Managing the Intangible Asset of Radio Frequency Spectrum in Hospitals

Important clinical functions like patient monitoring are reliant upon an invisible resource that is often poorly understood.

May 13, 2022 by John Dooley, spectrum engineer

Whether it be the physical structure of a hospital or the medical equipment that structure contains, healthcare facility managers are accustomed to curating tangible assets. Today, however, a new type of intangible asset is becoming an essential part of healthcare operations. As wireless technology evolves to support a growing number of clinical functions, the invisible radio-frequency (RF) spectrum that enables those functions has become critical to maintaining the safety and efficacy of patient care.

Of the many healthcare applications that have gone wireless, few are as important as patient monitoring. Over the past two decades, patient monitoring via medical telemetry has played a central role in the care of patients with cardiac risk factors. Studies demonstrate that monitored patient populations have significantly better outcomes than those that are unmonitored. This is true even in severe cases of cardiac arrest, where patient monitoring more than doubles the chances of survival.[1] The growing sophistication of medical telemetry is enabling these systems to not only alert staff during a cardiac event, but also detect trends that can warn clinicians well in advance of trouble. Through increasingly sophisticated software analytics, wireless patient monitoring is continually expanding its ability to save lives.

Yet, while wireless patient monitoring has helped to improve clinical outcomes, it has also thrust new and unfamiliar responsibilities upon hospital administrators. Though it may be intangible, the RF spectrum that makes patient monitoring work is an asset requiring the same level of diligence and maintenance as any physical part of a healthcare facility.

The Delicate Nature of the Wireless Spectrum Resource

By nature, the RF spectrum is a scarce and delicate resource. This is best understood if we compare the wireless medium to a wired medium like fiber optic cable. If we were to take all the usable radio frequencies available for wireless services, they would collectively fit into a single fiber optic cable many thousands of times over. Since we cannot make more RF spectrum, the finite radio-frequency resource must be carefully apportioned by regulators and license holders to ensure that essential services remain viable.

Whereas wired signals enjoy the ideal and interference free medium of fiber optic cable, wireless signals must transit the unpredictable medium of free space. Therefore, they are susceptible to interference sources and other deleterious environmental effects. In the often-unpredictable wireless medium, unrelated services on seemingly unrelated frequencies routinely interact with one another, producing a complex chaos of interference and noise. Making a wireless system work means not only managing the system itself, but also carefully controlling the environment in which that system operates.

Despite the countless wavelengths of radio-frequency emissions propagating all around us, it is easy to ignore the invisible drama occurring within the RF spectrum. Since our natural senses do not respond to radio-frequencies, we can neither see nor feel the RF spectrum. To comprehend what is happening, we must instead rely upon specialized instruments to help us visualize RF activity. Figure 1 shows a spectrum analyzer, which is the tool most commonly used to survey and diagnose problems in modern wireless networks. An RF spectrum analyzer is analogous to an optical prism, sweeping across a span of RF wavelengths and producing a graph that plots the relative intensity of emissions at each frequency. The resulting spectrogram allows us to understand not only what frequencies are active, but also how disparate frequencies may be interacting with one another to produced unwanted interference.

Figure 1: A spectrum analyzer allows engineers to visualize the RF spectrum. Equipment like this reveals complex interference relationships between seemingly unrelated wireless networks.

If we were able to deploy a modern spectrum analyzer a century ago, we would see only a handful of low frequency emissions combined with the collective noise of natural radio sources like the Sun and even the Milky Way galaxy. In modern times, the picture is very different. The natural radio sources are still there, but atop them are billions of man-made transmitters emitting energy across tens of Gigahertz of spectrum. From TV broadcasts to 5G cellular networks to Wi-Fi, innumerable wireless services must simultaneously operate in the same parcel of space. And, although they are regulated by the Federal Communications Commission, the sheer number and diversity of networks and technologies mean that unintended signal interaction simply cannot be avoided. Even ordinary people have become portable sources of interference, often walking around with multiple transmitters in their pockets, on their wrists, and in their ears.

When we use a spectrum analyzer to study wireless spectrum inside a typical hospital, we see an environment that is marked by the complexity and severity of its wireless interference. This is because hospitals contain a diversity of emissions that exist nowhere else. Like any modern enterprise, a typical healthcare facility will often have a robust Wi-Fi network, a distributed cellular network, and some form of two-way radio system. However, unlike most enterprise environments, hospitals also contain numerous medical instruments that leak significant amounts of RF radiation. These include things like MRI equipment, catheter ablation devices, and other diagnostic or therapeutic systems that use high powered radio emissions. The result is an extremely complex conglomeration of radiative RF sources, many of which are incompatible.

Creating a Protected Spectrum Refuge for Patient Monitoring

For most commercial applications of wireless technology, RF interference is a chronic complaint. However, the consequences of interference to most general-purpose commercial networks are economic. For example, a consumer focused 5G network may experience interference from a neighboring network, the net effect of which is reduced connection reliability or data speeds. When this occurs, the wireless carrier will have to weigh the cost of resolving an interference problem against the costs in lost revenue or subscriber churn that result from the interference. In many cases, networks and their users simply live with some level of RF interference.

Wireless patient monitoring networks in hospitals do not enjoy the same optionality as their general-purpose commercial counterparts. When used to monitor high-risk cardiac patients, wireless medical telemetry systems assume a life-critical role in healthcare facilities. Thus, by definition, the users of wireless patient monitoring networks cannot live with harmful RF interference.

Medical telemetry networks make use of selected portions of the RF spectrum, and the most common RF spectrum band used globally is the unlicensed allocation at 2.4 GHz. The 2.4 GHz band has long been attractive for medical applications due to the broad availability of components and the ease of unlicensed operations. However, it is becoming an increasingly difficult place to guarantee reliable patient connectivity. Whereas the 2.4 GHz band was once limited to niche industrial and medical applications, it has now become crowded with countless consumer device emissions from things like Wi-Fi, Bluetooth, and even microwave ovens.

To ensure that patient monitoring will have long-term protection from interference, the FCC established the Wireless Medical Telemetry Service (WMTS) in the early 2000s. WMTS provides a licensed refuge for patient monitoring in the RF spectrum, which cannot be violated by unlicensed non-medical services. The most compelling WMTS allocation is at 1.4 GHz, and it allows sensitive medical telemetry networks to be designed with long-term assurance of interference free operation. This is why the FDA has encouraged device manufacturers to move patient monitoring systems out of unlicensed bands and into licensed and protected WMTS allocations.[2] Figure 2 depicts a spectrogram taken at a Boston area hospital. Spectrograms like this clearly illustrate why the 1.4 GHz band is so important for patient monitoring. Isolated from the bulk of active commercial, broadcast, and government wireless services, the 1.4 GHz WMTS band gives sensitive medical applications an effective buffer against many common types of interference.

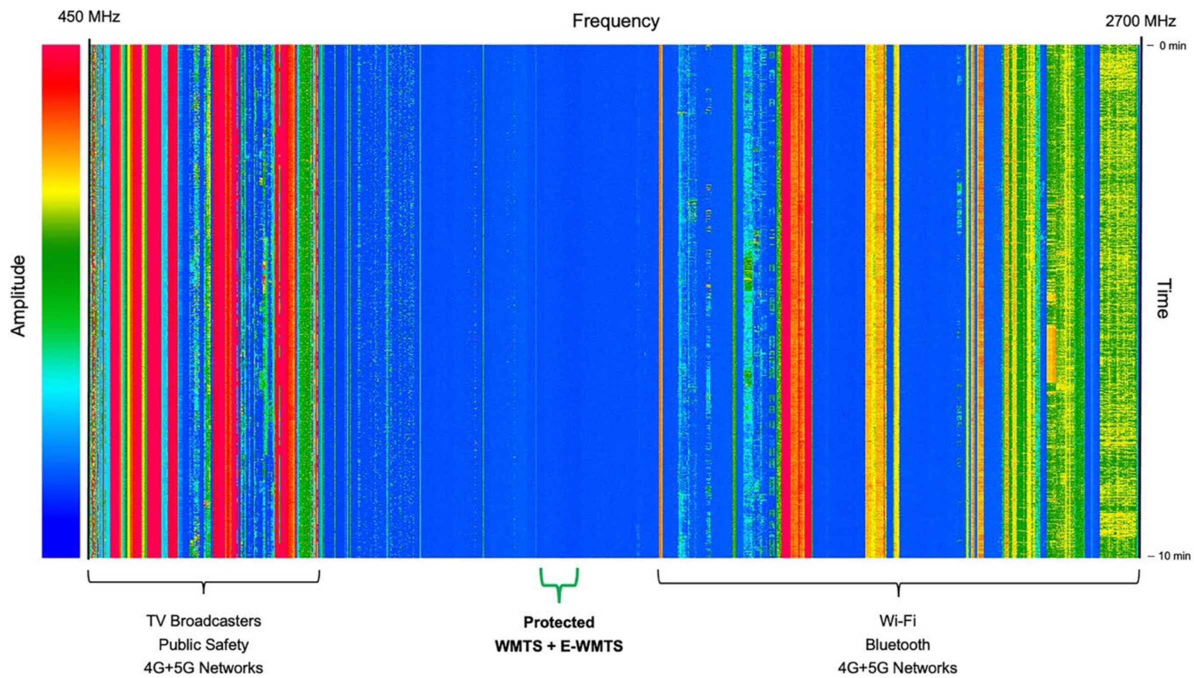

Figure 2: A spectrogram taken at a Boston area hospital before the activation of 1.4 GHz WMTS infrastructure shows an RF environment that is typical within many major healthcare facilities. The 1.4 GHz band exists in a protected refuge relative to the torrent of wireless activity elsewhere in the usable RF spectrum.

Actively Protecting and Enhancing Patient Monitoring Spectrum

The successful deployment of WMTS at thousands of hospitals across the United States underscores the importance of protected spectrum for patient monitoring applications. However, it is also a case study in the continual need for diligence on the part of hospitals and medical device vendors, even when that spectrum is licensed.

While 1.4 GHz WMTS sits at a comfortable spectral distance from many common wireless network services, it is not totally alone. When the FCC created WMTS, it also created a commercial service in the immediately adjacent band. In 2015, as TerreStar was preparing to deploy a nationwide utility network in the 1.4 GHz commercial band, we became aware that our system could negatively impact neighboring WMTS patient networks. Though both networks were operating well withing their FCC defined limits, the underlying architecture of certain WMTS receivers made them susceptible to interference from signals in the adjacent commercial band. Engineering studies concluded that, using the utility network technology available at that time, patient monitoring networks could be disrupted by either utility services placed too close to hospitals or by utility workers that might bring portable devices into hospitals.

The potential stakes for hospitals were high, and what could have been a healthcare disaster instead became a valuable collaboration between commercial and medical network operators. TerreStar suspended its utility deployment and began working with both ASHE and the major 1.4 GHz medical device manufacturers to develop a long-term solution. Unable to change hardware components within hundreds of thousands of existing medical devices, we instead worked on changing the commercial service, adapting it to both protect and enhance WMTS. The concept we arrived at was conceptually simple: define interference protection criteria for hospitals and create a special patient monitoring service with the adjacent 1.4 GHz commercial spectrum. In effect, instead of fighting patient monitoring services, our concept was to use the commercial service to enhance the capabilities of WMTS systems.

One of the elegant aspects of our solution was that many existing medical devices are able to utilize the expanded commercial band with just software modification, meaning that the service could be utilized quickly and with limited cost to healthcare facilities. With the help of ASHE, our medical device partners, and the FCC, this service was recently authorized as Enhanced WMTS (E-WMTS).[3] E-WMTS allows existing 1.4 GHz WMTS systems to make use of commercial spectrum at thousands of major healthcare facilities, many of which already have compatible equipment in operation.

In addition to removing interference risks from these life-critical applications, E-WMTS more than doubles the channel capacity of both current and future networks. This allows healthcare facilities to significantly increase both the number of monitored patients and the depth of real-time biometric data that medical telemetry networks can capture. A larger population of monitored patients combined with better patient data equates to improved clinical outcomes.

The Future of Healthcare Wireless

For reasons that have become obvious from our collective personal experience with mobile technology, the proliferation of wireless has enabled radical change and improvement across countless industries. The ability to sustain deep linkages between moving people and objects has compelled profound industrial evolution, the ultimate impact of which it remains too early to understand.

In certain aspects of healthcare, the magnitude of beneficial impact imparted by wireless is equaled only by the risks and responsibilities of providing critical care functions over radio-frequency links. Monitoring high-risk patients with wireless technology can mean faster and more certain recovery by allowing patient populations to be ambulatory, while ensuring that increasingly sophisticated analytics systems keep constant watch for precursors of cardiac events. However, it can also mean that patient safety is ultimately reliant upon an invisible and often poorly understood medium.

If healthcare wireless is to fulfill its extraordinary promise, then there needs to be evolution in how healthcare facility management views the RF spectrum resource that enables wireless services. In demanding licensed spectrum for critical care services while understanding how that spectrum is maintained, healthcare organizations will lay the foundations for continuing advancement in the standard of patient care.

John Dooley is a spectrum engineer, who helped create the E-WMTS patient monitoring solution with TerreStar spectrum. He is a full-time member of the 3GPP standards body and holds numerous patents for wireless device and infrastructure technologies.

[1] *See* https://www.researchgate.net/publication/50939241_In-hospital_cardiac_arrest_Impact_of_monitoring_and_witnessed_event_on_patient_survival_and_neurologic_status_at_hospital_discharge

[2] *See* https://www.fda.gov/medical-devices/wireless-medical-devices/wireless-medical-telemetry-systems#regs

[3] *See* https://www.terrestarmedical.com/fcc-terrestar