

Managing Your Wireless Spectrum ...

Making Wireless Technology Work in Your Hospital

H. Mark Gibson

Radio frequency spectrum is the lifeblood of the wireless revolution in healthcare. But as more and more wireless technologies and systems are introduced and rolled out in the hospital, proper management of this fundamental resource has never been more important. All wireless stakeholders across the enterprise share in this vital responsibility, but it tends to fall to those with “engineer” in their titles to manage this resource.

Because of their ability to provide greater mobility, instant access to data, increased efficiencies, and lower deployment costs, wireless technologies have become widely used and accepted throughout healthcare. Indeed, Forrester Research indicated recently that 79% of healthcare organizations are rolling out new mobile applications and services for employees, nearly double the implementation rate of non-healthcare firms.

Yet, the wireless environment in the hospital is already exceedingly complex. Trying to make new wireless technologies and systems work properly in the already crowded wireless-scape is like trying to find a seat in a dark and crowded movie theater. Add to this the

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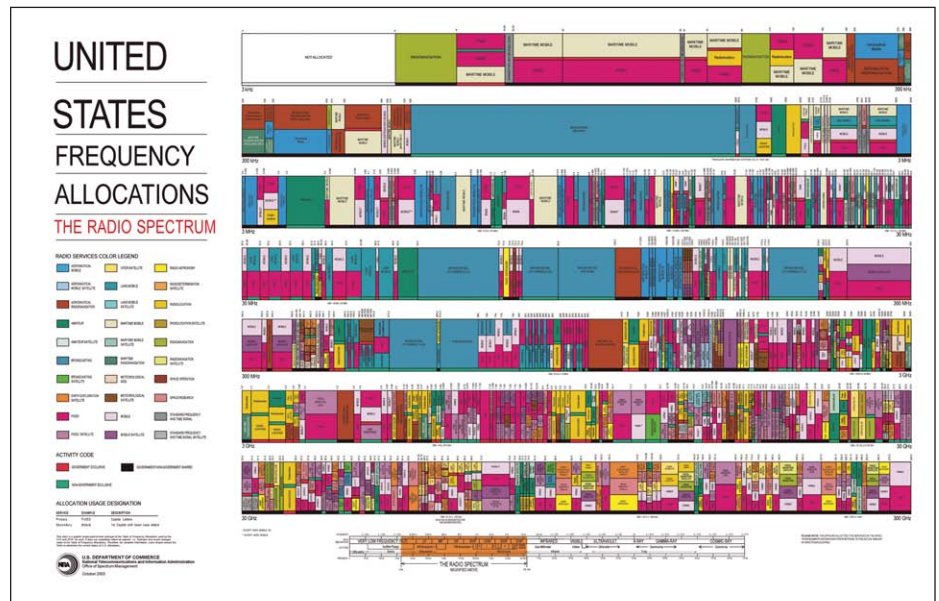


Figure 1: NTIA US Frequency Allocation Wall Chart. (To view the full-size chart, go to www.ntia.doc.gov/osmhome/allochrt.html.)

additional complexities brought on by wireless healthcare technologies, then throw in the host of other radiating devices in the hospital (e.g., fluorescent lights), and it’s easy to see that proper planning is essential for the safe and efficient rollout of wireless in healthcare.

The Radio Spectrum

A discussion of proper wireless planning should start with a look at the radio frequency (RF) spectrum. In the U.S., the RF spectrum is controlled by two regulatory bodies: the Federal Communications Commission (FCC), and the National Telecommunications and Information Administration (NTIA). The FCC is a stand-alone body that regulates all non-government spectrum use. The NTIA is under the Department of Commerce, and regulates all government spectrum use. Together these two bodies regulate our RF spectrum quite literally from DC to light.

The NTIA has created an excellent wall chart depicting U.S. spectrum allocations for both government and non-government use. An example of this chart is shown in Figure 1, and is also available from the NTIA website (www.ntia.doc.gov/osmhome/allochrt.html).

Interference is a byproduct of operation in the congested, shared radio spectrum. When evaluating the interference potential from wireless networks and devices, it is important to know their designated frequencies within the radio spectrum and whether they share these frequencies with other services. Sharing of radio spectrum is an efficient use of a scarce resource, but sharing will also increase the potential for interference among devices. Table 1 lists some commonly shared frequencies and indicates what might be found in the hospital.

One of the most congested chunks of spectrum in the hospital is the 2.4 GHz unlicensed band. As one of 11 internationally designated bands for industrial, scientific, and medical (ISM) applications, the 2.4 GHz band is home to an assorted set of devices including microwave ovens, cordless telephones, wireless local area networks (WLAN) including 802.11b (WiFi) and 802.11g, Bluetooth, motion detectors, medical telemetry, microwave communications systems, wireless video cameras, to name a few. The FCC's equipment certification database (<https://gullfoss2.fcc.gov/prod/oet/cf/eas/reports/GenericSearch.cfm>) lists more than 8,000 devices certified to operate in this band.

The good news is that most devices developed for use in this band have been designed for reliable operation in a congested spectrum. However, some do this better than others. Figure 2 shows a spectrum plot of a WLAN signal operating within 10 feet of a microwave oven. In this instance, the microwave oven caused the data rate of the WLAN to drop below dial-up speeds.

Interference

In order to fully understand the implications of the growing number of wireless devices in the hospital, it is important to understand what interference is and how to identify when it has occurred. The FCC defines harmful interference as "...interference that endangers the functioning of a radiocommunication service or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with [FCC] regulations." Interference is further defined as "...any emission, radiation, or induction, which specifi-

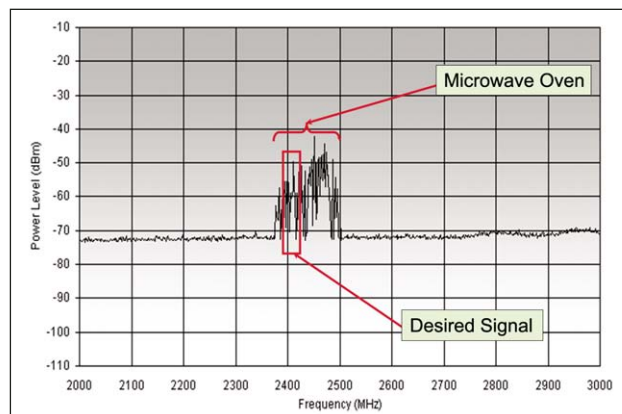


Figure 2: Spectrum plot showing WLAN signal and microwave oven

cally degrades, obstructs, or interrupts the service provided by such stations.”

The AAMI Technical Information Report, TIR 18:1997, *Guidance on electromagnetic compatibility of medical devices for clinical/biomedical engineers - Part 1: Radiated radio-frequency electromagnetic energy* describes the following types of interference:

electromagnetic disturbance (EMD): Any electromagnetic phenomenon which may degrade the performance of an equipment and/or system.

electromagnetic compatibility (EMC): The ability of an equipment and/or system to function satisfactorily in its electromagnetic environment without introducing intolerable EMD to anything in that environment.

electromagnetic emission: The phenomenon by which electromagnetic energy emanates from a source.

electromagnetic environment: The totality of electromagnetic phenomena existing at a given location.

electromagnetic interference (EMI): Degradation of the performance of a piece of equipment, transmission channel, or system caused by an EMD.

A complete treatment of all these types of interference is beyond the scope of this paper. Readers are encouraged to check the resources listed at the end of this paper for a more thorough discussion of all types of interference. However, the primary interference types in the hospital are EMI and EMC. The interference situation depicted in Figure 2 is a good example of EMI. EMC interference occurs when RF radiation interferes with susceptible devices. For example, a cell phone may adversely affect the operation of a heart monitor because of EMC interference.

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↓ FREQUENCY BAND	↓ TYPICAL USE	↓ HOSPITAL USE	↓ NOTES
<i>ISM BANDS (BAND DESIGNATION)</i>			
6.765 – 6.795 (6.78) MHz	Clock timing standard		
13.553 – 13.567 (13.56) MHz	RFID	RFID	Used for asset management
26.957 – 27.283 (27.12) MHz	Cordless Phones Garage Door Openers Wireless Auto Locks Wireless Mouse	Cordless Phones Wireless Auto Locks Wireless Mouse	
40.66 – 40.70 (40.68) MHz	Radio-controlled devices	None	
902 – 928 (915) MHz	Cordless Phones Paging Nurse Call RFID	Cordless Phones Paging Nurse Call RFID	
2.400 – 2.4835 (2.450) GHz	Microwave Ovens WLANs WiFi (802.11b) Bluetooth Cordless Phones Medical Telemetry	Microwave Ovens WLANs WiFi Bluetooth Cordless Phones Medical Telemetry	The FCC lists close to 8000 devices approved for use in this band
5.725 – 5.825 (5.8) GHz	WLANs (802.11a) Point-to-point microwave Systems	WLANs (802.11a) Point-to-point microwave Systems	
24.00 – 24.25 (24.125) GHz	Wireless Security Systems	Wireless Security Systems	
61.00 – 61.50 (61.25) GHz	Research		
122 – 123 (122.50) GHz	Research		
244 – 246 (245.00) GHz	Research		
<i>OTHER UNLICENSED BANDS</i>			
26.965 – 27.405 MHz	CB Radio	CB Radio	
72.0 – 73.0 & 75.4 – 76.0 MHz	Radio-controlled devices		
151.82, 151.88, 151.94, 154.57, & 154.60 MHz	Multi-Use Radio Service (MURS)		Like CB
402 – 405 MHz	Medical Implant Communications Service (MICS)	Medical implants	Primary allocation for meteorological aids at 400.15-406 MHz
406.0 – 406.1 MHz	Personal Locator Beacons (PLB)		
216.75 – 217.0 MHz	Low Power Radio Service (LPRS)		
462.5625 – 467.7125 MHz	Family Radio Service (FRS)	Family walkie talkies	
1920 – 1930 MHz	Unlicensed PCS Cordless Phones Wireless PBX	Unlicensed PCS Cordless Phones Wireless PBX	1910 – 1920 MHz reallocated to Nextel
5.150 – 5.250, 5.47 – 5.725, & 5.725 – 5.825 GHz	Point-to-point microwave Systems	Point-to-point microwave Systems	Unlicensed National Information Infrastructure

Table 1: Some common shared and secondary-use frequencies that may be found in and around the hospital

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<i>OTHER SECONDARY USE SPECTRUM</i>			
510 – 1705 KHz	Low power AM		Delivered through power lines
26.96 – 27.28 MHz	Radio controlled toys	Radio controlled toys	
40.66 – 40.7 MHz	Radio controlled toys & fireworks Remote entry Walkie talkies	Remote entry	
43.17 – 44.49, 46.6 – 46.98, 48.75 – 49.51, & 49.66 – 50.0 MHz	Cordless Phones	Cordless Phones	
49.82 – 49.9 MHz	Walkie talkies Wireless microphones Baby monitors	Walkie talkies Wireless microphones	
74.6 – 74.8, & 75.2 – 76.0 MHz	Walkie talkies Auditory assistance	Walkie talkies	
174 – 216 MHz	Broadcast TV (P) Medical telemetry Wireless intercom	Broadcast TV (P) Medical telemetry Wireless intercom	
300, 310, 315, 390 MHz	Government Land Mobile (P) Remote control (keyless entry, garage door opener)	Government Land Mobile (P) Remote control (keyless entry, garage door opener)	There have been multiple reports of interference with garage door openers from people living close to military bases.
303.875 MHz	Government Land Mobile (P) Auto and home security alarms	Government Land Mobile (P)	Keyless entry devices
318.6 MHz	Government Land Mobile (P) Radio security alarms Smoke detectors	Government Land Mobile (P) Radio security alarms Smoke detectors	Keyless entry devices
418 MHz	Government Land Mobile & Research (P) Auto security Remote transmitters	Government Land Mobile & Research (P) Auto security Remote transmitters	Keyless entry devices
433.5 – 434.5 MHz	Amateur Radio (P) Auto security		
470 – 668 MHz	Broadcast TV (P) Medical telemetry	Broadcast TV (P) Medical telemetry	
554 – 590 MHz	Broadcast TV (P) Wireless microphones	Broadcast TV (P) Wireless microphones	

Note: (P) indicates a primary allocation

Table 1(Continued): Some common shared and secondary-use frequencies that may be found in and around the hospital

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PROBLEM	EXAMPLE	NOTE
Equipment Malfunctions (or doesn't work at all) Intermittent Problems (NPF)	Testing of Digital TV signals has caused intermittent problems into telemetry sharing the 174-668 MHz band. This is the landmark case that spurred the allocation for Wireless Medical Telemetry Service (WMTS).	This problem is the most frustrating. Harmful interference can be itinerant, requiring good knowledge of the environment.
Audible Noise	A medical telemetry receiver was picking up a local FM radio station.	We performed measurements and identified a 250 KW FM transmitter within 3 miles.
High BER (bit errors)	Patient data link in the 2.4 GHz band was receiving harmful interference from a microwave oven.	This and the example below show how harmful interference manifests itself in digital systems.
Abnormally Slow Data Rate	WiFi access point data rate went to below dialup speeds in the presence of a microwave oven.	Depending upon the number and magnitude of harmful interferers, WiFi systems can grind to a halt.

Table 2: Examples of harmful interference

There are a number of radiating devices in and around the hospital that can cause EMC interference with wireless devices. Some examples include:

- Fluorescent lights
- Power distribution and switchgear
- Microwave ovens
- Building automation
- Medical devices
- Building alarm and monitoring
- TV, FM, and AM broadcast stations

All users of the RF spectrum experience interference at some point. Indeed, many systems will still function perfectly well in the presence of interfering signals. The point at which it's time to take action is when the interference becomes harmful. But how do we know when interference becomes harmful? Table 2 lists a few signs that may indicate the presence of harmful interference.

Once an interference problem is identified and the source of interference located, a hospital is faced with finding a solution that works for that particular applica-

tion. Table 3 lists our Six Rs for addressing interference. These solutions are intended to mitigate interference, not necessarily remove it.

Managing the Wireless Environment

Listed in Table 3 are reactive measures to identify and address RF interference. Yet, as a hospital's wireless environment becomes increasingly crowded and complex, it is good engineering practice to proactively manage the RF spectrum. Proactive spectrum management will help address and mitigate potential problems before they cause critical equipment outage.

The first step is developing a frequency/device inventory. This can function both as a baseline to determine what's in the hospital, and as a tool to keep track of new devices coming into the hospital. It can take the form of a flat data file, spreadsheet, or even a relational database. The inventory should list as many known RF radiating devices in and around the hospital as possible, and starts with a rooftop-to-basement assessment of operating and

INTERFERENCE MITIGATION SOLUTIONS – THE SIX Rs	
<i>Reduce</i>	One of the best ways to address harmful is <i>Reduce</i> the transmit power of the interfering device
<i>Retune</i>	If power reduction is ineffective, try to <i>Retune</i> the operating frequencies of both devices
<i>Repair</i>	The equipment may be malfunctioning. A <i>Repair</i> may be all it needs to get it back into spec
<i>Remove</i>	It's possible that the only way to mitigate harmful interference is to <i>Remove</i> one or both devices
<i>Replace</i>	If the equipment is old, out of spec, and can't be repaired, perhaps it's time to <i>Replace</i> it
<i>Regulate</i>	In specific cases (as with the WMTS), <i>Regulate</i> to change or make new rules protecting critical equipment

Table 3: Addressing Interference—The Six Rs

susceptible devices. The goal of the inventory is not to catalog everything in the hospital, but to develop a baseline of devices such as walkie talkies, points, monitoring systems, etc. and add to it as devices are brought into the hospital. Suggested data fields that should be considered in an inventory list is shown in Table 4. This data can be found in several locations including device documentation, on the device itself, on the Internet, by talking to those familiar with the equipment, vendors, etc.

SUGGESTED FIELDS FOR A FREQUENCY / DEVICE INVENTORY
DEVICE NAME
MODEL NUMBER
SERIAL NUMBER
DESCRIPTION
FCC DATA (if applicable)
Call Sign
FCC ID
Transmit Power
LOCATION
OPERATING FREQUENCIES
CONTROLLING DEPARTMENT
KNOWN INTERFERENCE ISSUES
NOTES

Table 4: Suggested data fields for frequency / device inventory

Areas of high congestion may require closer scrutiny when compiling the inventory. One example of this is the rooftop. Many hospitals with tall patient towers use the rooftop as an antenna farm. Typical rooftop antennas can include land mobile, paging, aeronautical (to talk with medevac helicopters), and even microwave and cellular/personal communications services. These antennas often radiate high powers, thus increasing the potential for interference. Figure 3 shows a hospital rooftop with a varied collection of antennas, including a 2.1 GHz microwave grid antenna.

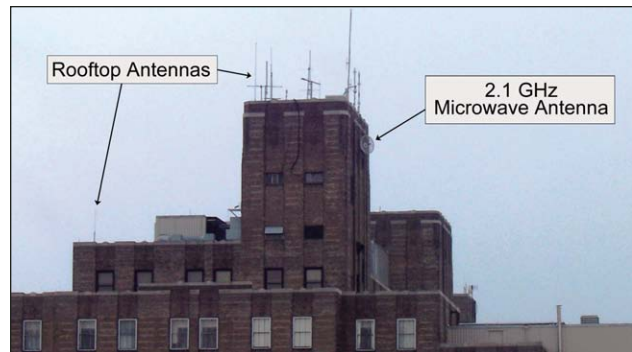


Figure 3: Rooftop antennas

Another good way to help develop a baseline for the inventory is through RF spectrum sweeps. Using measurement gear, such as power meters, spectrum analyzers, test antennas, measurements are taken at key locations throughout the hospital to characterize the RF environment inside the building from radiators both inside and outside. RF measurements are often the only way to locate interference sources. Measurements can determine signal strength and pinpoint operating frequency, two key elements when determining interference potential. It is a good idea to repeat measurements at regular intervals to maintain a current inventory. Depending upon how active the RF environment is, this could be quarterly, semi-annually, or annually. Measurement results can be tabulated in a format similar to that shown in Table 4. In addition, the results can be combined into a composite spectrum plot for the entire hospital, showing the relative frequency usage throughout. An example of a composite spectrum plot is shown in Figure 4.

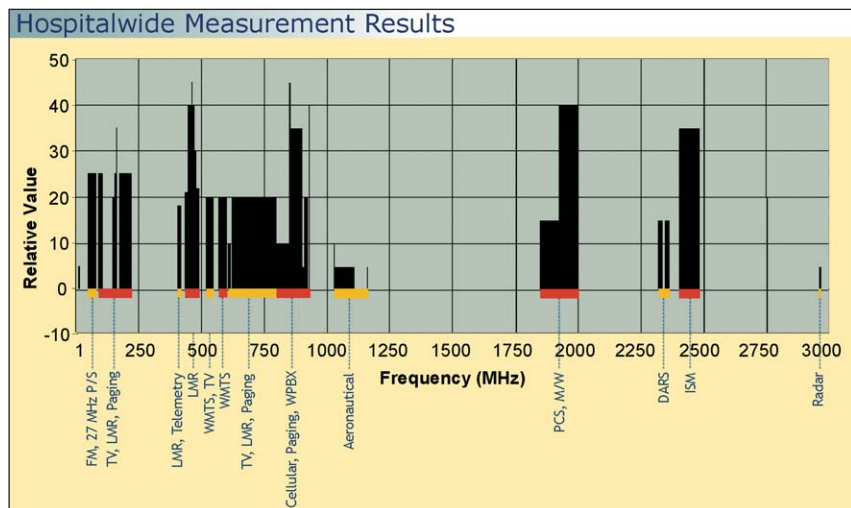


Figure 4: Composite spectrum plot

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The next step in managing the wireless environment is frequency engineering. Proper frequency engineering is one aspect of managing your spectrum that will help untangle the RF environment in the hospital. Start by using the frequency/device inventory and spectrum sweep results as tools to provide an excellent snapshot of the existing RF environment.

Wireless Planning

Proper design, deployment, and use of wireless technologies require detailed planning and hospitalwide coordination. Developing a successful wireless plan requires the involvement of all wireless stakeholders in the hospital (e.g., biomedical engineering, facilities management, IT, nursing, security, etc.) in comprehensive planning discussions. It's also a good idea to include risk management. Led by the engineering staff, all stakeholders should work together using the following simple guidelines:

- Know the RF environment in and around the hospital. Develop a frequency / device inventory, and back it up with hospital-wide spectrum sweeps.
- Understand technologies and develop technology visions. Understand the impact of new technologies on existing ones, and vice versa.
- Know the weak spots in your hospital. If there is a heavy concentration of 2.4 GHz systems in a location, be aware what the introduction of an additional one might do to all of them.
- Develop frequency coordination plans to harmonize the use of frequencies and systems throughout the hospital. The plans may be location-specific, but should accommodate the entire RF plant throughout the hospital.
- Develop and implement a proactive interference management program to address future wireless needs. This may include guidelines for introducing new equipment in the hospital, especially considering its interference susceptibility. Keep in mind that just because a device doesn't use RF spectrum doesn't mean it's not susceptible to interference.
- Coordinate wireless deployment strategies throughout the hospital. Some hospitals are hiring new staff whose primary function is to act as a wireless manager. Responsibilities may include developing wireless plans across the hospital and working to establish wireless task forces within the hospital to identify and coordinate wireless needs.

- Meet regularly and discuss wireless activities throughout the hospital. Many hospitals have established wireless task forces to discuss and plan wireless strategies and visions.
- Get help. Outside firms specializing in wireless technologies and engineering can provide specialized expertise such as engineering, spectrum management, measurement, and deployment support, as well as consulting and training. You don't have to go it alone. Managing the lifeblood of the wireless revolution in healthcare need not be a daunting task.

However, not doing so will indeed be daunting. In most situations, debilitating interference is not a matter of if but when. Hospitals can take steps to address and mitigate this threat with proper and proactive wireless planning by all wireless stakeholders. So if trying to make new wireless technologies and systems work properly in the congested wireless-scape is like trying to find a seat in a dark and crowded movie theater, proper planning and management of the wireless-scape will ensure that you'll always be able to find a seat. So sit back and enjoy the revolution. ■

Resources

- 1) **FDA CDRH website.** www.fda.gov/cdrh/emc
- 2) **FDA/CDRH Recommendations for EMC/EMI in Healthcare Facilities.** www.fda.gov/cdrh/emc/emc-in-hcf.html
- 3) **ASHE WMTS website.** www.ashe.org/ashe/wmts/index.html
- 4) **AAMI TIR 18:1997.** Guidance on electromagnetic compatibility of medical devices for clinical/biomedical engineers, Part 1: Radiated radio-frequency electromagnetic energy.
- 5) **AMA's Policy H-215.972.** Use of Wireless Radio-Frequency Devices in Hospitals.
- 6) **ANSI/IEEE C63.18.** Recommended practice for an on-site, ad hoc test method for estimating radiated electromagnetic immunity of medical devices to specific radio-frequency transmitters, American National Standards Institute, December 31, 1997.
- 7) **IEC Standard 60601-1-2.** Medical electrical equipment - Part 1: General requirements for safety - 2. Collateral standard: Electromagnetic compatibility - Requirements and tests.
- 8) **ECRI.** Guidance Article, Wireless Communication Devices and Electromagnetic Interference, ECRI's Updated Recommendations, *Health Devices*, Volume 30 (11), November 2001, pages 403-409.
- 9) **Comsearch.** Final Health Facility Measurement Report; Site Survey and Spectrum Analysis of the Culpeper Regional Hospital of Culpeper, Virginia; August 17, 2004.
- 10) **University of Oklahoma.** Center for the Study of Wireless Electromagnetic Compatibility, Managing Wireless Electromagnetic Compatibility Issues in Healthcare: A Resource Manual.