Dejero Resilient Wireless Technology

Why a resilient wireless system is critical to delivering reliable connectivity in portable devices

Dejero

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Executive Summary

Designing the wireless transmission solutions used by modern communications systems—especially portable devices reliant upon many wireless networks—requires a keen understanding of systems design considerations and trade-offs in the context of constraints imposed by safety requirements, by regulatory requirements, by the physics that govern RF performance and by the needs of particular use cases.

The challenge is even greater for the demanding use case of developing a portable device capable of delivering ultra-reliable, low-latency connectivity in challenging environments:

- Portability, thermal and usability requirements impose significant constraints on size, weight and industrial design
- Meeting safety standards and objective performance requirements necessitates complex systems design and creates challenges with the physical layout of components
- Providing the network diversity and carrier diversity needed to meet connectivity requirements calls for a multitude of antennas and supporting sub-systems

Dejero's Resilient Wireless Technology ensures ultra-reliable reception and transmission in even the most challenging environments, including remote field locations, deep within buildings and while on the move.

This advanced RF design works in tandem with Dejero *Smart Blending Technology* and *Hybrid Encoding Technology* inside Dejero EnGo mobile transmitters to get the most out of every bit of bandwidth—delivering high-quality live video streams no matter the hurdles.

Importantly, the EnGo 260 is tested and certified for SAR and other safety considerations, and is certified by regulatory, industry and mobile network operators including FCC, CE, IC, Giteki, PTCRB, and Verizon.

Introduction

Radio-frequency (RF) systems are all around us, enabling the wireless telecommunication which we take for granted in our information economy and connected society. For example:

- The broadcast and media industry relies on wireless communications to transport video and data from virtually anywhere in the world
- Transit companies can offer passengers Wi-Fi service thanks to antennas which connect to cellular and satellite networks; increasingly, connected vehicles use wireless connectivity to enable advanced use cases like autonomous driving and fleet management
- Public safety organizations have long relied upon mobile communications to enable response and coordination during times of crisis; in recent years, these organizations have introduced real-time video feeds from unmanned aerial vehicles and bi-directional data transfer to provide new levels of situational awareness
- Enterprises keep remote branch locations and mobile workers connected thanks to new technologies which can deliver fast, reliable network links

Designing the wireless transmission solutions used by modern communications systems—especially portable, multi-network devices—is no simple activity: it requires a keen understanding of systems design considerations and trade-offs in the context of constraints imposed by safety requirements, by regulatory requirements, by the physics that govern RF performance and by the needs of particular use cases.

This paper explores wireless system design for an especially demanding use case: developing a portable device capable of delivering ultra-reliable, low-latency connectivity in challenging environments. As we will see, these primary requirements impose additional requirements (e.g., low-power, multi-radio, multi-antenna) which must also be met.

The goal is to equip the reader with the knowledge and context necessary to choose a solution offering the best overall wireless system performance for a particular need.

Device Requirements

The two most important requirements when designing a wireless system are safety and performance. Closely related to these is meeting the criteria needed to achieve regulatory approval.

Of course, these requirements must be met in the context of additional constraints imposed by the use case: in this instance, the need for portability and the importance of usability.

As is the reality with any complex system design project, these requirements often come into conflict, demanding disciplined prioritization and innovative solutions.

Portability Requirements

For many antenna use cases, portability is not a concern. But when designing a mobile transmitter for field use cases, portability is an important and restrictive requirement.

To be practical in field environments—ranging from remote outdoor settings, to mobile production vehicles, to indoor locations where power and wired connectivity may not be available—the device must be compact, lightweight and be able to run for several hours off battery power; plus, because the device will be carried while operating, it must meet stringent safety (Specific Absorption Rate or SAR) requirements.

Additionally, portable devices often include GPS location tracking, which requires its own antenna and associated sub-system. We must also be aware that the GPS performance can potentially be impacted by interference from the embedded modems and other system components.

> When designing a mobile transmitter for field use cases, portability is an important and restrictive requirement

Already, we can see that after only a few moments of consideration we have identified a number of constraints and requirements which will impact the wireless system design. Our device must:

- Have **small dimensions and low weight** (and bear in mind the device itself must house multiple antennas, modems, processors, and other components like a battery to power the system)
- **Include a GPS system** which is sufficiently shielded from interference
- **Include global band support**, which necessitates global modems and global roaming connectivity, plus interchangeable SIM modules to allow for local SIMs and support for other wireless networks like Wi-Fi and Bluetooth
- **Meet safety requirements (SAR)**
- **Meet industry, regulatory and mobile operator requirements**

Additionally, our device must be durable enough to withstand vibrations, shocks (for example, it could be crash-tested to transportation safety specifications) and temperature variations.

To be a practical field solution, the device should be low power while operating and when in a standby state, and should contain an internal or attachable battery. Of course, this battery creates a trade-off: the larger the battery, the longer the device can operate, but at the expense of increased volume and weight.

Usability Requirements

Usability is an important design consideration in general, but is especially so when a device is expected to be used in challenging, time-sensitive, potentially chaotic—and even dangerous—environments. Table 1 outlines some basic considerations.

Usability Considerations	Description
Ease of Use	The device should be straightforward and relatively simple to use, which could include: • Limited manual configuration (e.g., automatic set-up and optimization) • Clear displays for performance, diagnostics and camera feeds • Accessible SIM cards, batteries, charging ports and data ports
Ergonomics	Ergonomic considerations include: • Size • Weight • Shape (e.g., no sharp corners or edges) • Balance • Thermal (including fan noise where applicable)

Table 1 — Usability and industrial design have an enormous impact on the user's experience and ability to maximize utility

Safety and Objective Performance Requirements: Certifications

Antennas radiate energy in the form of electromagnetic waves and can be dangerous when sufficiently intense. Therefore, safety is of paramount importance when designing a wireless system. Naturally, multi-antenna designs may exacerbate the risks because multiple antennas may be in use simultaneously and their emissions may additively increase exposure.

The primary safety consideration with antennas is to ensure that, when used appropriately, they do not cause the user to absorb unacceptably high levels of energy.

The metric by which antenna emissions are assessed is the Specific Absorption Rate (SAR), which is a measure of the rate at which energy is absorbed per unit mass by a human body when exposed to a radio frequency (RF) electromagnetic field.[1]

Additionally, our device must meet stringent requirements for objective performance:

- Total Radiated Power (TRP)—a live/active measure of how much power is radiated by an antenna when it is connected to a transmitter—to permit the antennas to transmit signals to wireless networks even in remote locations
- Total Isotropic Sensitivity (TIS)—a live/active measure which describes the total available receive performance of a device—to allow the antennas to receive signals from wireless networks even in remote locations
- Radiated Spurious Emissions (RSE)—emissions of any radio frequency not deliberately created or transmitted

To help bring clarity to wireless system safety and objective performance, and to ensure devices don't create unacceptably high levels of interference, regulators and mobile operators administer certification programs.

> Safety is of paramount importance when designing a wireless system

[1] Note that the manner in which an antenna will be used has a significant impact on its SAR. For example, a roof-mounted antenna does not have to contend with an operator standing right next to it, whereas a cellphone—or a tripod-mounted enclosure housing an operator-controlled camera and antenna array—does.

Carrier Certifications

In 1997, leading wireless operators established the PTCRB to define test specifications and methods to ensure device interoperability on global wireless networks.[2] The program is administered by the Cellular Telecommunications Industry Association (CTIA).

Additionally, some carriers operate their own certification programs; in particular, Verizon has a separate device certification program that is viewed by some as stricter even than PTCRB.

When considering objective performance requirements for wireless systems, it is wise to review the certifications that a device has attained as these demonstrate a commitment to high performance along with the objective testing to validate the performance.

PTCRB

connected by verizon

Regulatory Certifications

Regulatory bodies including the FCC (United States), CE (European Economic Area), IC (Canada), and Giteki (Japan) operate certification programs which focus on device safety (i.e., SAR) and minimizing interference through intentional radiation (transmission) or unintentional radiation (spurious emissions).

When considering safety and SAR requirements for wireless systems, it is reasonable to require simply that a device achieve certification from these regulatory bodies as this ensures they can operate within the jurisdiction covered by the regulatory body.

FC CE IC

[2] "PTCRB" originally stood for "PCS Type Certification Review Board," but now is simply a pseudo-acronym

Wireless System Design

In addition to the requirements already examined, our device must deliver ultra-reliable, low-latency connectivity in challenging environments—upon examination, this functional need imposes a new collection of design necessities.

Delivering Reliable Transmit and Receive

Consider a requirement of maintaining a consistent low-latency data stream at 10 Mb/s. In a region with strong and undersubscribed 4G-LTE coverage, this requirement doesn't seem all that daunting.

Now consider a remote outdoor environment with spotty cellular network coverage (3G, 4G-LTE, perhaps some low-band 5G coverage) or an indoor location like an underground locker room in an arena, surrounded by concrete and metal.

Achieving steady 10 Mb/s transmission while maintaining low latency now becomes a much greater challenge due to the factors outlined in Table 2.

> Many factors can impact cellular reception and link capacity in a dynamic fashion, increasing the challenge of delivering reliable transmit and receive performance

Matters become even more complicated when we consider that many use cases require the wireless device be in motion, subjecting it to even more dynamic cellular reception and hand-offs between different mobile cells and base stations.

To deliver to the low-latency 10 Mb/s transmission requirement, the device must be able to connect to different networks (across different spectral ranges) simultaneously, including different generations of cellular technology and Wi-Fi. This **network diversity** requires ultra-wideband antennas (ranging from 700 MHz to 6 GHz), to allow connection to many different wireless networks and wireless bands.[3]

Additionally, there must be **sufficient antenna isolation** to prevent interference and cross-coupling which degrades performance when multiple, co-located antennas are in use simultaneously.

But simply being able to connect to different network types isn't enough, because a particular carrier's network may be under heavy load or unreliable. To overcome this operational challenge, our device also needs to **provide carrier diversity**, a requirement which necessitates multiple modems (and therefore multiple antennas) even for the same network type.

As with many complex system design challenges, we now have potential conflict between requirements:

- Since our device must be portable, we face significant constraints on size, weight and power consumption
- To meet our performance targets, our device must integrate on the order of 10 antennas (plus the associated RF systems, including modems) and minimize the cross-coupling of these antennas, while meeting regulatory and carrier certifications

> Simply being able to connect to different network types isn't enough, because a particular carrier's network may be under heavy load or unreliable—our device also needs to provide carrier diversity

[3] To make maximally efficient and effective use of the multiple networks requires a technology to blend the many links into a single virtual connection, but that is beyond the scope of this paper—to learn more, please see Dejero *Smart Blending Technology*: Delivering reliable connectivity, anywhere

Factors	Explanation and Examples
Signal Strength	The strength of the cellular signal reaching the wireless device is impacted by factors including: • Proximity to cell tower/mast antennas: signal strength is inversely proportional to the square of the distance between transmitter and receiver • Obstructions: hilly terrain, dense foliage and large buildings may block signals • Building material and thickness: if inside, then wall thickness, basement depth and materials (e.g., metal, concrete, tinted and low-e glass) impact reception • Weather conditions: water particles from humidity, heavy cloud cover, fog and precipitation, electromagnetic interference in the atmosphere and temperature inversions can all harm reception
Network Congestion	Network links are shared resources, and capacity varies dynamically based upon: • The concentration of data-intensive users such as news/broadcast crews or first responders competing for bandwidth • The nature and efficiency of applications being used (e.g., photo and video sharing, efficient encoders vs poor encoders) • Demands placed upon the network by other users (e.g., crowds in attendance at an event)
Coverage Quality	Coverage quality varies considerably by location: • Urban areas typically have better (more complete, more uniform) coverage than suburban/rural areas • Regional, national and global roaming coverage varies by network provider • Fringe coverage areas and localized dead zones (even in urban areas) can impact the ability to transmit/receive
Spectrum Bands	Cellular networks rely upon RF communication within spectrum bands: • Different operators have licenses for different bands, which use different frequencies • Low-band radio waves (e.g., 700 MHz) travel further and penetrate buildings or obstacles more effectively, providing better coverage, but have lower throughput; higher bands offer more throughput but don't travel as far.

Table 2 — Many factors can impact cellular reception and link capacity in a dynamic fashion, increasing the challenge of delivering reliable transmit and receive performance

Multiple-Antenna Systems

Within an overall wireless system, an antenna—an array of conductors electrically connected to a receiver and transmitter—serves as the interface between radio waves and electric currents.

To transmit, the transmitter supplies an electric current to the antenna's terminals, causing the antenna to radiate energy as electromagnetic waves; to receive, an antenna intercepts power from a radio wave and produces an electric current at the terminals, which is then applied to the receiver (or modem) for amplification.

> In a portable device, providing reliable ultra-wideband connectivity is especially challenging because it requires fitting and isolating many antennas within a compact form factor

Physics inspired the creation of antennas and physics governs their capabilities; it also creates significant challenges which must be overcome by our wireless system design.[4] For instance:

- Antennas built to transmit and receive at lower frequencies are physically larger than those built for higher frequencies, because wavelengths are longer in the lower ranges: our requirement for ultra-wideband antennas means that our device will need to accommodate antennas that operate efficiently over a wide range of radio frequencies
- For an antenna to operate efficiently, RF interference must be carefully managed: our device is a multi-antenna system, which means the antennas need to be sufficiently isolated from each other and also from potentially interfering emissions internal to the device through shielding, separation and antenna placement to limit the electromagnetic interference (EMI)

In a portable device like ours, achieving this result is especially challenging—and the challenge becomes even greater when we consider the thermal realities which must be managed to keep the whole system operating safely.

Thermal Dissipation

Electronic systems produce waste heat, which must be dissipated to protect components and to ensure the safety of operators. In our case, the wireless modems and processors are the main sources of heat and the compactness of the device makes the problem of thermal dissipation more complicated.

As before, our available options come with trade-offs:

- Active cooling with fans increases airflow at the expense of power consumption and noise (which may be an issue in quiet broadcast environments, like an interview or news conference)
- Passive cooling requires larger and heavier components to attain the thermal dissipation needed

Therefore, the cooling system design is constrained by several competing requirements:

- Dissipate sufficient amounts of waste heat (where "sufficient" is dependent upon the properties of the system components) to permit sustained operation
- Exist within the size and weight constraints imposed by the portability requirements
- Operate below a particular decibel level
- Consume an acceptably low amount of power
- Be sufficiently rugged to pass stringent vibration and shock testing intended to simulate worst case field conditions

Developing an innovative approach to address the thermal design constraints in combination with usability needs, wireless performance and safety constraints results in purpose-engineered products which can perform to real-world operational requirements.

[4] The first antennas were built in 1888 by German physicist Heinrich Hertz during his experimentation to prove the existence of waves predicted by the electromagnetic theory of James Clerk Maxwell

Conclusions

Designing a portable device to deliver reliable low-latency wireless communication in challenging environments—including remote field locations, deep within buildings and while on the move—is no easy engineering feat:

- Portability and usability requirements impose significant constraints on size, weight and industrial design
- Meeting safety standards and objective performance requirements necessitates complex systems design and creates challenges with the physical layout of components
- Providing the network diversity and carrier diversity needed to meet connectivity requirements calls for a multitude of antennas and supporting sub-systems

Only purpose-designed equipment can hope to satisfy these demanding requirements and achieve the high standards set by wireless certification programs (e.g., Verizon, PTCRB) while meeting mandatory regulatory and safety requirements.

A Proven Implementation: Dejero Resilient Wireless Technology

Dejero's EnGo 260 is a mobile transmitter purpose-built for reliably sending high-quality live video from remote locations over wireless networks.

The EnGo 260 incorporates Dejero's Resilient Wireless Technology to ensure ultra-reliable transmission and reception even in challenging environments. Key to this design is a proprietary solution which separates multiple antennas to:

- Deliver sufficient transmission power (TRP)
- Enhance reception (TIS) by limiting interference
- Meet radiated spurious emission requirements (RSE)

Importantly, EnGo 260 is tested and certified for SAR and other safety considerations, and is certified by regulatory, industry and mobile network operators including FCC, CE, IC, Giteki, PTCRB, and Verizon.[5]

The advanced antenna design and efficient, powerful Dejero *Hybrid Encoding Technology* gets the most out of every bit of bandwidth—ensuring high-quality live video streams in even the most challenging environments.

Plus, like all Dejero solutions the EnGo 260 goes beyond simply meeting stringent performance needs—its large screen, three-hour battery life and convenient backpack ensure straightforward, reliable operation and simplifies portability.

Learn more about the EnGo 260 at www.dejero.com/engo.

RESILIENT WIRELESS TECHNOLOGY

[5] As of April 2020, seven Dejero products have received Verizon certification; for more information, please visit https://opendevelopment.verizonwireless.com/device-showcase and search for "Dejero"

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About Dejero

Driven by our vision of reliable connectivity anywhere, Dejero delivers fast and dependable connectivity required for cloud computing, online collaboration, and the secure exchange of video and data.

With our global partners, Dejero supplies the equipment, software, connectivity services, cloud services, and support to provide the uptime and bandwidth critical to the success of today's organizations.

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