AVALON RF

Wireless Solutions
For Audio & Video Links

# Application Note 1 – AN1

## The differences between single antenna, antenna switching diversity, RF mixing diversity, true diversity and Space-Time diversity receivers.

**AV010310/1-000**
**REV. X2 December 3, 2003**


Authored by Eli Weinstein
Prepared by Steve Jones

http://www.avalonrf.com/
Avalon RF, Inc. • 344 Coogan Way • El Cajon, CA 92020
Phone: (619) 401-1969 • Fax: (619) 401-1971 • Email: sales@avalonrf.com

## 1. Introduction

Reception at frequencies from 470MHz and higher is degraded by:

- Other users that transmit on the same channel. Severe at ISM bands of 900MHz, 2.4GHz and 5.8GHz.
- Channel fading caused by humidity and vegetation in the path from the transmitter to the receiver. Severe at 2.4GHz.
- Signal reflections from nearby objects called multi path distortion. This distortion can originate from moving objects, such as cars driving on the road, rotor blades of a helicopter and reflections from sea waves.

Diversity receivers overcome and/or compensate for many of these signal degradations at the penalty of complexity and cost.

There are multiple types of diversity:

- Frequency Diversity (FD). A link transmitting the same signal over multiple channels at different carrier frequencies. OFDM is one variant of FD. This method is spectrum inefficient.
- Time Diversity (TD). A transmitter transmitting the same signal multiple times and/or using Forward Error Correction. This method reduces the channel capacity.
- Space Diversity (SD). A receiver with multiple antennas, all tuned in to the same transmitter.

There are multiple space diversity receiver technologies, each with its advantages and disadvantages over no diversity single antenna receivers:

- Antenna switching diversity.
- RF mixing diversity
- True diversity
- Space-time diversity.

**AN1 focuses on space diversity receivers and describes the advantages and disadvantages of these popular diversity receiver technologies (compared to single antenna receivers) when used with NTSC/ATSC/PAL signals.**

## 2. Single antenna receivers

This is the simplest form of a receiver. **<u>It has one antenna and a single tuner</u>.** It is best suited for fixed transmitter and fixed receiver links with a clear line of sight.

**Its advantages are:**

- Simplicity
- Smaller size
- Low cost

**If operated in a mobile environment, its disadvantages are:**

- Requires omni directional low gain antennas, thus limiting the effective operating range for a given power level.
- Poor signal quality in the case of interference in the path from the transmitter to the receiver.
- Cannot compensate for multipath distortion very well.

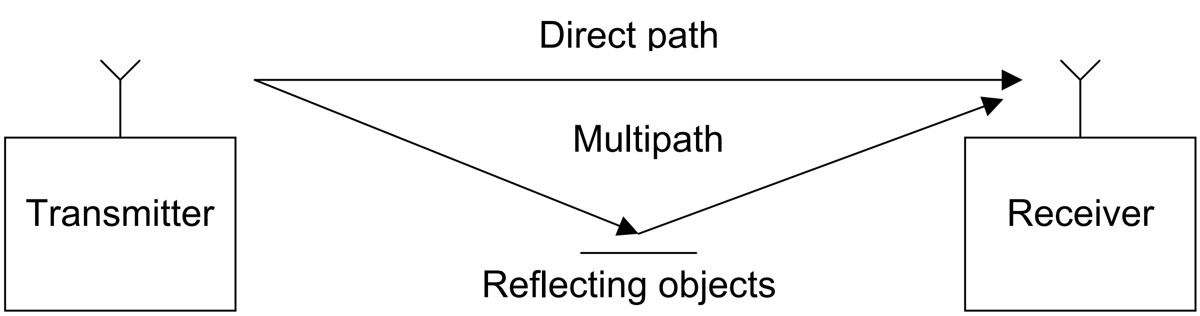
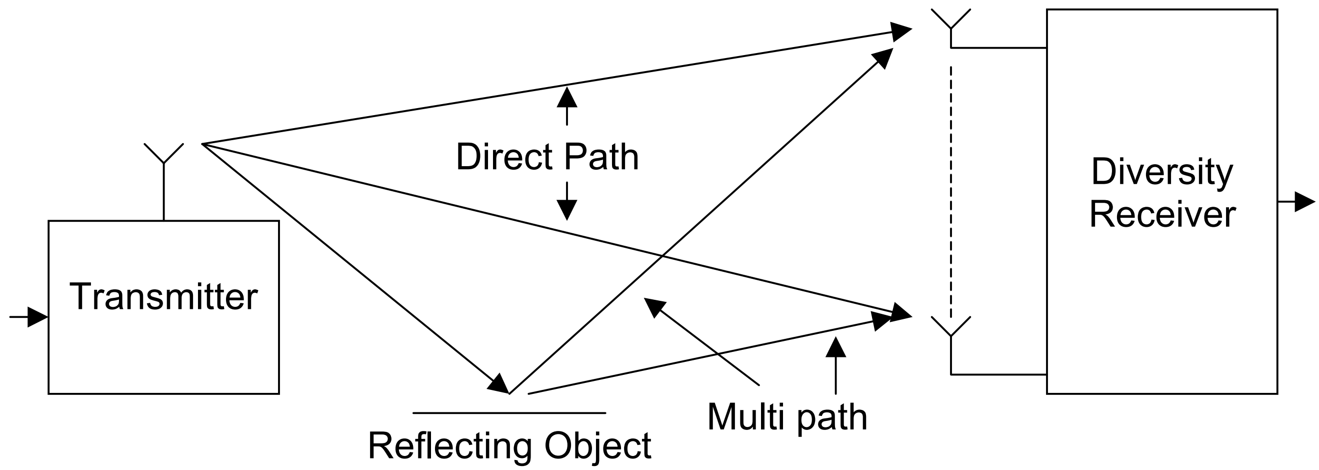



**Figure A – Single Antenna Receiver**

## 3. Space Diversity receivers

All space-diversity receivers have **multiple antennas and a receiver capable** of receiving from all the antennas.

**Figure B – Space Diversity Wireless Systems**




### A. The problem – Multi path distortion

A1 **Basics.**
The multi path (from the reflecting object) is longer than the direct path, delaying the multi path signal. The delay may cause the multi path signal to show up in phase or out of phase at a receive antenna. If it's in phase, it adds to the signal from the direct path, otherwise it subtracts, reducing the signal to noise ratio at the receiver.

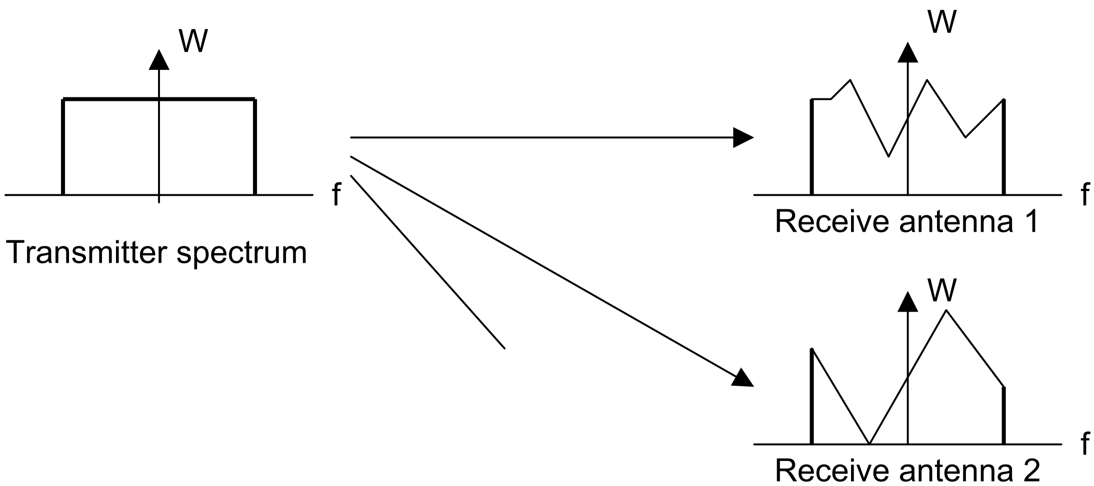
A2 **Multi path distortion of broadband signals.**
In the case of broadband transmission, the multi path signal will degrade only a portion of the spectrum of interest.

A3 **Multi path distortion of multiple reflecting objects**.
The degradation pattern gets complicated because there are numerous reflecting objects, located at different places, causing a highly complex add-subtract frequency domain pattern.

A4 **Multi path distortion of multiple reflecting objects in motion.**
When the transmitter, the receiver or the reflecting objects move, they cause a time variation in the distortion pattern and uneven Doppler shifts of the carrier in the direct path and the carrier in the various multi paths.

**B. The solution – Space Diversity (SD)**

**The basic principle of SD is that antennas placed at different physical locations will "see" a different distortion pattern.**




A SD receiver can always find an antenna that has the least amount of distortion or combine the signal from multiple antennas to reduce or eliminate the distortion at all.

**C. Notes on antennas used in SD systems.**

- The antennas must be spaced at least ½ a wavelength apart (of the minimum carrier frequency they will tune to).
- The more antennas (a receiver has), the better the probability of getting intermittent free reception. AVALON RF offers systems with 2, 4, 8 and 16 antennas diversity.
- Arranging the antenna array in space is an art by itself, having a great effect on improving reception and reducing interference.

## 3.1 Antenna-switching SD receivers

Antenna switching SD receivers connect multiple antennas to a single receiver via an antenna switch. At regular intervals, the receiver stops receiving, switches between the various antennas and selects the one with the “best” signal as input.

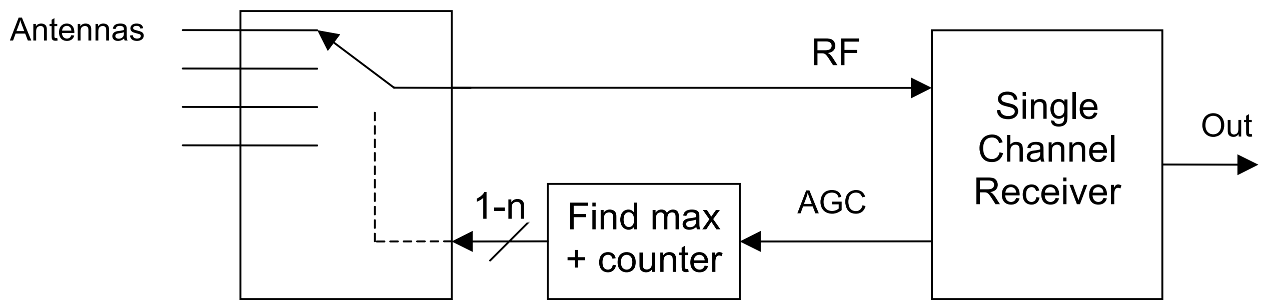



**Figure C – Block diagram of an Antenna-switching receiver**

For video systems, this antenna “scoring” is usually done during the vertical blanking period. The receiver switches to one antenna at a time; “looks” at the signal and with some scoring equations defines the signal quality. After testing all the antennas, it will switch to the one with the highest score.

**The advantage of antenna switching diversity receivers is:**

- Allows redundancy. If one antenna fades out, there is a fair chance another antenna is still receiving.

**The disadvantages of antenna switching diversity receivers in video applications are:**

- While the selection logic scores the antennas, there is a signal discontinuity in the video and audio outputs.
- The selection logic has a very short time to score channel/antenna quality (part of vertical blanking), resulting in poor scoring decisions.
- The antenna switch reduces the signal to noise ratio of the entire receiver by a few db.
- The antenna switch is limited to three or four antennas, otherwise the discontinuity in reception is too long.
- Video quality not admissible in court, because of the reception discontinuity.

### 3.2 RF Mixing space-diversity receivers

A RF mixing diversity SD receiver has one tuner per antenna. The diversity electronics is measuring the IF RMS signal (similar to AGC measurements) and blends the IF output of both tuners at a variable ratio prior to demodulation.

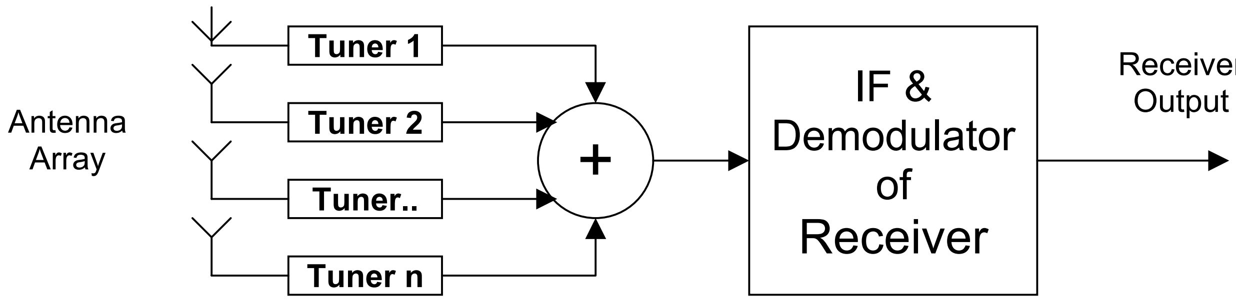



**Figure D – Block diagram of an RF mixing diversity receiver**

The IF output of all tuners is added at a ratio that corresponds to the relative signal strength (AGC), similar to the antenna switching receiver, and fed into a single IF strip and demodulator.

The advantages of a RF mixing receiver are:

- Better signal to noise ratio than antenna switching. All antennas participate in the reception. A receiver with two antennas and tuners has a 3db gain.
- Continuous reception.
- Lower cost than true diversity and space-time diversity receivers.

The disadvantages of a RF mixing receiver are:

- The strongest signal is not always the best. The receiver may not output the best possible signal.

### 3.3 "True Diversity" SD receivers

True diversity receivers have a tuner for every antenna and perform the diversity function in **baseband, after** the signal demodulator.

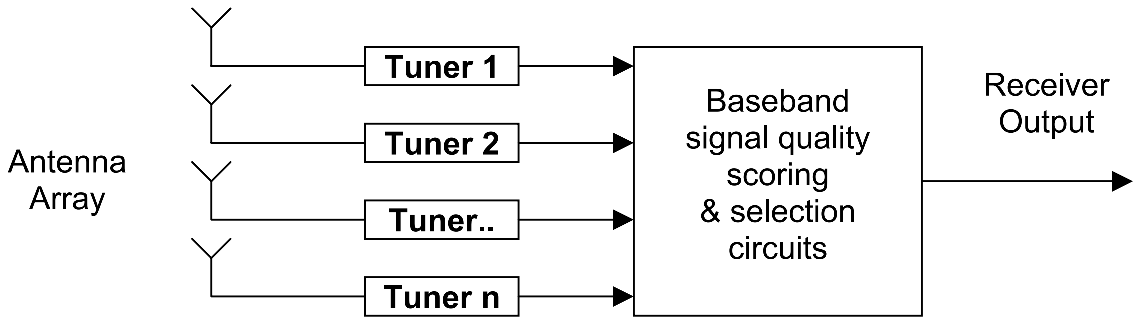



**Figure E – Block diagram of a True Diversity Receiver**

The scoring logic looks at the baseband signal from each and every tuner all the time, creating an AVERAGE score for each antenna/tuner and switching to the best tuner right after the vertical sync, in the back porch period of the vertical blanking interval.

The AVALON RF scoring function includes the following:

- Signal Strength
- Number of missed sync pulses or faint sync pulses due to fading.
- Number of excessive sync pulses due to poor signal quality, noise and multipass distortion.
- Indoor/outdoor service correction factor to avoid frequent switching between two antennas that have an almost identical score.

Switching the signal is done at the output of the tuner in an instant (and during horizontal or vertical blanking) without any degradation to the signal to noise ratio of the receiver.

AVALON RF true diversity technology can be used with no tuners to:

- Obtain a fiber optics diversity system.
- Create higher order diversity topologies to 8,16,64,128 and more antennas for one channel.
- Allow multiple transmitters to operate at the same frequency at the same site as long as the transmitters are spaced out.

### 3.4 "Space-Time diversity" SD receivers

Space-Time diversity receivers are software-defined radios **(SDR)** that have a tuner for every antenna and perform the diversity function in **baseband, before** the signal demodulator.

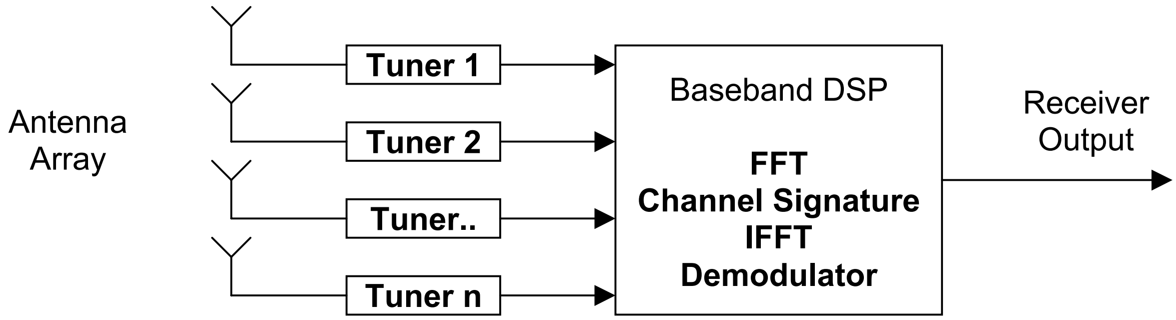



**Figure F – Block diagram of a Space-Time Diversity Receiver**

Space-time needs the transmitter to generate a periodic known calibration signal to perform "training" of the receiver to the varying channel transfer function. In case of NTSC/PAL or ATSC (DTV/HDTV) signals, the receiver can use the existing sync tips (every 16.7mSec) and the GC chirp signal in line 19 of the VBI.

The AVALON RF receiver computes the transfer function of the path between the transmitter and the receiver and compensates most, if not all, path distortions. The correction function is executed in frequency domain and is called the "Channel Signature Matrix" (Patent pending).

**The advantages of a space-time diversity receiver are:**

- Best possible signal to noise ratio. Receiver uses the signal from all antennas to create the output = 6db gain with a four antennas system.
- Cleans up most, if not all, multi path distortion.
- Compensates for receiver or transmitter motion by measuring Doppler shift and Doppler spread and shifting the spectrum back.
- Converts line of sight systems into non-line-of-sight systems by tuning in to the multi path signals in the absence of a direct signal.
- Eliminates jamming signals from unwanted directions.

AVALON RF space-diversity technology can be used with no tuners to:

- Obtain a fiber optics diversity system.
- Create higher order diversity topologies to 8,16,64,128 and more antennas for one channel.
- Allow multiple transmitters to operate at the same frequency at the same site as long as the transmitters are spaced out.

## Appendix 1 - Service Disturbances in UHF and Microwave

1. Over crowded spectrum.

2. Line of sight requirements.
   Operating in high UHF and microwave bands requires a line of sight between the transmitter antenna and the receiver antenna.

   Any large object directly in between, like stage scaffolding and props, or even a person walking right in front of either antenna, may disrupt the service.

3. Multi path and ghosting distortion.

   The transmitting antenna in mobile or semi mobile applications radiates its RF signal in a relatively wide angle. This signal can reach the receiver in a direct line and by reflections from metallic objects in close proximity to the direct line of sight. The reflections reach the receiver with a time delay, due to the longer distance they travel and will be OUT OF PHASE with the signal arriving in a straight line, reducing or adding to/from the overall signal strength.

   If the difference in distance is small (Short range radio links), it will cause multipass fading. If the distance is very large, it will cause ghosting.

4. Signal Fading.

   UHF and microwave signals are absorbed by humidity in the air, fog and rain. Operating in humid or wet climates (Like tropical climates around the equator) can significantly reduce the range of the radio link.

5. The advantages of diversity in overcoming these disturbances.

   - Redundancy.
     Having multiple antennas considerably improves the chance that at least one of them (At any given time) will not be subject to severe distortion.

   - Proximity.
     With multiple antennas placed at one site, one can control the proximity of the transmitter antenna (If mobile) to one of the receiving antennas at any given time during the take.

   - Active reduction in multipath.
     The amount of multipass and ghosting distortion can be engineered out with the use of narrow angle receiving antennas.