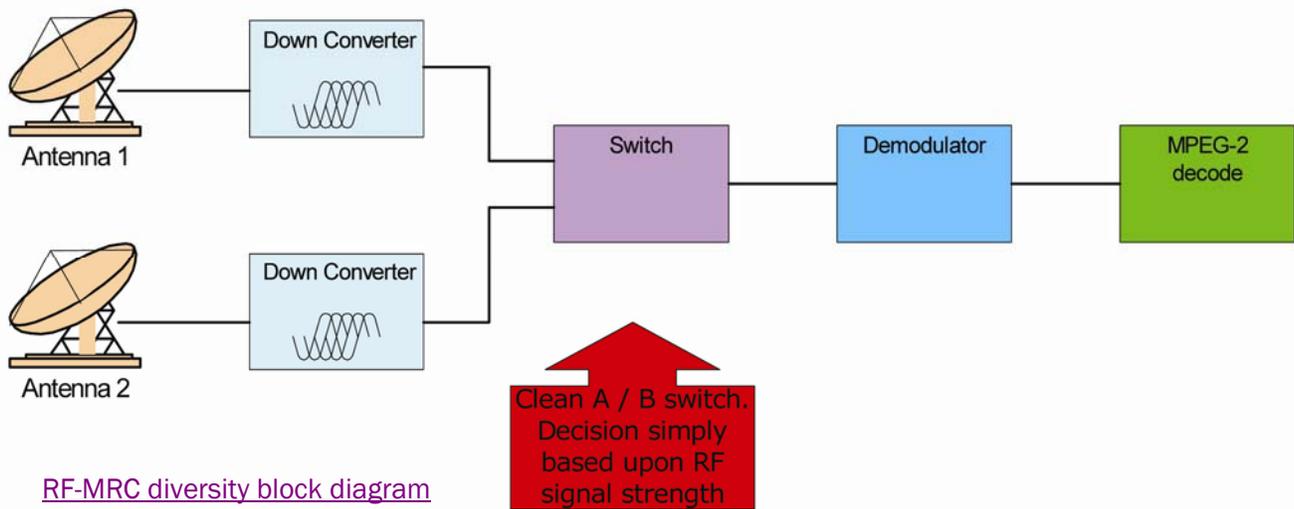
1. RF switch maximum ratio combining (RF-MRC)
2. Packet level switching
3. FFT maximum ratio combining (FFT-MRC)

Of these three, FFT-MRC provides by far the best performance but at the cost of technical complexity. This is the method implemented by BMS in a COFDM diversity receiver specifically designed for the mobile market.

3.1.1. RF-MRC diversity

RF-MRC is the most basic implementation of diversity. It utilizes two or more RF down-converters and selects between them on the basis of received signal strength, usually based simply on AGC.

This type of system is best suited to providing redundancy over fixed links. It is not suitable for non line of sight path systems or those in mobile environments where signal levels change at a rapid rate and the multi-path component has a high level of phase changes.



3.1.2. Packet level switching

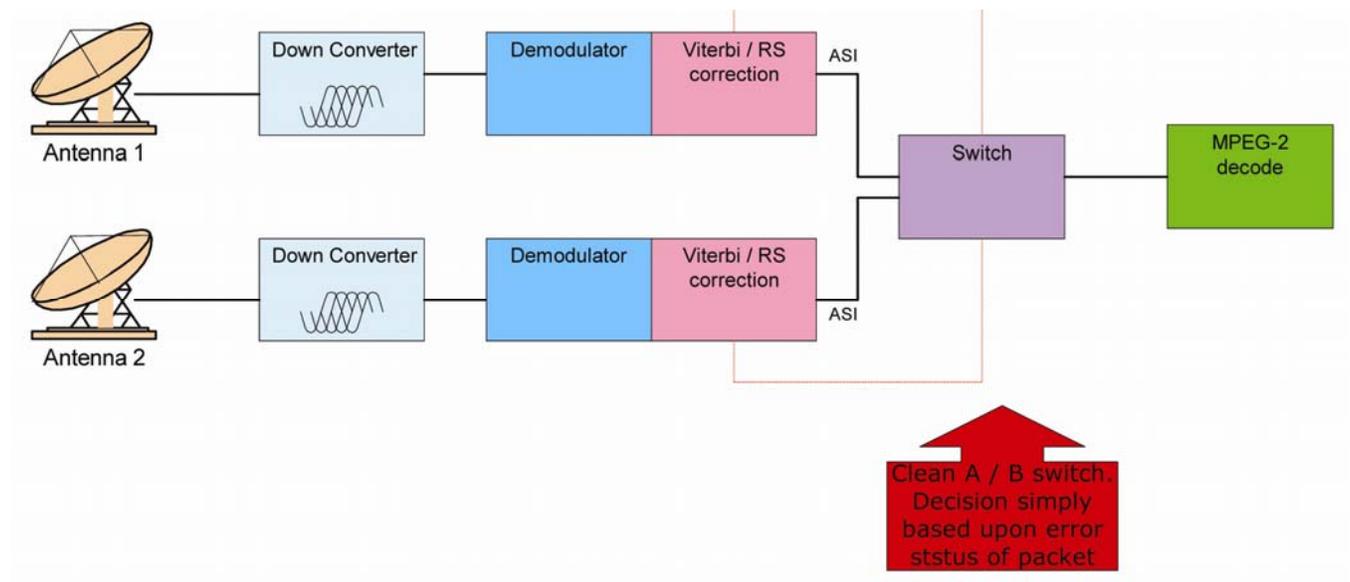
Packet level switching is a better alternative to RF-MRC and operates at the transport stream level once the RF signal has been completely de-modulated. A receiver employing this technique consists of multiple receivers, each outputting the recovered transport stream into a switch.

The switch is controlled by the error correction process, which ensures that only error-free packets (if available from any of the sources) are selected and passed to the MPEG decoder.

Packet level switching is efficient and effective under most conditions. However, it operates by making a clear selection at the packet level between the available receiver/demodulator chains. Ultimately, it fails to deliver the best possible performance because it cannot combine the signals received by the various antennas to improve by re-constructing an RF signal that has been severely degraded by multipath.

The packet level switching diversity technique is a method implemented by a number of manufacturers and does provide a performance increase over single channel and RF-MRC diversity reception. But it can only select the best signal available after the demultiplexing process. It can not make the best even better, which is a property unique to the FFT-MRC technique implemented by BMS.

Packet level switching diversity block diagram



3.1.3. FFT-MRC

FFT-MRC diversity is the most technically complex method and effective method. This technique is implemented into the DR2000 (2 input) and DR6000 (6 input) diversity receivers.

A receiver using the FFT-MRC technique has a dedicated tuner for each of the antennas feeding into a common demodulator specially designed to support FFT diversity.

Typically, the demodulator performs both of the FFT and channel equalization processes. The importance of channel equalization is key in an FFT diversity receiver. It utilizes pilot carriers and other information to assess the condition of each of the individual 2K carriers (which encompasses a mathematical "confidence value" relating to the level of perceived degradation and the confidence that the data within the carrier is correct). A diversity algorithm then assesses the separate confidence values returned for each input and carrier so that it can decide the ratio of which of the antenna inputs is combined, on a per-carrier basis.

This creates the possibility to re-construct each carrier providing the best possible signal for demodulation and then error correction by the subsequent Viterbi and Reed Solomon stages.

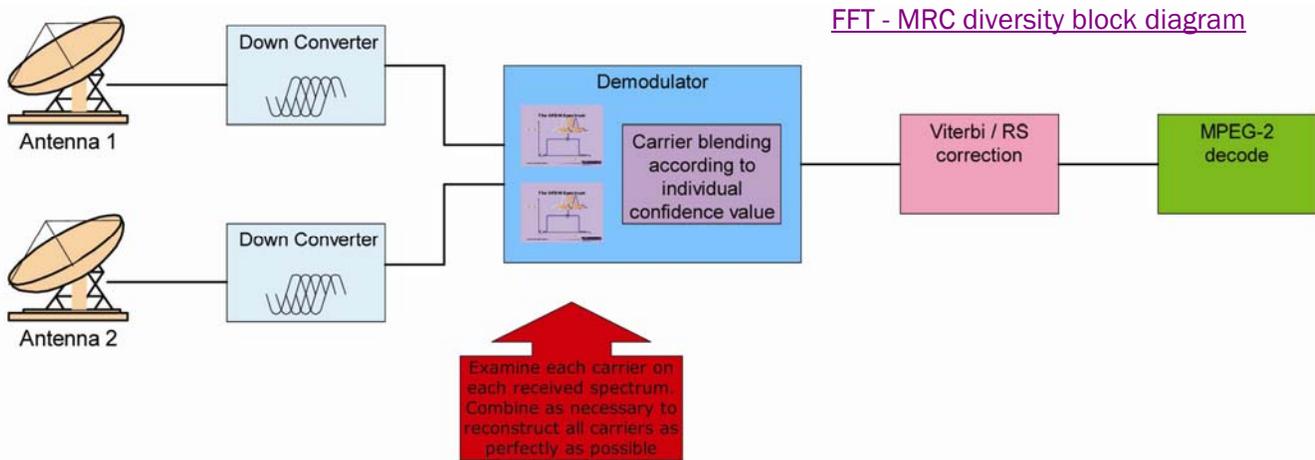
FFT-MRC is able to out-perform all other types of diversity switching because it is possible to use the output of any antenna in part or full combination to re-construct a damaged signal. This technique can be used to implement a very effective fully automatic diversity system, as there is no hard switching between inputs, thus allowing clean and progressive transitions to occur between antennas.

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4. Applications for diversity

The FFT-MRC diversity technology as described above can be used to provide significant system gains in a number of practical applications.

4.1. Wireless camera reception

Advanced diversity techniques can be used to significantly improve the performance of low power wireless camera systems that are often used in non-line of site applications and fast moving multi-path environments. Careful positioning of multiple antennas and the use of FFT-MRC diversity has proven to significantly improve the coverage area of such systems.

In addition, Broadcast Microwave Services, Inc. has proven the reliable use of 16 QAM modulation in the CT2001 wireless camera system when used with FFT-MRC based diversity receive systems. This is significant as it allows the use of higher video bit rates than were previously available with systems that were forced to use QPSK modulation to provide the required RF coverage.

4.2. Automatic central receive site operation

The characteristics of FFT-MRC diversity can be used to provide a fully automated diversity system switching between multiple numbers of antennas at a single receive site.



Flat Panel Antenna Mounted at Receive Site

A typical installation consists of 4 or 5 flat plate antennas, each with 17 dBi gain, to provide 360-degree coverage. Each antenna is connected to a separate down converter whose UHF output is fed into one input on the DR6000 6 way diversity receiver. The DR6000 automatically sums the signals received from multiple antennas and use the FFT technique to ensure the best possible combination and MER is achieved.

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Extensive field trials in real live ENG environments have proven that ENG trucks can go to any transmit site around the central receive facility and the fully automatic diversity process selects the correct antennas without any operator intervention.

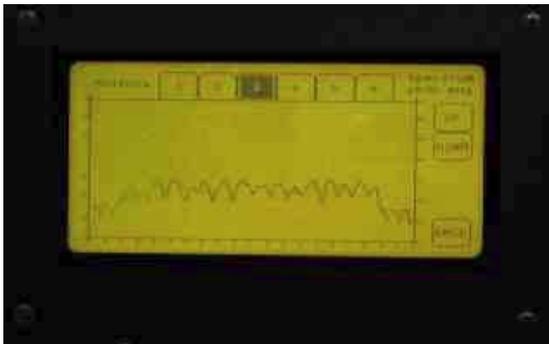
The images below show the signal received on the multiple inputs of the DR6000 from a 4 watt ENG van over an 8 Km non line of sight path.



Input 1



Input 2



Input 3



Input 4



Input 5



Summary screen

Multiple input diversity reception also eliminates the need to manually track or switch between antennas as the position of a mobile transmitter, such as a helicopter or moving car, changes.

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Multi-channel ENG operation is possible by feeding the UHF output of each block down converter in to a distribution amplifier. A number of diversity receivers, each tuned to a separate UHF channel, can be fed with the outputs of the amplifiers. Since the antennas are not physically switched, each receiver will automatically sum the OFDM signals available on its own RF channel without interfering with the operation of other receivers.

The use of high gain plate antennas gives more than adequate coverage for normal operation. Trials have shown paths of up to 90 Km are possible using normal ENG equipment. However, if higher gain directional antennas are required to be used, then they can be connected to the 6th port on the DR6000 receiver. This port may alternatively be connected to an up look antenna for situations where a helicopter may over fly the central receive site. In either situation, any signal from the antenna is used in the diversity summing process.

4.3. Area wide mobile reception

An extension of the seamless automated switching between antennas can be used to implement automatic hand over between a number of antennas mounted on separate receive sites across a city or urban area. The OFDM signals from the receive sites feed via fibre to a central diversity receiver which provides an output base summed from all received signals.

4.4. Improved link reliability

2-channel diversity can also be used to improve the reliability of fixed links where flat fading, due to weather or environmental conditions, are a problem. For example, microwave links are sent over a sea or mountainous path and the reception of standard DVB-T transmissions are located at a remote repeater transmitter site.

Two antennas spaced at greater than one quarter wavelength apart and fed into the separate inputs of a 2 channel diversity receiver will provide protection against link failure due to flat fading.

5. Diversity implementations

Broadcast Microwave Services has implemented 2 way and 6 way FFT-MRC diversity in products suitable for both Central Receive site and portable applications.

DCR 2000 (2 way) and DCR 6000 (6 way) Diversity Receiver



Designed for use at ENG central receive sites, the DR2000 and DR6000 both employ a dual IF/RF AGC control with 70 dB dynamic range and will typically produce a C/N improvement of 6-9 dB for a 2 way diversity system over a standard single channel receiver.

The front screen touch panel has a selectable separate spectrum analyzer display, MER and c/n readout for each input. Both units have 2 ASI outputs and an RS232 port which enables the spectrum displays and received signal parameters for viewing on a PC at a remote site.

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2-Way Diversity Portable Receiver



The DR2100 2-way diversity receiver is DC powered and compact in size. It is fully self-contained with built in down converters making it ideal for use on portable links and for wireless camera reception.

TT1260 2-Way Diversity Receiver

The TT1260 is now available as a 2 input diversity receiver, bringing all of the benefits of FFT-MRC diversity as well as a full range of professional broadcast output interfaces and scrambling options.

It is ideal for use in both fixed link and DVB-T repeater applications as well as any ENG applications when used with external microwave down converters.

6. Conclusions

COFDM offers significant improvements over analog FM modulation techniques, especially in a mobile environment.

Diversity reception presents the potential to increase optimal system performance of COFDM systems particularly when receiving mobile or non-line of sight transmission. However, it should be noted that there is a considerable difference between the 3 diversity methods and their implementation in reception systems.

BMS has developed an advanced implementation of the FFT-MRC diversity technology which offers a significant improvement on system performance that is now possible to use 16 QAM modulation for mobile transmission in circumstances where it was only previously possible to operate using QPSK.

The correct implementation of diversity reception offers users the opportunity for RF coverage performance improvements, delivering considerable operational benefits through ease of use, and the ability to run higher payloads through more reliable link performance.

7. Further information

For further information on Broadcast Microwave Services' diversity implementations, ENG and Wireless camera systems and products, please contact us at the address below. We will be pleased to send you a CD-ROM containing video clips showing the comparative performance of single receive and multiple diversity COFDM systems.

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