Eigen Wireless

# *Max-RF*™ *Rx*

## Breakthrough Fading Immunity, Receiver Intermod and Cochannel Interference Mitigation

Eigen extends range and throughput by 10X in interference burdened 802.15.4 and LMR/P25 wireless deployments supporting Military, Law Enforcement, Smart Grid, Medical and Industrial Remote Sensing.

## Standards-Compliant Smart-Antenna Systems for 802.15.4g and P25 Radios

***Max-RF*** ™ is a new smart antenna system consisting of unique antennas and receiver algorithms that can be incorporated into any radio design without system level or standards changes. By providing unmatched link budget improvements, RFIC and radio manufacturers can differentiate their industry-standards based products by licensing *Max-RF* ™.

**Performance:** As shown in Figure 1*, *Max-RF* ™ provides a 23dB improvement, at 1% PER, over single linearly-polarized receivers in high interference environments. When compared to Switched Polarization Diversity (SPD), *Max-RF* ™ provides a minimum of a 14dB improvement. Unlike switched diversity, *Max-RF* ™ finds the optimal SINR not just based on a subset in the preamble, but on the most appropriate a priori known packet structures.

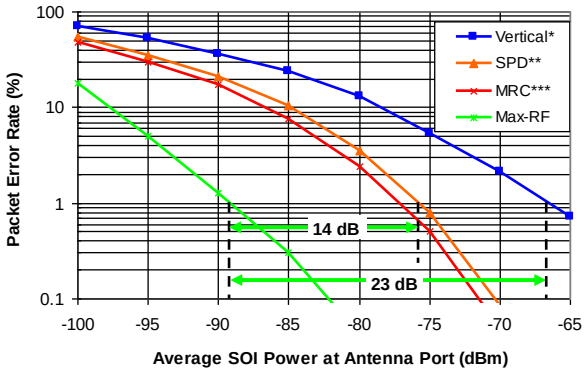


Figure 1: PER vs. Received Power

**Compact Algorithms:** *Max-RF* ™ is a two or more antenna combining technique similar to Maximal Ratio Combining (MRC) and Minimum Mean Square Error Combining (MMSC). Unlike both of these methods, *Max-RF* ™ does not require per-packet carrier recovery or long term carrier phase tracking to provide these SINR improvements. Therefore, not only is standards-independent *Max-RF* ™ applicable to non-coherent systems such as OOK and FSK, it is also able to provide per-packet interference mitigation on coherent Signals Of Interest (SOI) buried lower than 30dB in interference.

*Max-RF* ™ algorithms can be layered into any best-practice digital baseband architecture following the decimated ADC samples as shown in Figure 2.

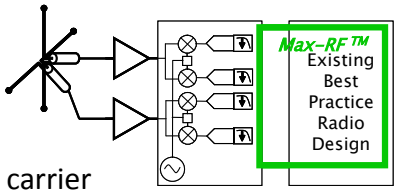


Figure 2: *Max-RF* ™ Integration

The computational load of *Max-RF* ™ is comparable to MRC minus MRC's required carrier recovery. For example, the *Max-RF* ™ closed-form optimal-solution and combining algorithms represent about a 3% overhead over the computational load required for synchronization and demodulation of a Project 25 (P25) packet. *Max-RF* ™ equations for a 192 symbol metering packet require just 200 µsec on an ARM M4 processor running at 25 MHz. *Max-RF* ™ is a per-packet adaptive algorithm without recursion, long term transmitter or channel state information, thus little memory is required.

**Unobtrusive Antennas:** Large antenna arrays, typically associated with smart antenna systems, are not aesthetically acceptable to police departments and homeowners in suburban environments.

Eigen's patented antenna designs solve the aesthetics issue with compact arrays contained in traditional vertical antenna form factors as shown in Figure 3.

Figure 3 Unobtrusive Antenna Arrays

Mobile police applications often involve "slick top" patrol cars. Eigen's arrays break up sight lines and are readily accepted by officers.

Many deployments require embedded antennas. Eigen's designers are able to integrate *Max-RF* ™ arrays in place of existing single antenna structures. Examples include meters as shown in Figure 4, remote sensors, handsets, laptops and tablets.

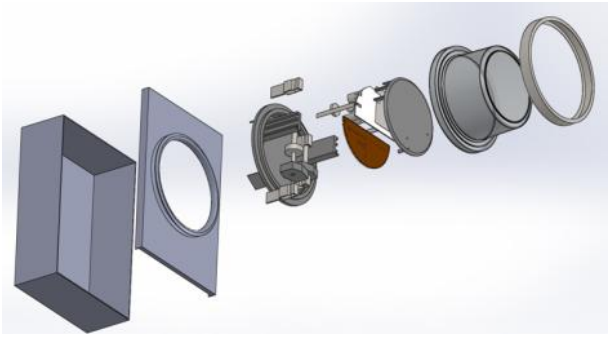

Figure 4 Custom *Max-RF* ™ Antennas

These custom *Max-RF* ™ enabling antennas can be embedded in any device currently supporting an antenna in the frequency band of interest.

An additional result of Eigen's emphasis on compact antenna structures is that traditional low cost antenna deployment methods are employed in *Max-RF* ™ enabled systems.

**Applications:** *Max-RF* ™ can be incorporated into any radio system. However, the critical nature of public safety and smart grid applications, with their associated interference problems, has focused initial *Max-RF* ™ integration efforts on these systems.

P25 radios have increasing cost pressures on the mobile equipment. Compliant adjacent band cellular base stations drive intermods in many nearby P25 radios. Cellular providers are forced to shut down compliant equipment, reducing capacity, to avoid disruption of public safety communications. P25 equipment manufacturers are reluctant to add costly band filters with sufficient performance to reduce their receiver intermods. The cochannel interference mitigation of *Max-RF* ™ also provides mitigation of receiver induced cochannel energy such as receiver intermods, IP2 and reciprocal mixing.

Advanced Metering Infrastructure (AMI) equipment and component suppliers must improve the performance and reliability of their un-licensed radio links as the RF environment becomes even more crowded with interference. They must also meet customer demands to conform to industry standards.
The patent pending *Max-RF* ™ technology solves both of these demands with ground breaking performance improvements which can be inserted into the best radio designs and overlaid on standards compliant radio systems.

A prototype system, consistent with P25 and 802.15.4 modulation formats, is available to demonstrate *Max-RF* ™ performance and allow interested RFIC suppliers and equipment manufacturers to evaluate applicability to their target markets.

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* **Signal Of Interest (SOI):** Uncorrelated Rayleigh-distributed power at each antenna input, with average power as shown.
**Interference:** AWGN, randomized for each packet:
Interference power at each antenna is uniform -116 to -81 dBm.
Polarization is approximately uniform over the Poincaré sphere.
Vertical is defined as any linear polarization (V, H, 45° etc.)
**Noise:** -111 dBm, each channel

** Ideal Antenna Selection for SPD (correlation over entire preamble), using *Max-RF* ™ antenna

*** Ideal Carrier Recovery for MRC, using *Max-RF* ™ antenna