WHITE PAPER:

Meeting the Challenge of Radio Interference in License-Exempt Bands

January 2009

I. Introduction

Interference – A Challenge for Wireless Communications in License-Exempt Bands

With increasing numbers of service providers opting to use license-exempt radio frequency (RF) bands, the need to understand methods for overcoming the challenge of interference - and selecting solutions that implement such methods effectively - is critical.

This white paper addresses the issue of interference in license-exempt bands and a number of approaches for its control and mitigation, with a focus on the product design elements necessary for delivering carrier-grade performance. By using products conceived specifically for delivering reliable service in license-exempt bands, service providers can overcome the challenge and deliver reliable services to their customers.

II. The Challenge of License-Exempt Deployments

Increasingly, service providers and system integrators are taking advantage of the benefits of license-exempt bands, both for situations where it is more cost effective and for areas where using these bands is the only viable solution. While license-exempt bands do offer the ability to deploy quickly and affordably, many environments have become crowded and services are sometimes affected by interference. Carriers must be certain that the systems they deploy can provide reliable service in such challenging environments and use deployment strategies that allow for co-existence with similar systems operating within the same geographical area.

While some sources of interference may be mitigated during installation and configuration on the day of deployment (via manual selection of the "best" channel at the time), new sources of interference may start to transmit at any time during the life of the product that may render unacceptable service. In license-exempt bands, sources of interference may include consumer and industrial products such as radio equipment, remote control units, motion sensors in security systems, radar installations and various RF devices. To deliver consistent service, carriers must employ a combination of intelligent planning and equipment that uses robust techniques for mitigating interference.

Meeting the Challenge – the RADWIN Solution

RADWIN's WinLink™ 1000 Family of high capacity carrier class radio systems has been designed to overcome the challenge of interference in license-exempt bands. By implementing advanced mechanisms and patented technologies, the WinLink 1000 is capable of relaying high bandwidth traffic in interference-laden environments with carrier-grade performance.

III. Provisioning Carrier Grade Service in License-Exempt Bands

At the core of the RADWIN WinLink 1000 system is a proprietary air interface protocol that enables carrier-class wireless TDM and Ethernet services in license-exempt bands.

To ensure high quality and reliable delivery of these services, the WinLink 1000 employs several mechanisms that work together to mitigate interference:

1. Automatic Channel Selection (ACS)
2. Automatic Adaptive Rate
3. Configurable Channel Bandwidth
4. Forward Error Correction (FEC)
5. Advanced Automatic Repeat Request (ARQ) Mechanism
6. Non-interrupted transmission
7. Hub Site Synchronization
8. Directional Antenna
9. Orthogonal Frequency Division Multiplexing (OFDM)

Mechanism 1: Automatic Channel Selection (ACS)

Automatic Channel Selection (ACS) is a mechanism by which the system ensures that transmission is performed in the best channel. ACS responds to interference by monitoring the available radio channels and then dynamically selecting a channel which is suitable for transmission at that time.

Once a channel is being used, the WinLink 1000 monitors that the service is being provided at acceptable quality. The threshold according to which a channel switch is performed is determined according to specific criteria, including the provisioned services, their required bandwidth and the level of interference.

Automatic Channel Selection is a key element for providing robustness in license-exempts bands. In particular, the "always on" nature of ACS is critical for mitigating the dynamic, non-deterministic interference common to these bands.

Mechanism 2: Automatic Adaptive Rate

Automatic Adaptive Rate is a method of dynamically adapting the transmitted rate by changing both the signal modulation and coding. Automatic Adaptive Rate optimizes the data throughput according to interference conditions, to optimize data throughput while maintaining the service quality.

When increased interference is detected, which could affect the quality of the link, the air interface rate is instantaneously modified to the most suitable rate. This decreases the Ethernet throughput temporarily while ensuring that TDM and Ethernet traffic is maintained, and that the link stays up. As the WinLink 1000 delivers both TDM and Ethernet traffic, the Ethernet throughput is reduced first so as not to affect TDM service. In addition, the overall effect of the automatic adaptive rate feature is increased quality of both TDM and Ethernet traffic, since retransmissions of failed packets are performed at lower rates, and therefore less susceptible to interference.

Whenever a change in rate reduction is necessary, both (a) the maximum available allowable rate is maintained and (b) the system returns to the highest possible rate as quickly as possible. This fast adaptation process does not affect services. Also, this mechanism always ensures the highest throughput possible according the current physical conditions.

The following example provides insight to how the mechanism works:

- A full duplex Ethernet service is transmitting at an air interface rate of 24 Mbps (16QAM Modulation).
- Current radio conditions induce an average PER of 1%.
- The resulting net symmetrical Ethernet throughput is 8.5 Mbps.
- While maintaining transmission at the 24 Mbps air interface, the relatively low error rate causes the system to probe a new rate at 36 Mbps.
- Under the current radio conditions, the 36 Mbps air interface rate experiences a PER of 10%, yielding an expected symmetrical net throughput of 11.9 Mbps.
- The link calculates the net difference of throughput and decides on the optimal rate[1]. In this case, (1-PER) x (Air Interface) = 11.9 Mbps, which is greater than the lower rate (8.5 Mbps). Therefore the link switches the air interface to transmit at the higher rate, despite the higher PER.

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[1] More generally, the feature operates according to the following rules:

Let P_R be the Packet Error Rate of Rate R

Let T_R be the theoretical symmetrical Ethernet throughout of Rate R under optimal conditions

Let N_R be the actual symmetrical throughput for Rate R.

N_R as a function of the packet error rate (PER) is calculated according to the following formula: $N_R = (1 - P_R) \times T_R$.

The system calculates the actual net throughput (N_R) for the set of available rates dynamically by probing different rates and selects the highest throughput. This sophisticated process is performed without affecting services.

The result:

$P_{36} = 10\%, P_{24} = 1\%$

If $T_{36} = 13 \frac{Mb}{s}, T_{24} = 8.6 \frac{Mb}{s}$

The system optimizes the throughput by constantly checking if $N_{R+1} > N_R$.

For TDM traffic, there is an additional mechanism that ensures the TDM quality is not affected by packet errors. The system constantly evaluates the PER of the lower and higher rates. If there is an error in the transmission of one or more TDM packets, the air interface rate is immediately lowered to the maximum acceptable PER air interface rate to retransmit the error packets. After all error packets have been transmitted successfully, the link returns to the higher rate. This entire process occurs in a matter of milliseconds and does not compromise the integrity or synchronization of the TDM traffic.

Mechanism 3: Configurable Channel Bandwidth

The WinLink 1000 enables users to select their desired channel bandwidth of 5 MHz, 10 MHz or 20 MHz. This flexibility enables the user to choose between higher channel bandwidth with relatively large spectrum footprint and lower channel bandwidth with narrow spectrum usage. In crowded environments, where interference-free spectrum is rare, the ability to configure the channel bandwidth is important for enabling optimization of the license-exempt frequency band.

Mechanism 4: Advanced Forward Error Correction (FEC)

Forward Error Correction (FEC) is a mechanism of error control for data transmission, whereby the sender adds redundant data to its messages which allows the receiver to detect and correct errors upon reception of the transmitted data. The advantage of forward error correction is that retransmission of data can often be avoided, at the cost of higher bandwidth requirements on average, and is therefore applied in situations where retransmissions are relatively costly or impossible.

RADWIN uses a Forward Error Correction technique that is optimized for the interference conditions prevalent in license-exempt bands. With very low overhead and algorithms specifically designed for the varying conditions of license-exempt frequency bands, the FEC mechanism used by RADWIN's products helps to ensure fast, robust and error-free communications.

Mechanism 5: Automatic Repeat Request (ARQ) Mechanism

RF interference can damage transmissions, resulting in corrupted data at the destination site. Without an intelligent method for detecting and resending corrupted or missing data, service can be significantly degraded, and, in some extreme cases, be halted entirely.

Automatic Repeat reQuest (ARQ) is a common protocol for error control in data transmission. When the receiver detects an error in a packet, it automatically requests the transmitter to resend the packet. This process is repeated until the transmission is error free or the error continues beyond a predetermined number of transmissions.

There are several commonly used ARQ methods. However, for license-exempt wireless communications, many ARQ implementations are too slow for time-critical traffic such as TDM. Particularly, in interference-laden environments, most ARQ methods are too inefficient to ensure transmission of all data within acceptable latency levels.

The WinLink 1000 ensures error-free service by using a patented, incomparably quick ARQ mechanism that ensures super-fast retransmission of errant data. This ARQ mechanism performs advanced error handling at the physical layer instead of at higher levels such as the TCP layer, resulting in much lower overhead than other ARQ methods. In many cases, the repeat transmission is initiated without having to wait for a request from the remote unit.

Furthermore, the system minimizes either the latency or the error rate to optimize performance for the type of services being delivered. For example, for TDM service, the ARQ mechanism assigns higher priority to the TDM retransmissions, thus ensuring flawless TDM data flow.

The result is real-time, extremely low-error TDM service that meets ITU standards for TDM transmission: end-to-end constant bit rate, jitter & wander, etc. RADWIN's unique ARQ mechanism is globally proven - in the thousands of deployed WinLink 1000 links that provide carrier-class TDM traffic in license-exempt bands today.

Mechanism 6: Non-interrupted Transmission

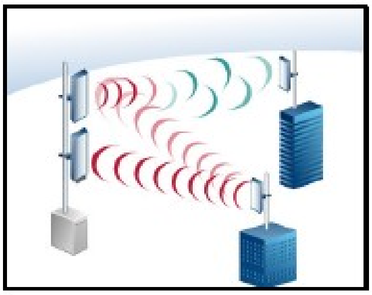
A particularly important design element in the WinLink 1000 interference mitigation strategy is a non-interrupted transmission service. Even when encountering significant levels of interference, the WinLink™ 1000 maintains the transmission and link stability.

In many wireless communication solutions, such as 802.11-based systems, interference in a channel causes the radio to halt transmission until the channel qualifies for transmission again. Obviously, this method of dealing with interference is not suitable for time-critical traffic such as TDM streams or carrier Ethernet.

The unique air interface protocol of the WinLink 1000 is designed to continue transmission, even when encountering interference. Combined with the other mechanisms used to mitigate interference, non-stop high quality communication is delivered even in the harshest conditions.

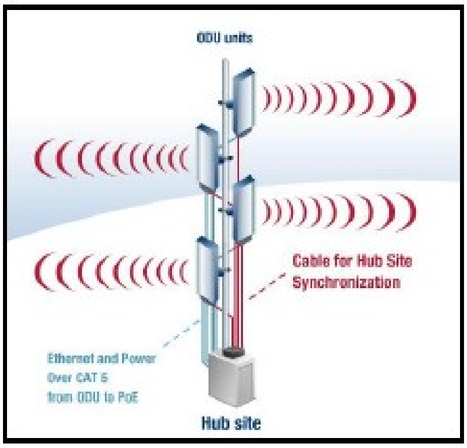
Mechanism 7: Hub Site Synchronization

Radios using the Time Division Duplex method can experience interference from other radios located at the same site if they are transmitting and receiving according to different time patterns.



Let's look at an example of how such interference can be created. Two radio antennas, Radio #1 and Radio #2, are installed on the same tower. Radio #1 is transmitting data to its remote transceiver. At the same time, Radio #2 is receiving data from its remote transceiver. This simultaneous, or near-simultaneous, signal transmission and signal receipt at the same location creates significant interference.

To remedy this possible source of interference, RADWIN has developed a method to synchronize the transmission pulses of all collocated WinLink 1000 systems.



Using an external cable connected to all collocated WinLink 1000 radios, a pulse is sent to each radio that synchronizes its transmission with the others.

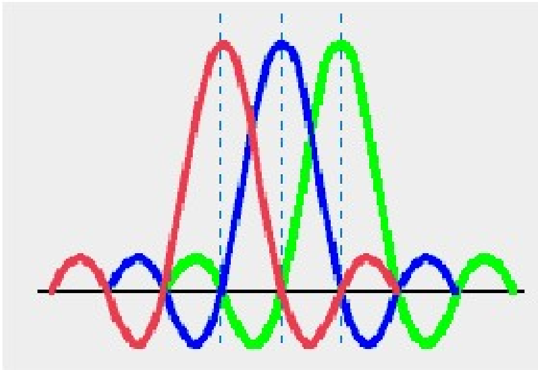
This pulse synchronization ensures that the transmission of packets occurs at the same time for all collocated units. This synchronized transmission also results in all of the hub units receiving data at the same time, eliminating the possibility of interference that could result if some units transmit while other units at the same location receive. This functionality allows for the installation of up to eight collocated units on the same mast.

Mechanism 8: Orthogonal Frequency Division Multiplexing (OFDM)

Orthogonal Frequency Division Multiplexing (OFDM) is a modulation technique for effective transmission of large amounts of digital data over a radio link. OFDM is widely considered to be the most suitable method for radio transmission, based on inherent characteristics such as low overhead, low latency and high resiliency to interference. Selected by standards organizations and leading telecommunications providers, OFDM is the technology of choice for terrestrial radio communications that require high efficiency in difficult environments.

Based on the concept of redundant transmission, OFDM works by splitting the radio signal into multiple, smaller sub-signals that are then transmitted simultaneously at different frequencies to the receiver.

By replicating the content signal using multiple narrowband sub-carriers to repeat transmissions over time, OFDM works to ensure that complete content arrives at the transmission destination. This technique is especially effective for protecting against the effects of multipath fading deriving from the cancellation of carriers under heavy interference conditions. When a system employing OFDM encounters RF interference, it recovers the affected signal from duplicate carriers that were not affected by the interference.



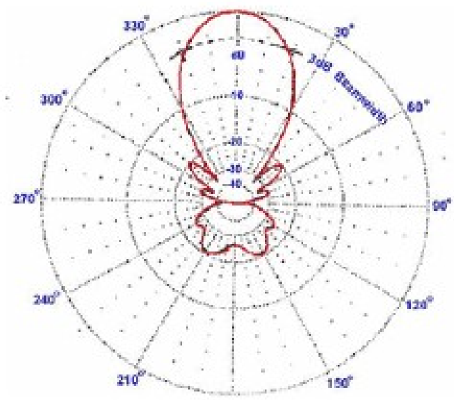
Example of multiple carriers using OFDM

Based on these considerations, RADWIN selected OFDM as the core modulation technique for all of its WinLink™ 1000 products. This robust, flexible technology provides an ideal platform for implementing the unique RADWIN interference mitigation mechanisms mentioned above.

Mechanism 9: Directional Antenna Design

The design of the antennas used at each end of a wireless link affects link budget and performance in conditions of RF interference. Directional antennas focus signal transmission and reduce interference effects.

Each radio in a WinLink 1000 point-to-point link uses highly directional antennas that suppress interfering signals received from the side and back lobes. The result is an improved C/I ratio and suppression of interference from nearby radios.



IV. Summary

To achieve carrier class radio transmission in license-exempt bands, the equipment deployed must be designed with inherent quality-enhancing mechanisms that mitigate interference and ensure smooth transmission of services.

The WinLink 1000 system design incorporates an exceptionally robust air interface based on patented technologies. Its superior design, proven in thousands of installations in all types of environments, makes the WinLink 1000 carrier class radio systems ideal for deployment of carrier grade services in license-exempt bands.

About RADWIN

RADWIN is a provider of innovative broadband wireless solutions for service providers and enterprises. With competitive prices, outstanding performance and the unique ability to support TDM and Ethernet over one platform, RADWIN's solutions deliver a winning business proposition by reducing capital expenditures, ensuring reliable performance and increasing revenue streams in a short time.

Operating in the unlicensed and licensed spectrum bands, RADWIN's industry-leading products provide a variety of applications including multi-site connectivity, broadband access and backhauling. To date, RADWIN's products are deployed at customer sites in more than 30 countries worldwide.

Founded in 1997, RADWIN is a member of the RAD Group, a world leader in data communications. RADWIN is organized around a winning combination of worldwide distribution network, strong global alliances, and field-proven products.

For More Information

Contact Us

RADWIN Ltd.
27 Habarzel Street
Tel Aviv, 69710
Israel

Tel: +972.3.766.2900
Fax: +972.3.766.2902

General Inquiries
info@radwin.com

Technical Support
support@radwin.com

Sales
sales@radwin.com

Partner Program
partners@radwin.com

Public Relations
pr@radwin.com

RADWIN USA
900 Corporate Drive Mahwah,
NJ, 07430-2013,
USA

Tel: +1.201.529.1100
(ext. 341)
Fax: +1.201.529.5777

RADWIN India
P-13, Basement 2
Malviya Nagar
New Delhi, 110017
India

Tel: +91.11.2667.1510
Email:
sales@radwin-india.com