



UNLICENSED SPECTRUM AND THE U.S. ECONOMY

Quantifying the Market
Size and Diversity of
Unlicensed Devices

January 2022

Consumer Technology
Association®

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1 Executive Summary

Unlicensed spectrum — more broadly, “permissionless” spectrum as discussed in Section 2.1 — has become a critical element of infrastructure in the United States. As a natural consequence of this importance, products using this spectrum also contribute significantly to the U.S. economy’s bottom line. The Consumer Technology Association (CTA)[®] estimates that permissionless spectrum generates \$95.8 billion per year in incremental sales value (ISV) at retail based on our comprehensive review of available wholesale device sales data. The wholesale ISV is \$79.8 billion.

This study uses only device sales data. It is a purposeful choice to focus on this tangible, direct benefit. Several excellent studies look at overall economic benefit, including things like productivity gains, from specific unlicensed technologies such as Wi-Fi[®]. These studies often show an order of magnitude economic benefit beyond the initial device sales. With some two years of challenging conditions brought on by the pandemic, we must note the societal benefits of unlicensed spectrum. Connected consumer technology enabled a huge part of the economy to continue functioning through work and education at home, and the vast majority of those connections were over unlicensed home networks.

This report — our first major update since 2014 when we reported \$62 billion in wholesale ISV — also accounts for the diversity of the unlicensed device ecosystem. Wi-Fi and Bluetooth[®] are a sizable portion of the overall market, but the unlicensed story continues through medical devices, automatic vehicle identification systems, wireless microphones, near field communications (NFC)-enabled contactless payment, consumer radar devices and many more. The products in this vast landscape of permissionless-enabled applications have an important role to play, in practice and in the economy.

In addition, the future for unlicensed technology looks bright. We note developments such as the

Federal Communications Commission’s (FCC’s) Spectrum Horizons rulemaking, the advancement of dynamic spectrum sharing and further work to identify candidate spectrum. We anticipate many more developments in unlicensed and permissionless spectrum use in the coming decade.

2 Introduction

Life without unlicensed wireless devices — garage door openers, key fobs, baby monitors, wearables, smartphones, not to mention Wi-Fi — is almost unimaginable. All of these technologies have diffused into our daily routines so completely that they are practically invisible. We know intuitively that their impact is enormous. In the 2014 version of this report, CTA quantified some of the economic benefit of unlicensed devices by analyzing the direct contribution of hardware sales of these devices. This report updates that analysis, adding a fresh look at additional spectrum and applications, as the FCC has opened up more bands for unlicensed and permissionless access.

At the outset, establishing precisely what should be counted in this report was a conundrum. Unlicensed spectrum is fragmented; it employs multiple frequency bands, has communications and non-communications applications and gives rise to an incredibly diverse product market, and unlicensed uses are often integrated with licensed uses in the same device. Furthermore, indirect benefits, which are derived from cost savings and intangible social value, are hard to identify and measure. Published estimates of unlicensed spectrum’s value, which focus mainly on the indirect benefits of Wi-Fi alone, range from the tens to hundreds of billions of dollars, depending on what is being measured.

The goal of this study is to quantify the ISV of devices that use unlicensed or permissionless access spectrum in the United States. ISV is the portion of device sales attributable to features that use unlicensed spectrum. ISV data is direct, easily measured, and tangible, making it a useful proxy for the value of unlicensed spectrum.¹

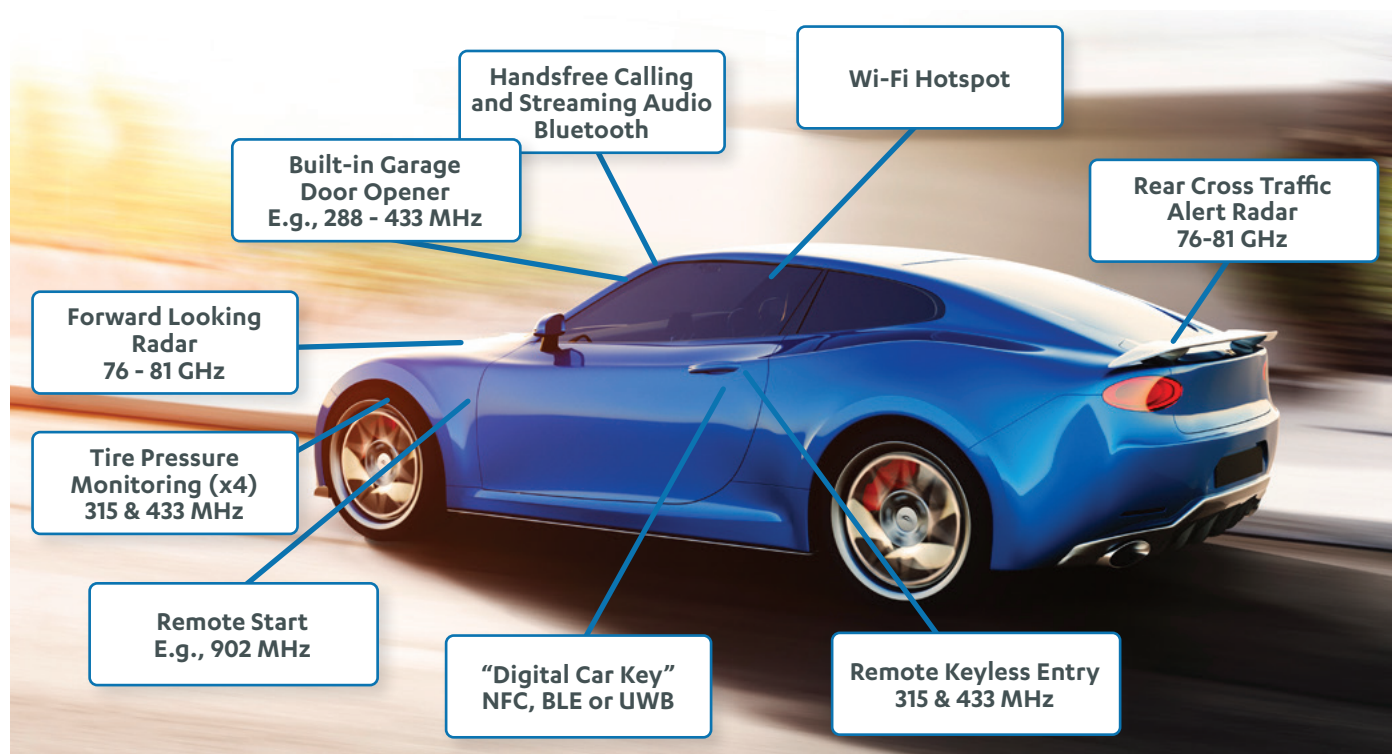
CTA estimates that, *solely in terms of the sale of devices using unlicensed or permissionless access spectrum*, these devices generate **over \$95.8 billion per year** in retail ISV, or \$79.8 billion at wholesale.² More detail is provided below on what is included with unlicensed and permissionless spectrum and how ISV is computed for devices containing licensed and unlicensed radios.

Of course, unlicensed spectrum is found somewhere within every industry, whether it is directly supporting the manufacture of goods or as an everyday technology in the home or office. By all accounts, the value of these indirect contributions

in terms of savings, productivity, and utility greatly exceed, and are additive to, unlicensed spectrum's direct input to the economy.³

Our cars are an excellent example of the pervasiveness and benefits of unlicensed spectrum. Today's cars bristle with unlicensed radios of all types (Figure 1) that provide navigation, safety features including tire pressure monitoring and crash avoidance radars, the convenience of passive entry and push-button engine start, streaming entertainment, hands-free calling, and productivity enhancing Wi-Fi connectivity.

FIG. 1 CARS MAKE ABUNDANT USE OF UNLICENSED SPECTRUM



¹ As explained in greater detail below, CTA could not capture every conceivable device category because some did not yield enough data to allow a conclusive analysis.

² This report uses a 20% markup from wholesale to retail to cover the range of purchasing environments from consumer to professional and industrial.

³ CTA is mindful that its findings capture only one factor contributing to the overall value of unlicensed spectrum.

2.1 Unlicensed and Permissionless Access

In the United States, radio frequency spectrum is a public resource managed exclusively by the federal government.⁴ The FCC manages spectrum for non-federal users and uses mechanisms to manage access and prevent interference among users. The National Telecommunications and Information Administration (NTIA) manages spectrum for federal users. Most unlicensed or permissionless spectrum is shared between FCC and NTIA regulation. This report deals with only devices regulated by the FCC that use unlicensed or permissionless spectrum.

An important first step is to define what is meant by “unlicensed” and “permissionless” access. FCC rules found in CFR 47 Part 15 for Radio Frequency Devices lay the framework for what many refer to as unlicensed spectrum by defining categories of devices that can be operated without an individual license. Along with Part 15, rule parts that do not require individual licensing are Part 18 (ISM), Part 95 (license by rule), Part 96 (CBRS – GAA), and Part 101 (70/80/90 GHz).

Although Part 15 defines and addresses unintentional, incidental and intentional radiators, this report addresses only intentional radiators: those familiar devices like Wi-Fi routers, smart speakers and garage door openers that intentionally emit radio waves. Many other sections of the FCC rules require a site license or an operator’s license. Some are described as “lightly licensed” or “licensed-by-rule”. Some bands and applications have spectrum access rules that are based on coordination or sharing, rather than site license.

For this report, the key feature that distinguishes the bands of interest is that *legally accessing the spectrum requires minimal effort once hardware is obtained*. This definition brings in more than the Parts 15 and 18 “License Exempt” categories, including for example “licensed-by-rule” categories in Part 95. Effectively, permission to use the spectrum comes with the product. This “permissionless access” characteristic allows users to gain the advantages

of the band and application with a hardware purchase. The key to permissionless access is that the product is in technical compliance with the rules.

This broader view of permissionless categories matches the FCC’s approach of using appropriate tools for the job. In practice, there are differences between unlicensed and licensed-by-rule. Part 15 unlicensed devices have no protection from interference and cannot cause harmful interference. Part 95 licensed-by-rule devices may have more protections from an allocation perspective; they may even be primary users of a band. However, there is variety in unlicensed and licensed-by-rule and a certain amount of overlap between their natures. The FCC may select unlicensed or licensed-by-rule for an emerging category as appropriate to the details of the band, but everyone benefits from the permissionless nature of the band.

For this report, we include devices authorized under Part 15 Subpart C (Intentional Radiators), Subpart D (Unlicensed Personal Communications Service Devices), Subpart E (Unlicensed National Information Infrastructure Devices) and Subpart F (Ultra-Wideband Operation). The report also covers certain devices authorized under Part 18 (Industrial, Scientific and Medical Equipment). Some devices under Part 95 (Personal Radio Services) also fall within this definition, as licensed-by-rule services.

In some “permissionless” cases, additional spectrum coordination is required, such as the Automated Frequency Coordination requirement for 6 GHz standard power devices. However, these requirements do not significantly detract from the out-of-box ease-of-use and decentralized nature of these services, so they also fall under the permissionless access umbrella. For brevity in the remainder of this report, we will use the term “unlicensed” broadly to mean unlicensed and permissionless access spectrum and distinguish where needed.

⁴ 47 U.S.C. § 151.

3 Methodology

This report comprehensively estimates the ISV of certain types of devices that use unlicensed spectrum.⁵ ISV represents a component of the direct contribution of unlicensed spectrum to American GDP.⁶

We define ISV as *the portion of product wholesale sales that is attributable to inclusion of an unlicensed spectrum feature*. ISV is computed for each product category by multiplying the total U.S. sales in that category times the unlicensed contribution in percentage terms.

Incremental Sales Value (\$) = Total U.S. Sales (\$) x Unlicensed Contribution (%)

Unlicensed contribution is a form of marginal value that varies by category. For example, in a wireless data link product that operates only on unlicensed spectrum bands, the unlicensed spectrum “feature” has an unlicensed contribution of 100%; literally the entire value of the product is due to unlicensed spectrum. Other products, such as smartphones, have utility without the unlicensed capability, but the unlicensed feature is always included. And in some cases, the unlicensed feature enhances the value of the product, yet there are alternatives in the market without unlicensed capability. Depending on the product category, the marginal value of an unlicensed spectrum feature (unlicensed contribution) may be a few percent or as high as the entire value of the product.

3.1 Determining Percentage of Unlicensed Contribution by Category

To structure this methodology in a formal manner, we apply these rules in the following order:

3.1.1 Test of Primary Function

If the unlicensed spectrum is required to use the device, the entire value of the device can be seen to come from this unlicensed spectrum access. For these products, the unlicensed spectrum effectively enables or defines the category.

If the product category meets the Primary Function test, the assigned ISV is 100% of the category’s sales.

- a. Example, a point-to-point wireless link product that operates only on unlicensed bands.
- b. Example, wireless earbuds; the total market for earbuds consists of separate wired and wireless categories. We do not have to tease out the portion of the value of the earbud market attributable to wireless because we have sales data on wireless earbuds that is separate from its wired counterpart that does not use unlicensed spectrum.
- c. Example, IP/Wi-Fi video cameras; this category includes security cameras and baby monitors. While a market for non-wireless products exists — such as wired security cameras — the wireless feature is important enough that buyers of one category are not generally looking at the other category.

3.1.2 Test of Market Capture

If the product can or did exist prior to the addition of unlicensed spectrum, but products now routinely include the feature, the market essentially has been captured by products with the wireless feature. While the feature is extremely important, the existence of a wired category before it became wireless indicates significant value without the unlicensed spectrum.

If the product category meets the Market Capture test, the unlicensed contribution percentage was selected between a minimum of 15% and a maximum of 30% to determine ISV. (In this category and in the following category, the report uses a subjective

⁵As explained in greater detail below, this report is representative of most of the overall sales but not all, because a portion of these sales are not tracked or reported upon.

⁶There are other ways in which a product could make contributions to GDP. For example, to produce a wireless headset, there may be mining operations for raw materials like copper; the copper may be sold to a company that produces wire; the wire is sold to the headset maker; the headset is sold to a retailer; and the retailer sells it to a consumer. Each stage implies multiple contributions to an overall economic value, such as the fuel purchased by the truck driver delivering copper wire. CTA has limited the scope of its inquiry to sales revenue for simplicity.

decision regarding this percentage in each case.)

- a. Example, smartphones; the majority of smartphone data travels unlicensed, but a smartphone without cellular is of little value.
- b. Example, mobile PCs; virtually all mobile computers include at least Bluetooth, with the majority including Wi-Fi as well.

3.1.3 Test of Significant Utility

If the product includes an unlicensed wireless feature but can reasonably be treated as having significant utility without the wireless feature, then the wireless feature has an important role to play and some finite value comes from this utility but less than in the prior two categories.

If the product category meets the Significant Utility test, an unlicensed contribution was selected between a minimum of 5% and a maximum of 15%.

- a. Example, smart TVs; a television has significant utility without being connected to the internet.
- b. Example, smart appliances such as connected refrigerators and connected ovens; here the situation is the opposite of the smart TV ecosystem: there are more examples of non-smart than smart appliances.
- c. Example, DSLR cameras; low-end cameras without wireless connectivity are a significant market, and wireless-enabled products are fully functional without their wireless features.

Note that a product group in the Significant Utility category may grow over time into a Market Capture product group, as consumers perceive the value and begin to reject products without the wireless

feature. There is also some blurring between these categories.

3.2 Calculating Incremental Sales Value by Category

Calculating ISV in a product category starts with an estimate of total U.S. wholesale sales for the category in dollars. For many consumer technology products that CTA tracks in our one- and five-year forecasts, we have total U.S. sales revenue available directly. See [Annex A](#) for details on “CTA Tracked” product categories. For other “quantifiable” product categories that CTA does not forecast, such as garage door openers, remote keyless entry and smart meters, we researched each segment to determine its ISV. See [Annex B](#) for analyses of these categories.

By multiplying the estimated total sales revenues by the percentage of unlicensed contribution (see [Methodology](#), above), we find the impact of unlicensed spectrum on annual sales in the United States, the ISV.

4 Data Sources

The category of unlicensed spectrum products encompasses tremendous variety, from smartphones to buried cable locators to medical imaging systems to enterprise data links. Multiple data sources contribute to the overall picture described by this report.

4.1 CTA Tracked Device Categories

Twice each year, CTA updates and publishes the *U.S. Consumer Technology One-Year Forecast*⁷, the benchmark by which the industry tracks past sales and forecasts sales of more than 125 consumer technology products. CTA's analysts produce the forecast by blending input from nearly 100 member companies and adjusting them using year-to-date

trending data from other quantitative and qualitative inputs, such as U.S. trade and tariff data.

This economic value report relies on the fine-grained sales history contained in the July 2021 update of the *One-Year Forecast* to provide 2020 sales data on 59 distinct product categories that make use of unlicensed spectrum. For these product categories, listed below, CTA has data on unit sales, average wholesale price and the resulting total revenue in 2020. The portion of revenue, or dollar value, attributable to the inclusion of unlicensed technology varies for each category. For each category, CTA assigned a percentage of the product's value attributable to unlicensed technology (see the [Methodology](#) section, above, for details). Specific percentage assignments and the resulting economic value contribution can be found in [Section 5, Findings](#).

TABLE 1: CTA TRACKED DEVICE CATEGORIES

360 Cameras	Electronic Gaming Portable Consoles
4K Ultra HD Blu-ray Players	E-Readers
5G Home Gateways	E-Toys (Connected)
Action Camcorders	Fitness Activity Trackers
Aftermarket Automotive In-Dash Monitors	Gamepads and Controllers
Audio/Video Receivers With Network/Internet Connectivity	Home Robots
Automotive Aftermarket Head Units With Bluetooth A2DP	Installed Home Systems
Bluetooth Headsets	IP/Wi-Fi Cameras
Blu-ray Players	Mesh Wi-Fi Systems
Camcorders (Solid State, Tape, DVD Blu-Ray, Hard Drive)	Mirrorless Cameras
Compact Systems	Mobile PCs (Laptops/Notebooks)
Connected Exercise Equipment	Modems/Broadband Gateways
Connected Health Monitoring Devices	Personal Computer Input Devices (Keyboards and Mice)
Connected Switches, Dimmers and Outlets	Personal Sound Amplification Products (PSAPs)
Connected Thermostat	Pet Tech
Cordless Phones	Portable Media Players
Desktop PCs	Portable Navigation Devices (Connected)
Digital Point and Shoot Cameras	Printers (Consumer)
DSLR Cameras	Smart Appliances
Electronic Gaming Headsets or Headphones	Smart Door Locks
Electronic Gaming Home Consoles	Smart Doorbells

⁷CTA forecast products, including the *U.S. Consumer Technology One-Year Forecast*, can be found at <https://www.cta.tech/Resources/Forecasts>.

Smart Home Security and Monitoring Systems	Soundbars
Smart Light Bulbs (Including Kits)	Sports Technology
Smart Smoke Detectors and CO Detectors	Standalone Wi-Fi Routers
Smart Speakers	Streaming Media Players
Smart TV	Tablets
Smartphones	Wireless Earbuds
Smartwatches	Wireless Headphones

4.2 Additional Quantifiable Categories

For categories outside CTA's scope of product tracking, we generated sales estimates from different sources: online research, direct manufacturer interviews and trade association data.

Next, CTA grouped together those categories for which we had reliable data. These are referred to in this report as Additional Quantifiable categories.

TABLE 2: ADDITIONAL QUANTIFIABLE DEVICE CATEGORIES

AM Broadcasting Hardware
Auditory Assistance Devices (Including LPRS)
Automatic Vehicle Identification Systems (AVIS)
Commercial Phone Systems
Drones and Radio-Controlled Hobby Craft
FM Broadcast
Garage Door Openers
Intelligent Transportation Systems (ITS)
ISM Part 18 Devices
Medical Devices
Multi-Use Radio Service
Near Field Communications (NFC)
Point-to-Point and Point-to-Multi-Point
Radiofrequency ID (RFID)
Remote Keyless Entry and Tire Pressure Monitoring Systems
Smart Meters and Mobile Meter Readers
Walkie-Talkies (Family Radio Service)
Wireless Microphones

Even within the Additional Quantifiable categories, we recognize that in certain cases we under-represent device sales. For example, Part 18 ISM band usage includes heating applications for factory processes (e.g., curing paints), food service (e.g., microwave cooking) and medicine (e.g., microwave diathermy). However, many of these device types are not tracked or have limited data available. For example, reliable data are available for microwave oven sales but less so for some of the other types mentioned. For categories without complete data, only the portion of sales that can be quantified is included in the device category.

In summary, our estimate of total ISV includes only amounts estimated for the Additional Quantifiable categories and only for those amounts within those categories that can be reliably determined. These factors mean our estimate of total ISV is conservative.

4.3 Non-Quantifiable Device Categories

After identifying Quantifiable categories, remaining categories were those where no data were available or data could not be sufficiently validated. These 10 categories are termed Non-Quantifiable. [Table 3](#) lists the device categories studied but determined to be Non-Quantifiable. These categories were not included in the total calculation of unlicensed device retail sales. Descriptions of these categories can be found in [Annex C: Non-Quantifiable Categories for U.S. Unlicensed Spectrum Devices](#).

TABLE 3: NON-QUANTIFIABLE DEVICE CATEGORIES

Baby Monitors
Cable Locating Equipment
Citizens Band Radio
Enterprise Wireless Headsets
Field Disturbance Sensors
Ground Penetrating Radar
Perimeter Security Systems (Field Disturbance Sensors)
Personal Locator Beacons
Stud Sensors and Wall Imaging Devices
Through-Wall Imaging Systems

There are three main reasons why these categories were not quantifiable.

1. Small, Private or Fractured Markets

This group includes small markets where there is not enough sales volume to be tracked. It includes highly fractured markets mostly of private companies, where the ease of integrating unlicensed spectrum makes it possible for many small companies to participate but difficult to quantify sales volumes:

- Citizens Band (CB) radio
- Enterprise wireless headsets
- Personal locator beacons

2. Service Industry Products

The sale of a single unit in these industries may drive months or years of service activity. Thus, these products have sporadic data unsuitable for inclusion in this study:

- Cable locating equipment
- Ground penetrating radar
- Stud sensors and wall imaging devices
- Through-wall imaging systems

3. Merged, Indistinguishable Product Types

Some product types include a subset of products that use unlicensed spectrum. Data may be available on larger groupings, but because no data is available on that subset of products, they could not be included in this study:

- Baby monitors
- Perimeter security systems (field disturbance sensors)

Were the Non-Quantifiable devices included in the study's aggregate numbers, they would add to the total value of ISV. Put differently, CTA's exclusion of certain unlicensed device categories from consideration causes the estimate of the total retail sales of unlicensed devices to be conservative.

4.4 Spectrum's Indirect Benefit Is Additive to CTA's Estimate

The Wi-Fi Alliance commissioned a comprehensive study by Telecom Advisory Services on the global economic value of Wi-Fi that illustrates the dramatic overall economic benefits of a ubiquitous, complementary technology such as Wi-Fi.⁸ This study identifies the total economic value of Wi-Fi use in the United States in 2021 at \$995 billion. The study cites five main drivers contributing to the total economic value of Wi-Fi in the countries studied⁹:

- Free Wi-Fi: benefit to consumers accessing Wi-Fi hotspots in public sites
- Residential Wi-Fi: provision of internet access and connectivity of devices at home
- Enterprise Wi-Fi: use of Wi-Fi to support a significant portion of enterprise broadband traffic and productivity gains from Wi-Fi enabled internet of things (IoT) and augmented reality (AR)/virtual reality (VR)
- Internet service providers (ISPs): savings for cellular providers who rely on Wi-Fi re-routing and revenues of Wi-Fi commercial providers

⁸ Telecom Advisory Services, The Economic Value of Wi-Fi®: A global view (2021 – 2025), September 2021 https://www.wi-fi.org/download.php?file=/sites/default/files/private/The_Economic_Value_of_Wi-Fi-A_Global_View_2021-2025_202109.pdf. Overview and additional links available at <https://www.wi-fi.org/discover-wi-fi/value-of-wi-fi>.

⁹Ibid. at page 10.

- Margins of manufacturing and Wi-Fi ecosystem companies, including manufacturers of Wi-Fi devices and equipment, IoT networks and AR/VR solutions

By focusing on direct contribution of device sales, CTA's study is purposefully focused on the "margins of manufacturing" factor. Indirect benefits include cost savings and productivity increases, as well as revenue from providing Wi-Fi services. The combined direct and indirect "economic surplus," to use economist terms, is orders of magnitude larger than the important contribution of device sales alone.

Broadly speaking, unlicensed spectrum has many indirect benefits:

- It lowers costs, which fosters innovation, competitiveness and rapid improvement, particularly for applications like machine-to-machine communication.¹⁰
- It allows device manufacturers more flexibility to respond to consumer demand.
- It improves internet access by making wireless infrastructure more ubiquitous.¹¹
- It has social and research value as a way to discover new uses for connecting devices wirelessly.

Collectively, these indirect benefits add to the economic contribution produced as a direct result of device sales.

¹⁰ See FCC, Connecting America: The National Broadband Plan 79 (2010).

¹¹ Milgrom, The Case for Unlicensed Spectrum, supra note 2, at 2 ("unlicensed spectrum is an enabling resource").

5 Findings

CTA estimates that the ISV, or value of wholesale sales attributable to unlicensed devices, is over **\$79.8 billion per year**. The following table shows ISV from greatest to least for every category of unlicensed device studied in this report. It is not surprising that the most popular consumer devices are the greatest contributors. Smartphones, laptops, wireless

earbuds, smart TVs and tablets capture five of the top six spots. Connectivity is paramount, and these devices drive lots of sales. For example, smartphones generated more than \$63 billion in revenue in the United States in 2020. In this report, we attribute 30% of that value to unlicensed to arrive at the nearly \$19 billion figure for smartphone ISV.

TABLE 4: INCREMENTAL SALES VALUE OF UNLICENSED SPECTRUM DEVICES

Product	Incremental Sales Value (\$ Million)
Smartphones	\$18,992
Mobile PCs (Laptops/Notebooks)	9629
Wireless Earbuds	8276
Near Field Communications (NFC)	3240
Smart TV	3225
Tablets	3194
Smart Speakers	3021
Drones and Radio-Controlled Hobby Craft	2700
ISM Part 18 Devices	2346
Radiofrequency ID (RFID)	2100
Wireless Speakers That Are Portable	2050
Smartwatches	1956
Point-to-Point and Point-to-Multi-Point	1320
Streaming Media Players	1155
Mesh Wi-Fi Systems	1089
Wireless Microphones	1081
Modems/Broadband Gateways	1046
Consumer Radar	1037
IP/Wi-Fi cameras	978
Wireless Headphones (Except Earbuds)	929
Connected Exercise Equipment	827
Smart Appliances	792
Electronic Gaming Home Consoles	782
Bluetooth Headsets	671
Smart Doorbells	659
Installed Home Systems	643
Desktop PCs	491
Fitness Activity Trackers	400
Smart Home Security and Monitoring Systems	375
Smart Light Bulbs (Including Kits)	323
Printers (U.S. Consumer Channels)	282
Standalone Wi-Fi Routers	275
Connected Thermostat	274

Remote Keyless Entry and Tire Pressure Monitoring Systems	\$259
Soundbars	222
Cordless Phones	207
Gamepad or Controller	190
Portable Media Players	183
Electronic Gaming Headset or Headphones	183
Commercial Phone Systems	178
Garage Door Openers	165
Connected Health Monitoring Devices	158
Smart Meters and Mobile Meter Readers	155
E-Toys That Are Connected	145
Personal Computer Input Devices (Keyboards and Mice)	138
Electronic Gaming Portable Consoles	132
Medical Devices	120
Connected Switches, Dimmers and Outlets	107
Auditory Assistance Devices (Including LPRS)	100
Home Robots	88
Smart Smoke Detectors and CO Detectors	76
Standard Handsets	75
Action Camcorders	67
Smart Door Locks	67
DSLR Cameras	66
Pet Tech	61
E-Readers	60
Mirrorless Cameras	48
Automotive Aftermarket Head Units With Bluetooth A2DP	45
Portable Navigation Devices That Are Connected	42
Automatic Vehicle Identification Systems (AVIS)	40
Aftermarket Automotive In-Dash Monitors	31
Digital Point and Shoot	26
4K Ultra HD Blu-ray Players	26
Audio/Video Receivers With Network/Internet Connectivity	20
Blu-ray Players	19
Sports Technology	18
5G Home Gateways	17
360 Cameras	15
Personal Sound Amplification Products (PSAPs)	12
FM Broadcast	10
Multi-Use Radio Service	10
Walkie-Talkies (Family Radio Service)	10
Compact Systems	5
Camcorders	2
AM Broadcasting Hardware	1
Intelligent Transportation Systems (ITS)	0
Total	\$79,758

5.1 Detailed Device and Category Contributions

In Table 5, we show a detailed breakout of categories and the values that lead to each ISV contribution. Please see Section 3, Methodology, for heading details. However, note that each product category has an associated revenue value, a percentage of value from unlicensed as explained in Methodology, the resulting unlicensed value and information about why the percentage was chosen for that category.

Also as described in the Methodology section, each category was reviewed in terms of whether the use of unlicensed spectrum was the primary function of the device, or the market has been captured by devices with unlicensed features, or the unlicensed feature

simply adds a significant utility. It is interesting to note that nearly every category in the top 25 ISV is of type Primary Function or Market Capture — the exceptions being smart TVs and smart appliances. We conclude that unlicensed spectrum features tend to either drive the function of the product or simply be so useful they take over the market. Indeed, 92.4% of total ISV in this study derives from markets where all products use unlicensed spectrum, because either it is the primary function of the device or products with unlicensed features have taken over the market.

Figure 2 visually presents the ISV data to show the scale of the top 20 categories of unlicensed ISV. Table 5 presents a more detailed breakout.

FIG. 2 TOP 20 CATEGORIES OF UNLICENSED INCREMENTAL SALES VALUE, RANKED BY SIZE (\$ MILLION)

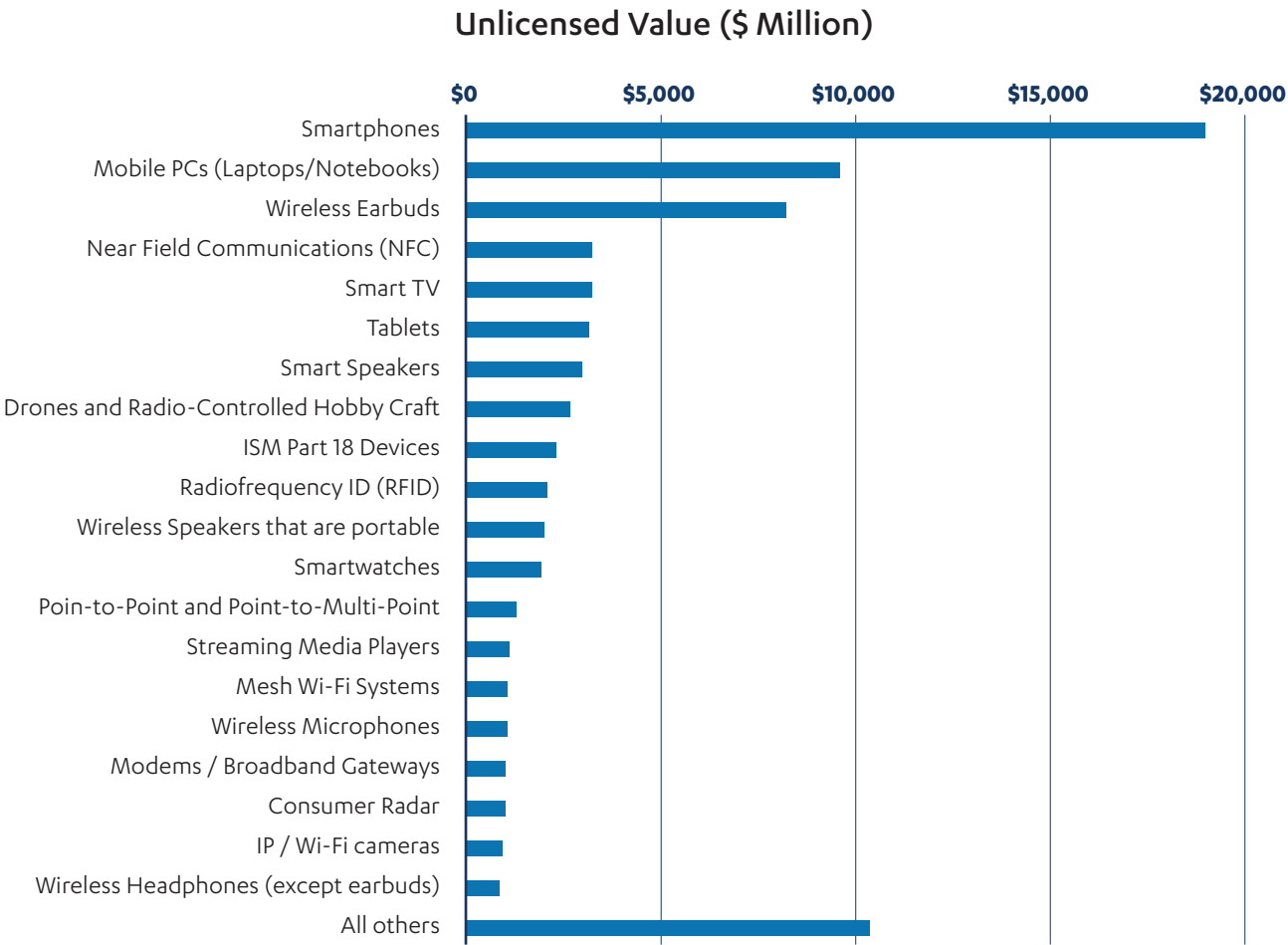


TABLE 5: DETAILED VALUATION OF CATEGORIES

Product Category	2020 Revenue (\$ Million) From Connected Products	% of Value Due to Unlicensed (ISV)	Unlicensed Value (\$ Million)	Primary Function, Significant Utility, or Other?	Comment
360 Cameras	\$102	15%	\$15	Significant Utility	Primary operation does not require unlicensed but cameras often wirelessly link to smartphone for display purposes.
4K Ultra HD Blu-ray Players	172	15	26	Significant Utility	Primary operation does not require unlicensed.
5G Home Gateways	58	30	17	Market Capture	5G function is licensed, but few if any devices available without a Wi-Fi access point feature.
Action Camcorders	337	20	67	Market Capture	Primary function is contained within the device but connectivity is needed for media exchange.
Aftermarket Automotive In-Dash Monitors	313	10	31	Significant Utility	Primary operation does not require unlicensed.
AM Broadcasting Hardware	1	100	1	Primary Function	Requires unlicensed operation for use. (Note that these devices are small consumer broadcast units.)
Audio/Video Receivers with network/Internet connectivity	203	10	20	Significant Utility	Primary operation does not require unlicensed.
Auditory Assistance Devices (Including LPRS)	100	100	100	Primary Function	Requires unlicensed operation for use.
Automatic Vehicle Identification Systems (AVIS)	40	100	40	Primary Function	Requires unlicensed operation for use.
Automotive Aftermarket Head Units With Bluetooth A2DP	181	25	45	Market Capture	By definition all available devices support unlicensed.
Bluetooth Headsets	671	100	671	Primary Function	Wired headsets are the available alternative choice.
Blu-ray Players	126	15	19	Significant Utility	Primary operation does not require unlicensed.
Camcorders (Solid State, Tape, DVD Blu-Ray, Hard Drive)	40	5	2	Significant Utility	Primary operation does not require unlicensed.
Commercial Phone Systems	1480	12	178	Significant Utility	Maintains primary function without unlicensed.
Compact Systems	96	5	5	Significant Utility	Primary operation does not require unlicensed.
Connected Exercise Equipment	2757	30	827	Market Capture	Non-connected exercise equipment was excluded from the market data.
Connected Health Monitoring Devices	632	25	158	Market Capture	Health monitoring devices, outside clinical settings, are generally wireless.
Connected Switches, Dimmers and Outlets	107	100	107	Primary Function	Traditional (non-smart) alternatives are available.

Product Category	2020 Revenue (\$ Million) From Connected Products	% of Value Due to Unlicensed (ISV)	Unlicensed Value (\$ Million)	Primary Function, Significant Utility, or Other?	Comment
Connected Thermostat	\$274	100%	\$274	Primary Function	Traditional (non-smart) thermostats are alternative.
Consumer Radar	1037	100	1037	Primary Function	The device operates entirely on unlicensed.
Cordless Phones	207	100	207	Primary Function	No operation without unlicensed.
Desktop PCs	2456	20	491	Market Capture	Functionality is not dependent on unlicensed, but market demands the feature.
Digital Point and Shoot	264	10	26	Significant Utility	Primary operation does not require unlicensed.
Drones and Radio-Controlled Hobby Craft	2700	100	2700	Primary Function	Requires unlicensed operation for use.
DSLR Cameras	658	10	66	Significant Utility	Primary operation does not require unlicensed.
Electronic Gaming Headset or Headphones (Corded or Wireless)	610	30	183	Market Capture	Corded and wireless available, but market data used was exclusively wireless.
Electronic Gaming Home Consoles	4347	18	782	Market Capture	Primary processing is on device but all consoles include wireless capabilities.
Electronic Gaming Portable Consoles	659	20	132	Market Capture	Primary operation does not require unlicensed, but all consoles include wireless capabilities.
E-Readers	299	20	60	Market Capture	Significant usage without connectivity, but connectivity required.
E-Toys That Are Connected	484	30	145	Market Capture	Wired connected e-toys are a very small share of market compared to wireless.
Fitness Activity Trackers	1335	30	400	Market Capture	Primary function is local to the device, but connectivity needed.
FM Broadcast	10	100	10	Primary Function	Requires unlicensed operation for use. (Note that these devices are small consumer broadcast units.)
Gamepad or Controller (Corded or Wireless)	634	30	190	Market Capture	Corded and wireless available, but market data used was exclusively wireless.
Garage Door Openers	165	100	165	Primary Function	Requires unlicensed operation for use.
Home Robots	875	10	88	Significant Utility	Primary operation does not require unlicensed.
Installed Home Systems	6426	10	643	Significant Utility	Primary operation does not require unlicensed.
Intelligent Transportation Systems (ITS)	0	100	0	Primary Function	Requires unlicensed operation for use as defined here; overtaken by licensed spectrum however.
IP/Wi-Fi Cameras	978	100	978	Primary Function	Wired camera systems are the available alternative choice.
ISM Part 18 Devices	2346	100	2346	Primary Function	Requires unlicensed operation for use.

Product Category	2020 Revenue (\$ Million) From Connected Products	% of Value Due to Unlicensed (ISV)	Unlicensed Value (\$ Million)	Primary Function, Significant Utility, or Other?	Comment
Medical Devices	\$1200	10%	\$120	Significant Utility	Maintains primary function without unlicensed.
Mesh Wi-Fi Systems	1089	100	1089	Primary Function	No operation without unlicensed.
Mirrorless Cameras	484	10	48	Significant Utility	Primary operation does not require unlicensed.
Mobile PCs (Laptops/ Notebooks)	40,121	24	9629	Market Capture	Devices have significant utility while disconnected but consumers expect connectivity and most usage requires it.
Modems/Broadband Gateways	3488	30	1046	Market Capture	Value attributed to the Wi-Fi gateway function.
Multi-Use Radio Service	10	100	10	Primary Function	Requires unlicensed operation for use.
Near Field Communications (NFC)	3240	100	3240	Primary Function	Requires unlicensed operation for use.
Personal Computer Input Devices (Keyboards and Mice)	459	30	138	Market Capture	Corded and wireless available in this category, but wireless has significant market share at retail.
Personal Sound Amplification Products (PSAPs)	123	10	12	Significant Utility	Primary operation does not require unlicensed.
Pet Tech	437	14	61	Significant Utility	Depending on product, primary operation may not require unlicensed.
Point-to-Point and Point-to-Multi-Point	1320	100	1320	Primary Function	Requires unlicensed operation for use.
Portable Media Players	611	30	183	Market Capture	Some standalone operation, but rare.
Portable Navigation Devices That Are Connected	282	15	42	Significant Utility	Primary operation does not require unlicensed.
Printers (U.S. Consumer Channels)	1879	15	282	Significant Utility	Likely unsellable without wireless connectivity but primary value is printing.
Radiofrequency ID (RFID)	2100	100	2100	Primary Function	Requires unlicensed operation for use.
Remote Keyless Entry and Tire Pressure Monitoring Systems	259	100	259	Primary Function	Requires unlicensed operation for use.
Smart Appliances	6598	12	792	Significant Utility	Depends on the appliance but most utility is not from connectivity.
Smart Door Locks	67	100	67	Primary Function	Traditional (non-smart) options are alternative.
Smart Doorbells	659	100	659	Primary Function	Category enabled by unlicensed.
Smart Home Security and Monitoring Systems	1250	30	375	Market Capture	Wireless products increasingly cover the market.

Product Category	2020 Revenue (\$ Million) From Connected Products	% of Value Due to Unlicensed (ISV)	Unlicensed Value (\$ Million)	Primary Function, Significant Utility, or Other?	Comment
Smart Light Bulbs (Including Kits)	\$323	100%	\$323	Primary Function	Traditional (non-smart) light bulbs are alternative.
Smart Meters and Mobile Meter Readers	1030	15%	155	Significant Utility	Maintains primary function without unlicensed.
Smart Smoke Detectors and CO Detectors	76	100%	76	Primary Function	Traditional (non-smart) options are alternative.
Smart Speaker	3021	100%	3021	Primary Function	Because these products depend on cloud connectivity, 100% of value is attributed to unlicensed.
Smart TV	21,500	15%	3225	Significant Utility	TVs have significant utility without connectivity.
Smartphones	63,307	30%	18,992	Market Capture	Most smartphone connected usage is unlicensed and all units have it, but a smartphone is primarily a licensed spectrum device.
Smartwatches	6521	30%	1956	Market Capture	Most utility comes from connectivity and all devices have it.
Soundbars	2215	10%	222	Significant Utility	Most products are wired.
Sports Technology	88	20%	18	Market Capture	The equipment is primarily for sports but uses connectivity for key functions.
Standalone Wi-Fi Routers	275	100%	275	Primary Function	No operation without unlicensed.
Standard Handsets	300	25%	75	Market Capture	Less value attributed to unlicensed for the shrinking category of handsets that are not smartphones.
Streaming Media Players	1155	100%	1155	Primary Function	Extremely limited operation without unlicensed.
Tablets	11,409	28%	3194	Market Capture	More utility comes from connectivity than laptops and virtually all units include wireless.
Walkie-Talkies (Family Radio Service)	10	100%	10	Primary Function	Requires unlicensed operation for use.
Wireless Earbuds	8276	100%	8276	Primary Function	Wired earbuds are an alternative, so this category passes the Primary Function test.
Wireless Headphones (Except Earbuds)	929	100%	929	Primary Function	Wired headphones are an alternative, so this category passes the Primary Function test.
Wireless Microphones	1081	100%	1081	Primary Function	Requires unlicensed operation for use.
Wireless Speakers That Are Portable	2050	100%	2050	Primary Function	Wired speakers are the available alternative choice.

5.2 Other Unlicensed Market Segments Not Included in ISV

Three market segments discussed in this section are not included in the \$79.8 billion total ISV of this report for three entirely different reasons. The first, Industrial IoT clearly has significant sales of devices using unlicensed connectivity. The challenge and the reason for not including an Industrial IoT dollar value in this report is the breadth of devices and insufficient information on end device sales and their reliance on unlicensed. The second, TV White Spaces (TVWS) is a unique market enabled by specific FCC rules that, to date, has had limited success in the United States. Finally, Citizens Broadband Radio Service (CBRS) is on the watch list for future consideration as a permissionless access technology.

5.2.1 Industrial IoT (IIoT)

Most device types considered in this study meet the criteria for being part of the IoT. The ISV numbers presented in this report are largely for consumer and enterprise applications. Due to the variety of applications in many categories of industrial IoT (IIoT), it is more difficult to present an ISV that reliably captures their impact. Instead, we focus on a few of the largest categories and their units shipped.¹²

5.2.1.1 Beacons and Asset Tracking

This category includes beacons for short-range asset tracking and pop-up information (such as in retail stores, where a beacon can trigger a smart phone alert about a sale item on a nearby shelf). Also included are tracking of people and animals and inventory management in general. Bluetooth Low Energy is the winner in terms of technologies with 85% of units shipped supporting that unlicensed spectrum technology. Wi-Fi, systems using IEEE 802.15.4 and ultra wide band (UWB) make up the balance. In 2020, there were approximately 122.8 million units shipped globally.

5.2.1.2 Energy Management

Energy management consists of smart technologies to automate building functions including security and

heating, ventilation and air conditioning (HVAC), smart utility meters and smart grid technologies. Systems based on IEEE 802.15.4 make up the majority of systems (77% according to ABI Research). Wi-Fi (mostly) and Bluetooth Low Energy make up the rest. Globally, some 50.5 million units shipped in 2020. A portion of the overall energy management market, namely smart meters, is captured in the ISV analysis of this report.

5.2.1.3 Healthcare

Healthcare applications not considered elsewhere in this report include monitoring of patients either in professional settings or at home. Bluetooth is a strong player with Bluetooth Low Energy accounting for almost 60% of applications, according to ABI. Systems based on IEEE 802.15.4 and Wi-Fi make up significant minorities in the total as well. Globally, some 28.2 million such healthcare solutions shipped in 2020.

5.2.1.4 Industrial Monitoring

Wireless monitoring of industrial equipment (other than transportation applications) helps with equipment performance and maintenance. This includes monitoring temperatures of refrigeration units in restaurants (for food safety); the flow through connected pumps and levels in tanks; gas station applications; retail applications and more. Virtually every industrial system has applications for monitoring movement, position, temperature, vibration, cycles and exposure. Wi-Fi is preferred, although Bluetooth Low Energy is also used. Global shipments in 2020 were some 2.2 million units but growing very quickly.

5.2.1.5 Smart City

Smart city applications involve smart parking, street lighting, intelligent transportation and other solutions to reduce congestion and improve experience by the use of connected technology. Smart city applications mostly use protocols based on IEEE 802.15.4, such as Zigbee and 6LoWPAN, and usually in the ISM bands. Bluetooth and Wi-Fi are used in some instances. Globally, some 4.4 million smart city units shipped in 2020.

¹² Unit shipment data in this section is largely derived from ABI Research's report, Wireless Connectivity Technology Segmentation and Addressable Markets, July 2021. <https://www.abiresearch.com/market-research/product/7779358-wireless-connectivity-technology-segmentat/>

5.2.1.6 Other Value-Added Applications

Along with the major categories listed above, applications for unlicensed spectrum are found in many other areas. Bluetooth technologies are used widely in these smaller categories. These categories also significantly use licensed connectivity, specifically 3G (mostly being phased out in early 2022), 4G and increasingly 5G. ATMs, retail terminals and kiosks and digital signage are some examples. Bluetooth and Wi-Fi dominate the unlicensed technology picture here. Some 57 million units shipped globally in these various categories in 2020.

5.2.1.7 IIoT Summary

Some 270 million IIoT units with unlicensed wireless technology shipped globally in 2020.

5.2.2 TV White Spaces (TVWS)

TVWS was a promising opportunity that has not seen great success in the United States. The FCC approved unlicensed use of available TV channels in 2008 with final rules in 2010. TVWS devices access a spectrum database for geolocation-based channel allocation, with the intent to avoid interfering with local broadcast television. The Airband Initiative is a partner program started by Microsoft to help rural ISPs and others find funding and TVWS equipment to solve last-mile internet access problems.

In its Q4 2020 report, the FCC Technological Advisory Council's Future of Unlicensed Operations working group described TVWS spectrum sharing as "A valuable (albeit difficult) first step on spectrum sharing database technology" and included the following lessons learned:

- First large-scale commercially managed dynamic spectrum database solution
- Suffered from regulatory uncertainty due to the TV station repack
- TVWS database certification was performed in serial, leading to commercial delays
- Enforcement was not fully clarified

TVWS use in the United States has been subject to delays in implementation, lawsuits and other

challenges. In the United States, there is not yet a significant market for these devices, although the lessons learned have informed spectrum sharing efforts, particularly in CBRS.

5.2.3 Citizens Broadband Radio Service (CBRS)

CBRS operates in the range 3.55 GHz to 3.70 GHz. The FCC recognizes three kinds of users in this band: incumbent users, priority access licensees and General Authorized Access (GAA) users. Incumbent users include the Navy and fixed satellite service earth stations; wireless protected zones also exist for legacy Part 90 services including "quiet" and border regions. Priority access licensees are companies who obtained licenses in a competitive bidding process.

GAA is a category for permissionless (licensed-by-rule) usage. This category is new enough that the estimate for 2020 sales is effectively zero. Several applications provide major opportunity, making this an exciting category for future study.

CBRS GAA may be used in any business communications application. GAA may also be used for short-range high-speed links, such as in VR headsets (between the console and the headset). The key characteristics are the excellent spectrum location in the middle of the desirable 3 GHz band, the 150 MHz bandwidth available and the spectrum sharing that reduces interference from competing applications. CTA anticipates significant growth in this category going forward.

6 Conclusions

The value of unlicensed spectrum is difficult to quantify, yet we generally accept that it is extremely valuable. This study copes with that difficulty by choosing a narrowly tailored metric, ISV, for which there is concrete data, particularly in the consumer segment. CTA concludes that unlicensed and permissionless spectrum add over \$95.8 billion in retail sales (\$79.8 billion wholesale) per year in hardware sales to the economy.

The power of easy-to-use spectrum is clear when one considers that almost all of the product categories in this study either owe their existence to unlicensed or have had their market captured by it. Relatively few categories have only incidental use for unlicensed. And across this broad landscape, ISM band usage is nearly ubiquitous; this easy and flexible band has found its way into most categories in one way or another.

However, other bands have important niches, and new opportunities are rising, particularly with the maturing of dynamic spectrum sharing and the availability of new frequencies.

In addition to the significant incremental sales value (ISV) of the categories above, industrial internet of things (IIoT) has a massive presence, with unlicensed-powered applications for asset tracking, healthcare, equipment monitoring and more. Hundreds of millions of IIoT devices using unlicensed and permissionless spectrum can be found spread across virtually every business sector, from retail and food service to manufacturing and agriculture.

In licensed spectrum, a design goal of 5G was to handle the projected growth of connected devices. The ubiquitous deployment and growth of unlicensed and permissionless devices shows that this is a two-front war: demand for connectivity means demand for both licensed and unlicensed spectrum, now and in the future.

Annex A: CTA-Tracked Categories for U.S. Unlicensed Spectrum Devices

This annex provides details on the dozens of unlicensed spectrum device types that are tracked by CTA through its regular market research activities. The primary source of material for products in this annex came from CTA’s *U.S. Consumer Technology Five-Year Industry Forecast*; CTA’s most comprehensive forecast report, charting U.S. market size and shipment volumes for nearly 300 products and services.

As a reminder, we call the economic value totaled in this report the ISV, which is defined as *the portion of product wholesale sales that is attributable to inclusion of an unlicensed spectrum feature*. ISV is computed for each product category by multiplying the total U.S. sales in that category times the unlicensed contribution in percentage terms.

Incremental Sales Value (\$) = Total U.S. Sales (\$) x Unlicensed Contribution (%)

Unlicensed contribution is a form of marginal value that varies by category. Depending on the product category, the unlicensed contribution may be a few percent or as high as the entire value of the product. Table A-1 provides an overview of the three main tests or “buckets” into which product categories are divided for purposes of determining the Unlicensed Contribution percentage. Please refer to [Section 3](#) in the main report for a full description of these tests.

TABLE A 1: DETERMINING PERCENTAGE OF UNLICENSED CONTRIBUTION

Test Applied	Summary	Range of Unlicensed Contribution (%)
Primary Function Test	Unlicensed spectrum is required to use the device	100%
Market Capture Test	Products routinely include the unlicensed feature, including nearly 100% of the market	15%-30%
Significant Utility Test	Unlicensed enables feature(s) but is not required for the product to have significant utility	5%-15%

Definitions of CTA-Tracked Categories

The following definitions are provided to indicate the scope of categories tracked in CTA’s One- and Five-Year Forecasts and to show what is included or excluded from the U.S. sales revenue numbers used from those reports.

For further information on these categories, total revenue, average sales price and more, please refer to CTA’s [U.S. Consumer Technology Five-Year Industry Forecast](#).

360 Cameras	A camera with a 360-degree field of view in the horizontal plane, or with a visual field that covers (approximately) the entire sphere.
4K Ultra HD Blu-ray Players	A Blu-ray player that can play 4K Ultra HD Blu-ray discs. Home component Blu-ray players; excludes Sony PlayStation models.
5G Home Gateways	Home gateways with an embedded 5G wireless transceiver; includes units with or without built-in Wi-Fi. Includes gateways/modems shipped to broadband providers.
Action Camcorders	Hands-free action cameras that are designed for capturing point-of-view footage.
Aftermarket Automotive In-Dash Monitors	Automotive (infotainment) head units that can provide both audio and video-playback (multimedia).
Audio/Video Receivers With Internet Connectivity	Audio component incorporating a tuner, a preamplifier and a power amplifier and that can connect to the internet.
Automotive Aftermarket Head Units With Bluetooth	Automotive head units that support Bluetooth; typically advanced audio distribution profile (A2DP), also known as “stereo Bluetooth.”
Bluetooth Headsets	In-ear/on-ear/over-ear mono chat headsets and stereo headphones using Bluetooth; excludes those meant for electronic gaming.
Blu-ray Players	Home component Blu-ray players; excludes Sony PlayStation models and non-4K UHD models.
Camcorders	Standard standalone camcorders.
Compact Systems	Devices that integrate the functions of a multi-component home stereo system (does not include products with only portable media docking capability, such as clock radios with MP3/smartphone docks).
Connected Exercise Equipment	Includes any exercise equipment with the ability to interface wirelessly with a mobile app and/or includes screen that provides on-demand fitness routines or other content to enhance the exercise experience.
Connected Switches, Dimmers and Outlets	Home lighting switches, dimmers and outlets that can be controlled via smartphone or tablet.
Connected Thermostat	Electronic, programmable and self-learning Wi-Fi-enabled thermostat that optimizes heating and cooling of homes and businesses to conserve energy.
Cordless Phones	All cordless landline telephones.
Desktop PCs	A personal computer (PC) in a form intended for regular use at a single location.
Digital Point and Shoot	A still camera designed primarily for simple operation; does not include mirrorless camera types.
Drones	Unmanned aerial vehicle (UAV) whose flight is controlled either autonomously by onboard computers or by the remote control of a pilot on the ground or in another vehicle. Sold through consumer sales channels.
DSLR Cameras	A digital still image camera that uses a single lens reflex (SLR) mechanism. Can include packages with lenses and accessories included.
Electronic Gaming Headset or Headphones	In-ear/on-ear/over-ear mono chat headsets and stereo headphones (wired or wireless) meant for electronic gaming.
Electronic Gaming Home Consoles	Standalone, non-portable game consoles such as Xbox One/One S, Sony PS4/PS4 Pro and Nintendo Switch (not Switch Lite).
Electronic Gaming Portable Consoles	Portable or handheld game console devices such as Nintendo 3DS, Sony PS Vita and Nintendo Switch Lite.
E-Readers	Standalone electronic device designed primarily for the purpose of reading digital books or magazines.
E-Toys That Are Connected	An electronic toy that can be controlled with a mobile app or has the ability to transmit information via Wi-fi, Bluetooth or NFC. Includes products such as electronic educational devices, handheld electronic games, analog radio-controlled vehicles, other battery-operated vehicles, robots and electronically controlled action figures, musical instruments and karaoke machines. Does not include home robots.

Fitness Activity Trackers	Includes wearable devices that use sensors to measure or track movement, activity levels and/or certain vital signs. Display screen is typically incorporated into the wristband and/or is the same width as the wristband and is typically less than 1.5 inches wide.
Gamepad or Controller	Regular gamepads or controllers (wireless).
Home Robots	Autonomous robots often used for indoor/outdoor household chores including robotic vacuum cleaners, floor-washing robots and lawn mowers.
Installed Smart Home Systems	Wireless home automation technologies that are typically installed by a professional. Includes lighting controls, climate systems and whole house controllers.
IP/Wi-Fi Cameras	Video camera that can send and receive data via a computer network and the internet. Includes baby monitors that communicate over Wi-Fi/IP.
Mesh Wi-Fi Systems	Wireless home network equipment designed to establish a consistent, strong Wi-Fi signal throughout a home. Also known as home mesh networks. Typically includes a hub that connects directly to a modem and one or more nodes that extend Wi-Fi coverage.
Mirrorless Cameras	A camera similar to a DSLR but designed without the reflex lens. Can include packages with lenses and accessories included.
Mobile PCs (Laptops/ Notebooks)	Includes notebooks, netbooks, Chromebooks and convertible PCs.
Modems/Broadband Gateways	Home broadband gateways and modems with built-in Wi-Fi. Includes gateways/modems shipped to broadband providers. Does not include 5G gateways/modems.
Personal Computer Input Devices	Computer keyboards and mice, wireless.
Personal Sound Amplification Products	Over-the-counter hearing devices designed primarily to amplify ambient sound and that include a Bluetooth feature for settings and music, podcasts or other electronic audio.
Pet Tech	A connected device used to monitor, entertain, feed or track household pets, typically controlled by a smartphone.
Portable Media Players	A portable device that plays back digital audio or video files. May include a touch screen and the ability to run apps.
Portable Navigation Devices That Are Connected	A battery powered, GPS-based navigation device that is portable. Does not include navigation devices that are built into vehicles.
Printers	Computer printers designed for home use. Includes laser, inkjet, bubblejet, dot matrix and multifunctional printers. Does not include enterprise printers.
Smart Appliances	Refrigerators, dishwashers, washing machines and dryers with built-in connectivity that enables notifications and remote control through a mobile app.
Smart Door Locks	Door locks that send and receive data via a computer network and the internet. Typically controlled through mobile app.
Smart Doorbells	Doorbells that send and receive data via a computer network and the internet. Typically include video camera. Typically controlled through mobile app.
Smart Light Bulbs (Including Kits)	Light bulbs that send and receive data via a computer network and the internet. Typically controlled through mobile app. Includes packages with multiple light bulbs.
Smart Smoke Detectors and CO Detectors	Devices that can alert a user's mobile device as well as sound an alarm when smoke/carbon monoxide is detected.
Smart Speaker	Wireless speakers that can receive voice commands and enable interactivity with a digital assistant, including those with built-in displays.
Smart TV	Digital televisions that have consumer-oriented apps loaded on the set that deliver internet-based content through a wireless internet connection.
Smartphones	Wireless handsets that employ an operating system (e.g., Android, iOS) and can use apps.
Smartwatches	A wearable device whose design invokes that of a traditional timepiece and that is designed to be worn on the wrist. Smartwatches include sensors that measure or track movement, activity levels and/or certain vital signs. Display screens are typically greater than 1.5 inches wide.

Soundbars	Home theater speaker system in a single cabinet that simulates surround sound and that connects to a DTV wirelessly.
Sports Technology	Device that tracks and analyzes performance and activity for a specific sport and communicates this information wirelessly to another device, such as a smartphone.
Standalone Wi-Fi Routers	Basic Wi-Fi routers that are not whole home Wi-Fi solutions and that do not include a modem. Products may include Ethernet ports.
Standard Handsets	Wireless handsets that employ a proprietary operating system and include Wi-Fi or Bluetooth. Also known as "feature phones."
Streaming Media Players	A wireless internet-enabled set-top box or streaming stick that enables viewing of content from subscription video on demand services or live streaming TV services. Includes Roku, Apple TV, Amazon Fire, etc.
Tablets	Mobile devices operated by a touch screen larger than 6.6 inches, with Wi-Fi.
Wireless Earbuds	Earbuds or in-ear headphones that receive audio signal via Bluetooth. Audio jack not included. Earbuds are not connected to each other with a cable or band. Includes devices that CTA previously defined as "hearables," such as earbuds that track heart rate and activity levels. Does not include personal sound amplification products or over-the-counter hearing aids.
Wireless Headphones (Except Earbuds)	Wireless headphones that are worn on or around the ear.
Wireless Speakers That Are Portable	Wireless speakers that receive audio signals via Bluetooth, Wi-Fi or AirPlay and have the capability to operate on battery power.

Annex B: Additional Quantifiable Categories for U.S. Unlicensed Spectrum Devices

Introduction

This annex expands on 19 categories of unlicensed spectrum devices included in this report. The data for these categories are not reported to CTA by manufacturers for the forecasts as described previously for the categories in Annex A. Instead, each category was researched individually to determine an estimate of the ISV. ISV is the portion of device sales attributable to features that use unlicensed spectrum. Due to the variety of products in this annex, a number of methods were used to calculate ISV. To determine the dollar value of these product categories input sources include third-party market research, company websites and interviews with suppliers and experts. See [Section 3, Methodology](#) in the main body of this report for details.

Each section includes a short definition of a category and its available bands. Rules permitting these uses in these categories and bands are primarily contained in 47 CFR 15 and the unlicensed portions of 47 CFR 95.

For each category, sample products are identified to provide examples of the applications of the spectrum. To the extent available, original manufacturer's information is used throughout this annex.

Where possible, the categories are separated by the frequency band of interest. This is particularly important where the common name for a device type is generic. For example, products called "walkie-talkies" can be found in multiple bands, some licensed and some unlicensed.

In short, this annex summarizes the definitions of the categories, examples of the products and their uses

and the annual U.S. ISV impact of these unlicensed spectrum devices.

B.1. AM Broadcasting Hardware

Overview

The overall market has not changed much since our last review in 2014, although some sectors have transitioned to mobile technologies. The pandemic shutdown of 2020 has, however, led to a significant increase in sales to organizations who are foregoing in-person activities but permitting in-car participation. Churches especially have turned to unlicensed AM broadcast, putting the signal in the parking lot for drive-in "socially distant" services.

Unlicensed AM transmissions use the U.S. broadcast AM band, 535-1705 kHz. Licensed AM radio stations operate in this band, but consumers and small businesses may operate unlicensed AM low-power transmissions in the band as long as the licensed stations do not experience interference. Educational institutions may configure for a stronger signal provided the signal coverage is limited to the campus. But for most use cases, the low level of effective power means that application of unlicensed AM falls into two categories.

First, transmission by a single antenna for a single locale. A typical example is a parking lot at a historical monument or the property of a house that is for sale.

The second kind of implementation is so-called "carrier current" transmission. In this case, the AM signal is fed into the power lines (e.g., for a high school campus). Anyone within a few tens of meters of a power line at the school can potentially receive the signal. The signal is blocked by power company transformers, so the transmission can be controlled to one campus.

These unlicensed applications fall into FCC rules under a section commonly called "Part 15" (specifically 47 CFR § 15.219-221), so these applications are sometimes referred to as "Part 15 transmitters."

Note that this category is distinct from Travelers Information Service (TIS) which is an AM band

licensed service used to inform traveling public of safety information or traffic conditions.

Common applications for unlicensed AM include:

- Churches and other places of community gathering, at a time when such gathering is restricted by social distancing as in the 2020 pandemic.
- Departments of Transportation: Information at rest areas, toll collection areas, weigh stations.
 - The Massachusetts Bay Commuter Railroad Company uses Part 15 (unlicensed) low-power AM transmitters to inform commuters of train arrivals and other daily information at their rail stations.
- Industry/Military: Critical information for visitors or truckers at truck depots, loading docks, facility gates, weigh-stations or check points.
- Hospitals and public health: Broadcast updates on health status, procedures and patron information.
- Micro-broadcasters and hobbyist applications (low-power operators in general): Niche programming not available commercially (e.g., religious programming and campus stations [K-8, high school or college campus radio broadcasting]). More information may be found at [Hobby Broadcaster — Broadcasters Resource Directory](#).
- Outdoor advertising: In association with billboards along highways and in cities.
- Theme parks, historical sites and societies, national parks and outdoor recreation: For interpretation and visitor information (parking, programs and events, historical or nature information).
- Tourism industry (general): Information and translation for area of interest.
- U.S. borders and highway checkpoints: Regulations and procedures for motorists.

Some categories noted in the 2014 version of this report have fallen significantly due to those industries moving to internet-based services targeting mobile phones or transitioning to higher frequencies and more modern data-capable technologies. These sectors include auto dealers,

banks, holiday lighting, pharmacies, real estate, restaurants and theater. Other application examples mentioned in the 2014 version of this report no longer list an AM radio option, so it appears that this transition is happening broadly.

Market Segments and Suppliers

The primary impact of this category comes from transmitter hardware sales. A secondary impact on the perceived value comes from consumer electronic devices that include an AM radio feature. A secondary impact on businesses comes from using such services in place of other forms of advertising or consumer information. Finally, installers serve micro-broadcasters.

In application, Hamilton, Ramsey and InfOspot have good market share, but they are by no means alone. Other suppliers include:

- [Chez Radio](#)
- [Grain Industries](#)
- [Hamilton RangeMaster](#)
- [TalkingHouse](#)
- [TheRadioSource](#) (InfOspot series)
- [SSTran](#)

Market Size Determination

Companies in this segment are small private companies. Public information is not available. Based on interviews, we estimate that this market is approximately \$1 million/year in total, including both assembled product and “kit” product. The percentage of value attributable to the unlicensed spectrum is 100%, as unlicensed spectrum is required to use the device (Primary Function test).

Technical Notes

Part 15 rules (47 CFR § 15.219) permit only 100 mW to the antenna, a short antenna and a short path to ground. Effectively these restrictions mean that the antenna must be placed on the ground or nearly so. Theft of these systems is common, and the resulting low height above average terrain (HAAT) and low effective isotropic radiated power (EIRP) limit the service to the scale of a single property lot as opposed to a neighborhood or town.

Advocates have asked the FCC for 1W power to a 50-foot antenna, but there has not been sufficient support to change the rules.

B.2. Auditory Assistance Devices (Including LPRS)

Overview

Auditory assistance devices or assistive listening systems are permitted under the FCC's Low Power Radio Service (LPRS) at 216-217 MHz. Such devices can also use infrared (IR), FM radio frequency or induction loops. These systems are used at events to provide the public with enhanced audio or to provide supplemental information, especially translated dialog. FM systems operating in the 72-74 MHz band have been in use from the 1970s. In 1992, the Commission expanded the band due to increasing problems with interference to include 74-76 MHz. Over the past few years Wi-Fi assisted hearing systems, including low-latency systems have slightly risen in popularity; however, FM and IR systems dominate the market. The 49 MHz band is used to a limited extent for PSAP, but most of PSAP uses Bluetooth instead.

Unlicensed spectrum (or IR light) is used to broadcast the auditory portion of an event, or other auditory assistance, at places of public gatherings such as churches, theaters or sporting events. The 1990 passage of the American Disabilities Act (ADA) has helped with the sales of these devices, because the law requires any business with 50 or more seats in an area of public assembly, such as an auditorium, theater or movie house, to make such devices available. With over 41,000 U.S. indoor movie screens alone, many sites require these devices.

By providing stronger, cleaner and enhanced audio, these systems minimize the effects of background noise and reverberation on speech that would otherwise be received via a loudspeaker system. Persons with hearing difficulties benefit from these systems. Those who also have hearing aids can, in some cases, connect the hearing aid directly to the auditory assistance receiver.

The 72-76 MHz products (under Part 15) are used for relatively small spaces. An inductive loop plugs into

a hearing accessory to pick up the audio program; inductive loops are short-range technology.

Common applications for auditory assistance systems include:

- Places of worship
- Conference centers
- Schools
- Auditoriums
- Theaters
- Meeting halls
- Sporting events

Another important application is simultaneous translation. In May 2013, the Commission modified the definition of "auditory assistance device" in Part 15 to permit these devices to be used by anyone at any location for simultaneous language interpretation (that is, simultaneous translation, where the spoken words are translated continuously in near real time); this change harmonized Part 15 with Part 95 LPRS in this detail.

Market Segments and Suppliers

These systems are sold and installed in public places. Hardware sales and installation are the primary impact:

- **Anchor Audio** provides ISM-band (902-928 MHz) unlicensed assistive listening systems.
- **Comtek** provides assistive technologies at 72-76 MHz (Part 15) and at 216-220 MHz (Part 95 Low Power Radio Service).
- **Listen Technologies** provides assistive technologies at 72-76 MHz.
- **Nady** provides assistive systems at 72-76 MHz as well as professional sound products.
- **Williams Sound** provides hearing assistance systems.
- In addition, **AudioLinks**, **Barinas** and **Centrum Sound** are distributors for Williams, Listen and others.

Market Size Determination

We estimate that sales of these devices amount to some \$100 million/year, of which \$50 million/year alone is the 72-76 MHz category. Various unlicensed frequencies make up the remainder of sales, including a small amount in the 49 MHz category. This application is also served by Bluetooth and other

ISM band applications. The percentage of value attributable to the unlicensed spectrum is 100%, as unlicensed spectrum is required to use the device (Primary Function test).

B.3. Automatic Vehicle Identification Systems (AVIS)

Overview

Automatic vehicle identification is a subset of the larger ITS market. These systems automatically identify vehicles using RFID-compatible readers and individual vehicle-mounted transponders, or “tags.” The original tags were boxy windshield-mounted devices where the form factor was partly driven by the size of the internal antenna. Technology developments have allowed for small inexpensive stickers with integrated antennas and RFID chips. Some car manufacturers have integrated multi-protocol tag transponders into vehicles at the factory. Transponders operate on 900 MHz and 2.4 GHz ISM bands and on various Part 15 frequencies in 2.9-3.6 GHz specifically designated for AVIS.

In residential use, AVIS can be used to control access to parking lots; in commercial use, it can help track fleet vehicles and other transportation systems vehicles. In public use, along with the other commercial applications mentioned, they are used for automatic toll collection. The hardware

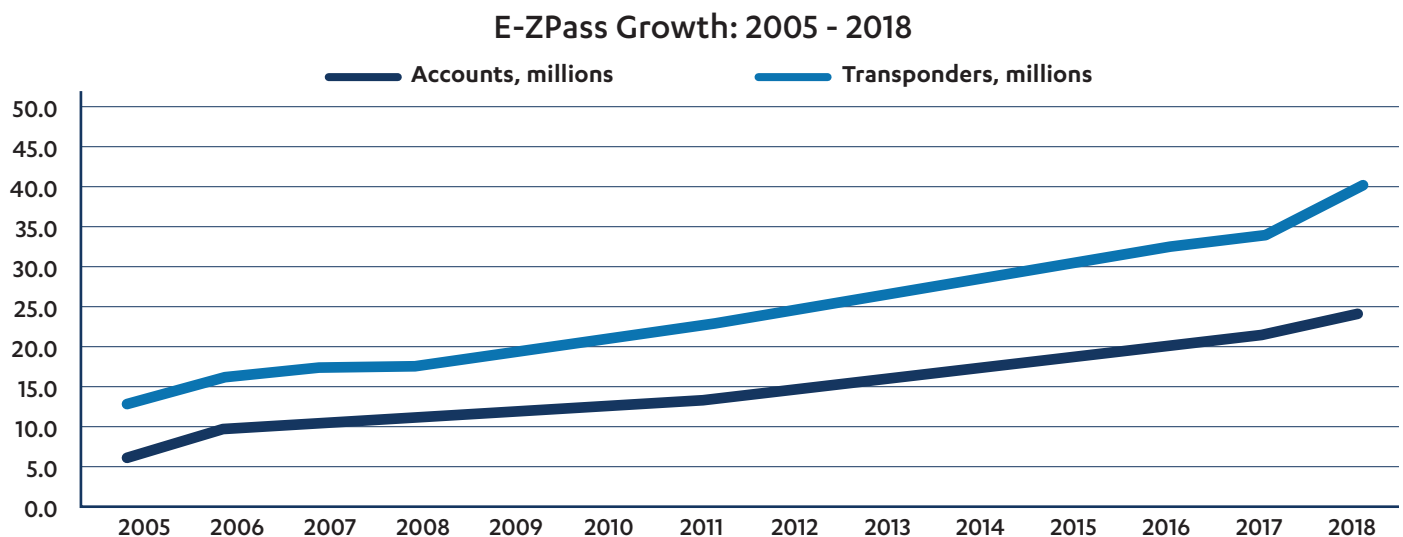
consists of a “tag” (RF identification device, placed on the asset to be tracked) and a “reader” (a device, hand-held or mounted in a fixed place, capable of collecting data from the tag device). The tag may require an antenna. For these applications, distances are typically limited to a few tens of meters or less.

Common applications for AVIS include:

- Gated and assisted living communities
- Condominium parking
- Commercial parking
- Airports and seaports
- Universities
- Hospitals
- Fleet control (in/out access and management)
- Train location/positioning
- Electronic toll collection

Regarding electronic toll collection, E-ZPass is the clear market leader. It has also experienced significant growth in the past decade. From 2005 to 2018, E-ZPass accounts have risen 267%, with transponder sales up 205% and individual transactions — cars past the toll both reader — up 70%. The ease, efficiency and overall practicality of this unlicensed spectrum application can clearly be seen in this growth (see [Figure B-1](#)).¹³

FIG. B-1 GROWTH OF E-ZPASS USERS AND TAGS



¹³ <https://www.e-zpassag.com/about-us/statistics>

Market Segments and Suppliers

AVIS is another “installed” category. This category business comes from tag and reader hardware makers, distributors and system integrators.

Suppliers provide standards-compliant readers and tags. Standards in use in the United States include:

- ATA (Air Transport Association of America) Spec2000
- California FasTrak, often referred to as CalTrans Title-21
- ISO/IEC 18000-6C
- Kapsch TDM (formerly IAG)
- TransCore SeGo

The systems used by states for automatic electronic toll collection vary and go by different names, but all are based on the above standards and all use the 902-928 MHz unlicensed band. Of these, E-ZPass is the largest with 17 states choosing it as their system.¹⁴ In addition, there are intra-state compatibility agreements that allow a tag purchased under one state system to be used in another state:

- AutoExpreso (Puerto Rico)
- Downbeach Express Pass (New Jersey)
- Express Pass (Utah)
- EXpressToll (Colorado)
- E-ZPass: (Delaware, Illinois, Indiana, Kentucky, Maine, Maryland, Massachusetts, Minnesota, New Hampshire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, Virginia, West Virginia)
- EZ Tag (Texas)
- FasTrak (California)
- Freedom Pass (Alabama)
- GeauxPass (Louisiana)
- Good to Go (Washington)
- GO-PASS (Colorado)
- K-Tag (Kansas)
- NexpressToll (Michigan)
- PalmettoPass (South Carolina)
- Peach Pass (Georgia)
- Pikepass (Oklahoma)

- SunPass (Florida)
- TollTag (Texas)
- TxTAG (Texas)
- Finally, the states that do not have electronic toll collection include: Alaska, Arizona, Arkansas, Connecticut, District of Columbia, Hawaii, Idaho, Iowa, Mississippi, Missouri, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Tennessee, Vermont, Wisconsin, Wyoming

Besides electronic toll collection, AVIS are used for a variety of other vehicle asset applications. Systems and suppliers include:

- **TagMaster** products are used in AVIS, fleet and train management. They operate at the 2.4 GHz ISM band.
- **Telematics-Wireless** has an electronic toll system as well as AVIS products.
- **Intermec** makes both tags and readers.

Market Size Determination

In toll collection, E-ZPass is the largest segment of this market. Over 43.4 million E-ZPass transponders were in use in 2020. The transponders cost states approximately \$9.00; some 4.4 million units are sold per year for an annual amount of \$39.6 million.¹⁵ The percentage of value attributable to the unlicensed spectrum is 100%, as unlicensed spectrum is required to use the device (Primary Function test).

Increasing deployment nationwide, following the success of E-ZPass and other regional programs, has led to more deployment and interoperability in these programs. However, the corresponding unit growth in vehicle transponders has been offset significantly by the advent of inexpensive RFID window stickers and a corresponding offset in cost and revenues.

Other than E-ZPass, AVIS applications include parking garage access, security and train positioning as shown above. Individually, these applications are smaller than E-ZPass, but combined they are potentially a large segment. Some data on

¹⁴ Ibid.

these components is included in [Section B.15, Radiofrequency ID \(RFID\)](#).

B.4. Commercial Phone Systems

Overview

This category refers to phone systems and accessories used in business settings and call centers. Voice over IP (VoIP) systems often connect to an office local area network (LAN) and use unlicensed frequencies to eliminate the wired connection between the desk phone and headsets or use Wi-Fi where wired LAN connections are not available. In addition to Wi-Fi, VoIP phones often use Bluetooth technology or Digital Electronic Cordless Telephone (DECT) technology. DECT is the digital cordless access technology standardized by the European Telecommunications Standards Institute (ETSI) and used worldwide. Most consumer cordless phones (accounted for separately in this study) use DECT.

Wireless VoIP phones can be a stand-alone system (e.g., a desktop phone with wireless capability, or an accessory handset to a base station or corded phone). In the commercial phone market, DECT VoIP phones are popular in retail, construction, warehouse and hospitality industries where mobility is prized. Wi-Fi VoIP phones are often seen in healthcare settings.

Market Segments and Suppliers

The primary impact for the purposes of this study comes from hardware sales of desktop phones, conference phones, cordless handsets and accessories such as headsets. Market estimates for the overall enterprise voice or VoIP markets include VoIP service providers, like RingCentral and 8x8. According to IBIS World, total VoIP industry revenue (both wired and wireless) in the United States in 2020 was \$15.2 billion.¹⁶ The COVID-19 pandemic shutdown has brought a surge in demand for VoIP and unified communications services and thrust new players like Zoom into the spotlight. Even considering only the hardware components, the market is diverse. Most enterprise phone systems have migrated to VoIP,

and office phone service via unlicensed is becoming predominant.

In office environments, unified communication systems (UCS) is the talked-about capability. In UCS, all the communications service needs are merged into a single platform. These services include voice calling and call forwarding; video conferencing; screen sharing, file sharing and virtual white boarding; instant messaging and chat; and live status of personal availability.

In virtually every commercial enterprise where phone support is needed and smartphones alone are not sufficient, IP phones have taken over:

- Business systems companies include:
 - [Cisco](#)
 - [Fanvil](#)
 - [Grandstream](#)
 - [Gigaset](#)
 - [Panasonic](#)
 - [Polycom \(now Poly\)](#)
 - [Sangoma](#)
 - [Spectralink](#)
 - [Yealink](#)
- Companies using unlicensed spectrum for headsets and earpieces include:
 - [Cisco](#)
 - [Jabra](#)
 - [Logitech](#)
 - [Plantronics \(now part of Poly\)](#)
 - [EPOS|Sennheiser](#)

Market Size Determination

CTA estimates the entire VoIP phone hardware market in the United States to be \$1.48 billion. The percentage of value attributable to the unlicensed spectrum is 12%, as the product includes an unlicensed wireless feature but can reasonably be treated as having significant utility without the wireless feature (Significant Utility test). The market estimate combined with the value percentage results in unlicensed economic impact of \$178 million for this segment.

¹⁶ Ibid.

B.5. Consumer Radar Devices

Overview

This category is dominated by vehicle radar, although the market is growing for non-vehicle applications.

Vehicular radar operates in the 76 GHz to 81 GHz band. In July 2017, the FCC voted to expand U.S. spectrum allocations to this full band to be consistent with allocations internationally, and as part of a transition out of the 24 GHz band for vehicular radar applications. Under 47 CFR § 15.37 “*Transition provisions for compliance with this part*”, vehicular radars using the 22-29 GHz band were no longer certified after September 20, 2018.

The band also supports non-vehicle radar applications, such as motion-sensing lights and security devices. Growth in 60 GHz consumer radar applications (47 CFR § 15.255) is expected to be very strong although the market is nascent at this time. Products have been demonstrated that use consumer radar for gesture-based smartphone interfaces and to do presence detection in cars. CTA is working with Google and others to develop standard software application programming interfaces (APIs) for consumer radar implementations to ease the design of products using this new capability.

Vehicular radar applications are becoming more common in automotive applications including:

- Adaptive cruise control
- Autonomous emergency braking
- Rear traffic crossing alert
- Blind spot detection and lane change assistance
- Forward collision avoidance
- Side and rear collision avoidance
- Intelligent parking assist

Several ranges are used: long range, on the order of 250 m; and short to medium range, on the order of 50 m. Long-range radar technology can resolve distances with an accuracy of under a meter and is used for adaptive cruise control. Medium- and short-range radar can resolve under 10 cm. Medium-range

technology is used for rear traffic crossing alert, blind spot detection and lane change assistance. Short-range technology is used when tight tolerance and a higher field of view are required, such as for intelligent parking assist and close-in or lower-speed collision avoidance. As a result, a modern vehicle may have a long-range device in the front of the vehicle, medium-range devices in the rear and short-range devices in the front and rear sides. These placements can cover all the intended applications from forward cruise control to rear collision detection and parking assist functions, plus more.¹⁷

Following the usual adoption pattern for enhanced technology in the automotive industry, these technologies were initially available on luxury brands like Jaguar and Mercedes. Now virtually all makes have the feature available. The radar transducer (signal transmitter) is available from semiconductor companies (see examples, below).

Finally, in a waiver adopted April 14, 2021, the FCC announced that the 57 GHz to 64 GHz band will be used by at least six companies for in-vehicle motion detection. The primary function is “to prevent risks of children inadvertently left unattended in a rear seat in hot weather.” Other features can be supported by the technology, particularly theft prevention. The FCC granted this waiver for these companies to operate at a higher power level than would ordinarily be permitted for this unlicensed band.

For non-vehicle applications, in-air gesture recognition is expected to grow quickly as enabling technologies — inexpensive transducers, chips and software — have become available. Gesture recognition may be seen as an alternative to voice commands. Since voice commands imply a listening device, there are concerns with consumer perceptions of privacy. Gesture recognition neatly sidesteps the privacy question.

Market Segments and Suppliers

Adaptive cruise control and other (external) vehicular radar is increasingly offered as a standard feature on many car models. Gesture recognition is expected

¹⁶ <https://www.ibisworld.com/industry-statistics/market-size/voip-united-states/>

to grow swiftly as a category, and motion sensors are an application area for radar technologies as well (although other technologies, such as IR, can support motion detection).

- Virtually all major vehicle manufacturers use radar for driver assist and safety functions. Examples include:
 - **Audi Driver Assistance Systems**
 - **Ford Adaptive Cruise Control**
 - **GM Super Cruise**
 - **Hyundai Occupant Alert System and Hyundai SmartSense**
 - **Infiniti Intelligent Cruise Control**
 - **Jeep Safety and Security**
 - **Porsche Adaptive Cruise Control**
 - **Volvo Radar Unit**
- Manufacturers of radar sensors for both vehicle and non-vehicle applications include:
 - **Analog Devices**
 - **Aptiv**
 - **Autoliv Inc.**
 - **Continental AG**
 - **DENSO Corporation**
 - **IEE Sensing Inc.**
 - **Infineon**
 - **NXP Semiconductors**
 - **Robert Bosch GmbH**
 - **SaberTek, Inc.**
 - **Tesla**
 - **Texas Instruments**
 - **Valeo**
 - **Vayyar Imaging Ltd.**
 - **ZF Friedrichshafen**

Market Size Determination

We estimate the U.S. share of automotive radar to be \$1.01 billion in 2020. While consumer non-vehicle applications have tremendous growth potential, the current market is still small with \$27 million in 2020. The total of the two major categories is \$1.037 billion in 2020. The percentage of value attributable to the unlicensed spectrum is 100%, as unlicensed spectrum is required to use the device (Primary Function test).

B.6. Drones and Radio-Controlled Hobby Craft

Overview

Two main product categories cover small remotely controlled or piloted craft: drones, also known as unmanned aircraft systems (UAS); and hobby remote-controlled craft such as cars, planes or boats. All products in both categories are typically under 25 kg (55 lbs), which is the maximum weight for “small” UAS per FAA rules. Small UAS (sUAS) operate under FAA 14 CFR Part 107.

These products typically use 900 MHz, 2.4 GHz and 5.8 GHz under Part 15 unlicensed rules. Drones without video capability tend to use 900 MHz; those with video tend to use the higher bands. Manufacturer’s radios are rarely interoperable, but external radios can be added to a controller. The user must “bind” or “pair” the controller radio with the drone or craft radio; this operation is analogous to Bluetooth “pairing” of devices.

An older technology is the Radio Control Radio Service (RCRS, formerly known as the Class C Citizens Radio Service). RCRS is a private, one-way, short distance non-voice communications service for the operation of devices at remote locations. Channels authorized for this service are between 72.0-73.0 MHz and 75.4-76.0 MHz. Six channels between 26.995 MHz and 27.255 MHz also may be used to control devices. The RCRS service was more commonly used in the past, but the higher band radios have overtaken the legacy technology and now dominate the market. Wi-Fi is not typically used for this category, except for some drones’ video data interfaces.

This category’s applications include drones, model planes, boats, cars, trucks and the like.

Market Segments and Suppliers

This category covers hardware sales of models with integrated radios, radio subassemblies and components and transmitter units.

¹⁷ See https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2057-1-201801-I!!PDF-E.pdf

The vendors in this category are numerous and include:

- Radio modules and radio-controlled craft manufacturers include:
 - [Futuba](#)
 - [Spektrum at Horizon](#)
 - [Traxxas](#)
- Radio-controlled craft and parts (retailers) include:
 - [AMain Hobbies](#)
 - [Horizon Hobby](#)

Market Size Determination

Drones have grown quickly to surpass other radio-controlled devices in market size. The total radio-controlled business is roughly split between non-drone hobby craft at \$1.2 billion and drones at close to \$1.5 billion. We estimate the total sales at \$2.7 billion in 2020. The percentage of value attributable to the unlicensed spectrum is 100%, as unlicensed spectrum is required to use the device (Primary Function test).

B.7. FM Broadcast

Overview

This category covers unlicensed low-power broadcast of FM signals in the licensed 88-108 MHz FM band.

In prior years, this category included both “products” and “features within products.” For example, there are FM devices that only perform the function of wireless audio transmission from an audio output device to a television. There have also been complete products with many features, only one of which is FM transmission; an example of this is a full-featured satellite radio receiver that includes an FM transmitter. However, this latter group has fallen off significantly with the increased adoption of Bluetooth audio in media products and is no longer considered significant.

Thus, this category is about dedicated audio-to-FM-broadcast devices. Such devices are sold for three main applications:

- The first primary application is to move audio from a personal media player (often a smartphone or portable Blu-Ray disc player) to another system (most often, a car stereo). These applications

crop up wherever consumer audio occurs. These devices can be used to broadcast FM sound to car stereos, so that the driver can enjoy audio using the higher quality car speakers, or a passenger can watch a video on a media player while the audio is presented on the car infotainment system. The audio source input to the accessory device may be line audio (for media players with an audio jack) or Bluetooth (for smartphones or media players with Bluetooth audio support). The output is FM-compatible transmission. Here, “line audio” is an industry term for low-voltage analog audio typically presented on a 3.5 mm jack, and compatible with commodity headphones.

- The second primary application is for auditory assistance. Some hearing aid systems put a microphone and transmitter on the person speaking (e.g., a teacher), and an FM receiver on a hearing-impaired person (e.g., a student). Some hearing aids are made specifically compatible with this approach by including either a telecoil input or direct audio input.
- The last application to consider is for site-specific information broadcasting. A house of worship or other institution may offer audio programming in a hyper-local fashion.

FCC rules (47 CFR § 15.239) effectively limit the range of these devices to about 200 feet when used with a standalone antenna. The FCC has a Knowledge Base article ([KDB #470998](#)) that describes different ways this type of intentional radiator can inject the FM signal into a vehicle antenna or wiring system.

Market Segments and Suppliers

For the above reasons, this category includes standalone devices that act as translators from (typically) line audio to FM broadcast. A second kind of translator accessory is Bluetooth-to-FM; this product bridges between smartphones that have Bluetooth audio output and cars that have no Bluetooth audio input. Sales of both kinds of accessory have declined as cars increasingly support Bluetooth audio input in their infotainment systems. Other market segments are the auditory assistance and site-specific broadcast segments.

Generally, this category is primarily about hardware sales as there are no integrators.

Suppliers in the three main segments include:

- Audio player accessories (transmitters for smartphones/media players car stereo/television audio)
 - [Belkin](#)
 - [Poly \(Plantronics\)](#)
 - [Scosche](#)
 - [Whole House](#)
- Audio assistance
 - [AVR Sonovation](#) (see Logicom FM)
- Site-specific audio
 - [Williams Sound](#)

Market Size Determination

With the rise of Bluetooth and the decline of single-purpose MP3 players and iPods, sales of products in the primary application of *media-player-to-car-stereo* have dropped in the years since the initial version of this report. The remaining primary applications, *auditory assistance and site-specific broadcasting*, remain level but small. We estimate the U.S. ISV of accessories with this feature to be roughly \$10 million per year. The percentage of value attributable to the unlicensed spectrum is 100%, as unlicensed use of spectrum is required to use the device (Primary Function test).

B.8. Garage Door Openers

Overview

These unlicensed spectrum devices allow short-range remote opening of garage doors.

This category is self-descriptive, although “garage door opener” could be generalized to “intermittent control signal devices.” From the FCC rules that garage door controls operate under, the more general list is “...*alarm systems, door openers, remote switches, etc. Continuous transmissions, voice, video and the radio control of toys are not permitted. Data is permitted to be sent with a control signal.*” However, “garage door opener” and its acronym GDO is the more common category

name. Of course, garage door openers are a main application. Also, there are home automation and security systems, audio-video system RF remote controls and extenders, and a variety of smaller applications where some light data traffic for control is required. For example, DIRECTV makes use of 433 MHz in its remote controls for whole house operation.

The rules permitting unlicensed operation of these devices call out over 60 frequency bands. However, in the market, devices operate most often in the range 100-400 MHz, with 310 MHz, 315 MHz, 318 MHz, 360 MHz, 390 MHz and 433 MHz being common. Some operate on other (higher) frequencies as well.

The most significant change in recent years is the inclusion of Wi-Fi in garage door opener systems for integration with smart home platforms. An example is the [myQ](#) hub and smartphone app from Chamberlain Group that links garage door openers to the homeowner’s Wi-Fi network for remote access and lighting control.

Market Segments and Suppliers

Products sold in this category include retail and professional garage door systems, plus automakers include HomeLink RF remotes as part of the vehicle interior equipment. (HomeLink has been installed in at least 50 million vehicles in the past.)

Garage door openers and access control systems are sold to commercial and residential markets. The market analyzed here focuses on residential garage door openers. The market leader by far is the Chamberlain Group, which owns the two top brands: LiftMaster and Chamberlain.

Suppliers and products include:

- Garage door openers—Top garage door opener and entry system companies as reported by construction companies according to Farnsworth Group, 2018.
 - [LiftMaster](#) (50% of installations)
 - [Chamberlain](#) (15% of installations)
 - [Overhead Door](#) (10% of installations; part of

Overhead Door Corporation, a Sanwa Holdings Company)

- o **Genie** (8% of installations; owned by Overhead Door Corporation, see also Alliance, BlueMax, Code-Dodger, Crusader, Excelsior, Hercules, Intellicode, Lift-a-Door, Norelco, Pro-Max, and Python)
- o **Craftsman** (5% of installations)
- o See also **HomeLink** (Gentex Corporation)
- Home A/V remotes
 - o **DIRECTV** (remotes use 433 MHz)
 - o **NextGen** (remote extender)
 - o **Universal Remotes** (See **URC MX-780**, uses 418 MHz)

Market Size Determination

The combined estimated annual sales and annual replacement sales of remote-controlled garage door operators are \$164.5 million. The percentage of value attributable to the unlicensed spectrum is 100%, as unlicensed spectrum is required to use the device (Primary Function test). Wi-Fi-based home control applications are covered in a separate section.

B.9. Intelligent Transportation Systems (ITS)

Overview

Intelligent transportation systems (ITS) is a broad term used for a variety of transportation-related information and communications solutions. These solutions are intended to reduce traffic congestion and increase safety on the roadways. Wireless systems planned for ITS have included licensed spectrum (mobile phone technology) and unlicensed spectrum (DSRC [Digital Short-Range Communications]).

DSRC was researched and prototyped for two decades. The 2014 version of this report noted the potential for significant use of unlicensed spectrum by DSRC hardware and applications. However, DSRC technology never moved into full scale deployment.

Finally, in November 2020, the FCC voted to transition away from the dedicated unlicensed spectrum allocation for DSRC. The FCC reallocated

the lower 45 MHz (5.850-5.895 GHz) for unlicensed uses and designated the upper 30 MHz (5.895-5.925 GHz) for enhanced automobile safety using cellular vehicle-to-everything (C-V2X) technology.

(Licensed) C-V2X has nearly completely taken over the role intended for (unlicensed) DSRC. Some applications of Wi-Fi technology in ITS are still planned, but a broad rollout of DSRC — and therefore unlicensed spectrum — in ITS is no longer possible.

Market Size Determination

Although licensed spectrum applications in the C-V2X space have potential, DSRC deployment has essentially been ended by the FCC's decision. We therefore revise our estimate for *unlicensed* spectrum applications in ITS to be effectively zero.

B.10. Industrial, Scientific and Medical (ISM) Part 18 Devices

Overview

The Industrial, Scientific and Medical (ISM) bands are radio bands reserved internationally for industrial, scientific and medical purposes other than communications.

These are specifically not voice or data devices. These devices are generally heating systems for one purpose or another, although other uses of these bands exist, including for example magnetic resonance imaging (MRI). Examples of applications in these bands include industrial process heating, microwave ovens, medical diathermy machines, electrosurgery and a variety of laboratory and scientific equipment.

Because there are so many sub-categories under this main category, a more detailed list of applications with a sample product for each is provided in a following section.

Market Segments and Suppliers

As can be imagined from the breadth of this category, the hardware market cuts across many kinds of suppliers: food service equipment, general manufacturing equipment, laboratory equipment and healthcare systems.

¹⁸ From 47 CFR 15.231.

A list of some applications (adapted from <http://www.telecomabc.com/i/ism.html>) with a sample product shown for each item includes:

- Heating (1-100 MHz)
 - Drying, molding, welding and thawing: [Litzler Radio Frequency Ovens & Dryers](#)
- Medical equipment
 - Short-wave and microwave diathermy and hyperthermia equipment: <https://www.mettlerelectronics.com/autotherm-390/>
 - Electrical surgical units (ESU): [Megadyne Mega Power Generator](#) (main component for their ESU system)
 - MRI: [Philips MRI](#)
- Microwave equipment (above 900 MHz)
 - Domestic microwave ovens: [Samsung Microwave Ovens](#)
 - Commercial microwave ovens: [Microdry Applications; Thermex Microwave Systems](#)
 - Food tempering, thawing and cooking: [Panasonic Heavy Duty Microwave Ovens](#)
 - General curing, drying or annealing: [Microcure/Lamda Thermal Applications](#)
 - Rubber vulcanization: [Rubicon Microwave Vulcanization Lines](#)
 - Pharmaceutical processing: [GEA Single-Pot Processors](#)
- Laboratory and scientific equipment
 - Signal generators: [Anritsu Microwave Signal Generator](#)
 - Flow meters: [Monitor Technologies Powder Flow Meter](#)
 - Electronic microscopes: [Hitachi TEM Microscope](#)

Market Size Determination

This category encompasses a wide variety of products and applications under a relatively small section of rules. According to the Association of Home Appliance Manufacturers (AHAM), domestic microwave ovens alone account for \$2.219 billion in annual sales; this is up 15.7% from 2012, reflecting a combination of growth in unit sales and decline in average sale price (ASP). Polaris Market Research

estimates that industrial microwave heating units make up \$1.06 billion in global sales; scaling by the estimate of U.S. manufacturing share of 12% from the Brookings Institution's global manufacturing scorecard leads to an estimate of \$127 million for U.S. sales.

Combined, these numbers lead to a value of \$2.346 billion in ISV for the United States. The percentage of value attributable to the unlicensed spectrum is 100%, as unlicensed spectrum is required to use the device (Primary Function test).

Product groups which could not be quantified for this report include commercial microwave (food) ovens, medical applications, lab and scientific signal generators and various other important tools in the industrial and medical areas. These categories do not require compatibility with each other, and so their use of spectrum is not a "headline" element of the product. For an alternative example of this, consider the Wi-Fi router. "Wi-Fi" is an essential element of the product title. This is not so with, for example, medical diathermy units which use unlicensed spectrum.

As a result, non-communications applications of unlicensed spectrum are much less likely to promote the nature of their spectrum characteristics. This makes it difficult to track them.

However, the value of these unassociated, untracked markets is clearly quite high, and future efforts on such quantitative studies may be able to shed more light on the magnitude of the market size here.

B.11. Medical Devices

Overview

This category includes implantable or wearable healthcare devices that monitor, regulate or, in some cases, replace, critical human biological functions. In the United States, healthcare professionals can communicate with these lifesaving products by the Medical Device Radiocommunications Service (MedRadio, formerly MICS/Medical Implant Communication Service) and Wireless Medical Telemetry Service (WMTS).

The MedRadio band has been set aside by the FCC for very low-powered systems used for communications between implanted medical devices and nearby monitoring equipment. MedRadio includes the 401-406, 413-419, 426-432, 438-444, 451-457 and 2360-2400 MHz bands. Previously, some implantable devices used the older 175 kHz and 402-405 MHz MICS bands, and many still support the lower band. MICS has been replaced by MedRadio which is intended for longer-range communications than what was available with 175 kHz. The 400 MHz radios can operate at 2-5m range and 250 kbps rate; significantly increasing usability and flexibility over the 175 kHz (inductive) system, which was limited to 8-cm range and 50 kbps rate. MedRadio is found in cardiac pacemakers, implantable cardioverter-defibrillators (ICDs), neurostimulators, hearing aids and automated drug delivery systems.

WMTS has 14 MHz permitted at 600 MHz and 1400 MHz under Part 95. Use of WMTS is limited to authorized healthcare providers. This includes licensed physicians, healthcare facilities and certain trained and supervised technicians.

In consumer applications, a “health and fitness” category includes products with a range of monitoring solutions suitable for casual runners and marathoners; dieters; and anyone interested in watching their own body statistics. These products are treated separately as smartwatches and fitness activity trackers. These consumer applications use Bluetooth, Bluetooth Low Energy (BLE), ANT/ANT+ or other wireless personal area network (WPAN) protocols.

Some products also use BLE for communications purposes. While most Bluetooth is broken out separately in this report, some Bluetooth-compatible product is included here rather than in the larger group, due to the specialized nature of these devices.

MedRadio is used to wirelessly connect implantable medical devices such as ICDs, pacemakers, neurostimulators, sensors, diagnostic devices, drug pumps and insulin pumps. MedRadio is also used for ingested devices and in other sensor applications requiring ultra low-power streaming data performance.

Medical conditions that indicate use of these devices include neural stimulation for spinal cord damage, unexplained fainting or palpitations, diabetes (for glucose management) and atrial fibrillation. In 2009, a New York woman with atrial fibrillation became the first person to receive a pacemaker wirelessly connected to her doctor.

Typical monitoring functions include electrocardiogram, noninvasive blood pressure, saturation of peripheral oxygen, and electroencephalogram. Of course, any monitored condition is a candidate for wireless transmission. Aging patients can wear a wireless pendant that transmits an emergency signal in case of accident (e.g., fallen and can’t get up) or health incident (e.g., cardiac arrest).

WMTS is used to monitor patient physiological data in real time in clinical settings via wireless sensors worn by the patient. The healthcare facilities eligible for the WMTS are defined as those that offer services for use beyond 24 hours, including hospitals and other medical providers. Ambulances and other moving vehicles are not included within this definition. Per the FCC’s April 2010 order, WMTS operations are licensed by rule, without separate Commission authorization, but must be registered with the American Society of Health Care Engineering of the American Hospital Association (ASHE), the WMTS frequency coordinator, prior to operation. The WMTS database is hosted by Comsearch at <https://www.wmtsearch.com>.

In 2015, the FCC revised its rules to allow unlicensed TVWS devices to operate in the 600 MHz band (TV channel 37) provided the devices are kept a minimum distance from hospitals. However, TVWS has seen very limited use.

Market Segments and Suppliers

Product in this segment includes implantable devices, monitoring systems and services (hospital and surgery, but also outpatient monitoring services). Abbott announced exciting devices in this category at CES 2022, including the Lingo wearable product line.

Suppliers and developers of wireless medical implants and wireless implant monitoring systems include:

- Professional healthcare industry
 - **Abbott (Heart Monitoring), Abbott (Neural Stimulation)**
 - **Alere**
 - **Biointellisense** (Biobutton)
 - **Biotronik Home Monitoring**
 - **Cardiacom**
 - **GE Healthcare**
 - **Healthsense** (using Wi-Fi in remote patient/pendant applications)
 - **Marmax Distribution** (supplies infrastructure components)
 - **Medtronic**
 - **Microsemi** (example of a wireless chip designed for these applications)
 - **Philips Patient Monitoring** (1.4 MHz WMTS, 2.4 GHz ISM, 2.4 GHz 802.11, 5 GHz)
 - **Roche Diagnostics**
 - Spacelabs Healthcare (WMTS) **Telemetry Transmitter**
 - **Toumaz Group**
 - **Viterion** (uses Bluetooth)
 - **Vignet Corporation** (press release on ANT usage in healthcare with Vignet)
 - Others include: ACS Diagnostics, Applied Cardiac Systems, Asahi Kasei Corporation, Astro-Med, BioTelemetry, Boston Scientific, BPL Medical Technologies, ChronicWatch, Cisco Systems, Comarch, Finmeccanica SPA., Honeywell International, IBM Corp, Koninklijke Philips, Lepu Medical Technology, Lindsay Corporation, Medicomp, Medi-Lynx, MeTrax GmbH, Meytec, MicroPort Scientific Corporation, Nihon Kohden, Philips Healthcare, Preventice Services, Progetti Srl, SCHILLER AG, Shenzhen Mindray Bio-Medical Electronics, Shree Pacetronix, Siemens AG, Sonamba, Telerhythmics, The Scottcare Corporation, Tytocare, Welch Allyn, and Zoll Medical Corporation.
- Consumer electronics
 - **Bio-Signal Group** (uses Bluetooth)
 - **Biomedical Systems** (uses Bluetooth)

- **BodyMedia**
- **FitLinxx**
- **Garmin** (Dynastream Innovations)
- **Ideal Life** (uses Bluetooth)
- **Nike**
- **Polar Electro**
- **Suunto** (makes fitness monitor watches that use ANT wireless)
- Industry groups for further research
 - **Bluetooth SIG** (healthcare page)
 - **Continua Healthcare Alliance** (includes a list of certified products)
 - **ZigBee Alliance** (healthcare page)

Market Size Determination

Over 120,000 Americans receive a new implanted pacemaker or defibrillator each year, at an average unit cost of about \$10,000. This represents \$1.2 billion/year in the United States. Further, similar products and wireless telemetry devices represent an additional \$8 billion. However, this number includes a significant amount of mobile (typically 3G/4G) based product and so is not used in our estimate. However, there is certainly upside in the more conservative \$1.2 billion number if telemetry were to be included.

Each of these products serves a potentially life-saving function. The ability of the healthcare professional to interact with the device is a critical capability. Different devices have different interaction capabilities. In some the interaction is helpful; in others the interaction is a necessary function. The primary function of the device is the medical purpose, but the wireless connectivity is present in the vast majority of applications (Market Capture). However, the overwhelming importance of the medical portion of the device indicates that the wireless value (ISV allocation) would be appropriate on the low end of that range, or 15%. Other applications are growing and will represent an important contribution in the future. Net, the total market number we use, is \$1.2 billion with 15% of value contributed by the permissionless frequency capability, for an incremental value of \$180 million.

B.12. Multi-Use Radio Service (MURS)

Overview

Multi-Use Radio Service (MURS) radios are low-power two-way walkie-talkies often used in buildings and on construction sites, operating under FCC MURS rules.

Per the FCC, MURS uses narrowband FM and is limited to 2W maximum transmit power. At 151 and 154 MHz, this service can reach a few miles between handheld units, and 10 miles or more with external (building mounted) antennas.

Because MURS is lower in frequency than Family Radio Service (FRS), MURS has better propagation characteristics outdoors and FRS has better indoors. This coverage capability, plus the license-free nature of the Service, has made MURS a natural for building and construction trades. MURS radios are also used for device alerts and for specific point-to-point voice applications.

Similar in use to MURS are Part 90 business radios. MURS (under Part 95) requires only equipment approval, not an operator license as do Part 90 systems. Many Part 90 two-way radios can operate on MURS frequencies, leading to potential confusion about what is “MURS-capable.”

Market Segments and Suppliers

The primary impact of this category comes from hardware sales, and a sample of suppliers is provided here:

- [BaoFengTech](#) (BTECH MURS-VI)
- [Dakota Alert](#)
- [Garmin](#) (uses MURS for Group Ride feature)
- [Motorola](#)
- [Retevis](#)
- [Ritron](#)

Market Size Determination

Only a few companies sell MURS product, and one dealer calls MURS “the best-kept secret of two-way radios and wireless intercoms since their introduction.” Little literature is available on the size of this market, but it appears to be on the order of \$10 million annual sales. The percentage of value attributable to the unlicensed spectrum is 100%, as

unlicensed spectrum is required to use the device (Primary Function test).

B.13. Near Field Communications (NFC)

Overview

Near field communication (NFC) is a contactless communication technology operating at 13.56 MHz, which allows smartphones, payment cards, access cards and similar devices to exchange small amounts of data by touching them together or bringing them into close proximity, usually no more than a few centimeters.

Under the auspices of the [NFC Forum](#), predecessor NFC standards have been consolidated and made interoperable to enable a wide variety of applications. The most visible application to many consumers is tap-to-pay technology as embodied in Apple Pay, Google Pay and Samsung Pay. NFC also supports tags and stickers that carry website links for marketing information and phone numbers to activate a phone call or even take action, like turn on smart lights when coupled with an appropriate smart home app. Present and anticipated applications include badge scanning and contact exchange for events, electronic door locks, automotive digital keys and handsfree device pairing, securely storing and reading health or fitness information and one-touch setup of Bluetooth and Wi-Fi. In 2020, NFC Forum approved a Wireless Charging Specification to enable NFC devices to manage both communications and charging of low-power IoT devices such as smartwatches and fitness trackers.

NFC-enabled payments are a specialized and fast-growing segment. One of the forces behind interoperability of payments is [EMVCo](#), overseen by American Express, Discover, JCB, Mastercard, UnionPay and Visa. EMVCo manages the EMV specifications that originated in 1999 with the specification for secure chips in payment cards. EMVCo specifications now cover payment technologies including Contactless and Mobile (the two NFC-based technologies), as well as Contact, QR Code and Payment Tokenization.

Market Segments and Suppliers

NFC is driving chipsets and software and adding features to phones. Billions of NFC tags are being produced. Readers are being deployed at retailers. NFC technology is being used to deter counterfeiting, access hotel rooms and provide marketing information with the tap of a phone.

NFC Forum maintains a searchable [product showcase](#). Other suppliers in the NFC ecosystem include:

- NFC readers and NFC-specific test and instrumentation
 - [Comprion](#)
 - [Rohde & Schwarz](#)
 - [Cantaloupe](#)
 - [Square](#)
- Tags, stickers and semiconductor vendors
 - [Broadcom](#)
 - [Identiv](#)
 - [MStar Semiconductor](#)
 - [NXP Semiconductors](#)
 - [Polaric](#)
 - [Samsung](#)
 - [STMicroelectronics](#)
 - [Texas Instruments](#)

Market Size Determination

NFC is projected to continue double-digit growth through the foreseeable future. Inclusion of NFC in smartphones is a significant driver. The NFC market value associated with smartphones is captured in the breakout for smartphones. The estimated U.S. market size for Tags, ICs, NFC readers and related hardware in 2020 was \$3.24 billion. The percentage of value attributable to the unlicensed spectrum is 100%, as unlicensed spectrum is required to use the device (Primary Function test).

B.14. Point-to-Point (PTP) and Point-to-Multi-Point (PMP)

Overview

Point-to-point (PTP), as a name, means direct wireless communications between two fixed (installed, not mobile) antennas. In the context of

unlicensed spectrum, these links can include voice, data and video connections. Multiple unlicensed spectrum bands are used, including 900 MHz, 2.4 GHz, 3.55-3.78 GHz, 5.2-5.8 GHz, 5.9-7.1 GHz, 24 GHz, 37-37.6 GHz, 37.6-40 GHz, 57-64 GHz and 64-71 GHz. Note that the 3.55-3.7 GHz band now falls under Part 96 CBRS rules, but fixed wireless is permitted in GAA.

Point-to-multi-point (PMP) implies wireless links between a primary base station and individual nodes. Fixed nodes may be used, or the individual nodes may be mobile. The term “PMP” is not generally used for mobile voice and broadband services or backhaul, although there are technical similarities. PMP is used in both indoor and outdoor applications.

Unlicensed data links are inexpensive compared to licensed options, and particularly suited to low density areas where there is less chance of interference, as the unlicensed user has little to no regulatory recourse in the case of an interfering signal.

These systems are used to connect buildings and sites for users in Government, Municipal, Healthcare, Education, Banking, Financial, Utilities and Energy industries. More specifically, large corporations use such systems to connect buildings in a city; small broadcasters connect studios to transmitter sites. Large multi-building healthcare campuses and universities connect buildings to share data. Wireless internet service providers (WiSPs) use both unlicensed and licensed PMP systems. These technologies can also provide a solution for fixed wireless access for business and residential customers; backhaul for mobile networks, small cell and “campus” Wi-Fi networks; and any time two points need to be connected.

The intent is essentially to establish communications between one point and one or more other points when it is inconvenient, expensive or impossible to run cable. Identifying terms include “unlicensed” or “license-exempt”; combined with “microwave point-to-point,” “packet radio” or “wireless back-haul.”

Typically, these systems use the familiar (directional) dish antenna. Such antennas can be seen scattered

along the tops of buildings and radio towers all across the country. However, smaller in-building or local applications also use other antennas. Omnidirectional antennas may be combined with directionals when the omni is in a central location and the directionals are in the outlying locations.

We do not include “light(ly) licensed” fixed wireless. In the lightly licensed case, the spectrum is licensed over a period of years in a specific region for a nominal fee. The fee is often no more than what might be expected for paperwork handling costs, rather than the significant costs of spectrum in fully licensed bands. The purpose of the license is simply to record the necessary data so that the regulator can alert adjacent or co-located users of potential interference.

As this report is specifically about unlicensed spectrum, licensed and lightly licensed fixed wireless products and applications are not included here.

Market Segments and Suppliers

PTP and PMP systems are often professionally installed, but the user (company or individual) can do the installation in some cases. Therefore, the economic impact comes from hardware sales and integration business.

The unlicensed 60 GHz band (57-64 GHz) is an important element of mobile carrier backhaul. Where 2G/3G was all about coverage, 4G was about speed and this need drove adoption of 60 GHz for PTP links. 5G deployments move further down a similar requirements path. In parallel, the public is consuming more and more wireless data. The need for backhaul has risen dramatically. The unlicensed 60 GHz band can be used for small cell backhaul, base-to-base backhaul and base-to-switch backhaul. The lack of FCC mandates for antenna gain and pattern allows vendors to offer concealable antennas, which can be popular with municipalities.

Examples of suppliers include:

- [Alvarion \(SuperCom\)](#)
- [Cambium Networks](#) (formerly Motorola)
- [DragonWave Small Cells and Packet Radios](#)
- [FastBack Networks](#) (LTE at 5 GHz)

- Huawei
- LigoWave [LigoPTP](#) and [LigoPTMP](#)
- [MMWave](#)
- [NEC](#)
- [Netronics](#)
- Nokia Microwave Packet Radio, see for example [Agile Optical Network and Microwave Packet Radio for highways and Mission-critical transmission networks for railways](#).
- [Proxim](#)
- [SAF Tehnika](#)
- [Trango Systems](#)
- [Ubiquity Networks](#)

Market Size Determination

Based on manufacturer input, we estimate the U.S. market for unlicensed fixed PTP and PMP systems is some \$520 million in 2019, with 21% growth year on year to \$630 million in 2020. A major component (58%) of that market in 2019 is wireless residential internet access service; the majority of which is WiSP service, plus tier 2 and tier 3 carrier fixed wireless broadband service.

The market for 60 GHz unlicensed mesh networking (also called radio LAN or RLAN) will see significant growth in 2021 and beyond, as chipsets for this technology moved into broad availability in 2020. This segment of the total market described above was only \$20 million in 2019 but grew to \$80 million in 2020.

We estimate the overall U.S. market for unlicensed fixed PMP microwave is some \$520 million and that of unlicensed fixed PTP is some \$800 million, for a total of \$1.32 billion. In all cases, the percentage of value attributable to the unlicensed spectrum is 100%, as unlicensed spectrum is required to use the device (Primary Function test).

B.15. Radiofrequency ID (RFID)

Overview

Radiofrequency ID (RFID) is technology used for a variety of monitoring and tracking applications in logistics and retail. RFID systems uniquely identify something by a data code read wirelessly. Originally envisioned as a replacement for barcodes, RFID includes a wide range of applications using active and passive tags operating in a variety of unlicensed bands.

Typical applications include access control, asset management and supply chain management. Systems consist of a small tag with encoded information, an antenna and a reader with its associated antenna. The reader emits a radio signal to read or write data from or to the tags attached to the items to be tracked. Passive tags capture energy from the reader and respond using “backscatter.” Active tags are battery powered, which increases their range of operation and the amount of data that can be read and written. [Table B- 1](#) provides information on commonly used RFID frequencies and their typical applications.

In 2003, Walmart told its top suppliers that they would have to tag cases and pallets with RFID tags within two years. The technology had teething pains, but by 2013 more manufacturers and retailers supported its use. The [RAIN RFID Alliance](#) was formed in 2014 to standardize and grow the use of passive UHF RFID technology. The RAIN Alliance reported that more than 15 billion tag chips were sold in 2018.

Government and corporate applications include asset tracking and logistics. The U.S. military uses millions of RFID tags world-wide, primarily for asset tracking. RFID is used in building access control (card keys); for animal tracking; and for baggage, cargo and container tracking. High growth areas for passive RFID include aviation, food supply, healthcare and retail, with the latter being the biggest segment according to some market research.

TABLE B- 1 RFID FREQUENCIES, RANGES AND USAGE

Frequency	Range	Typical Applications
Low frequency 125-148 KHz	3-5 feet	Animal identification and tracking Inventory control Car immobilizer
High frequency 13.56 MHz	Up to 3 feet	NFC (reported separately) Item tracking Transit tickets
Ultra high frequency 433 MHz	Up to 500 feet	Active tags Real-time location systems Container tracking European remote keyless entry
Ultra high frequency 860-930 MHz	Up to 40 feet	Department of Defense and Walmart-mandated asset tracking Healthcare Electronic toll collection
Microwave frequency 2.45-5.8 GHz	Up to 300 feet	Real-time location systems Electronic toll collection

Market Segments and Suppliers

RFID systems require transponders, readers, software and services (integration).

AtlasRFIDstore.com provides a list of its [suppliers](#). The RAIN Alliance has a [member directory](#) that is searchable by category and region.

Market Size Determination

CTA estimates the US RFID market size at \$2.1 billion, based on global reports of \$11.6 billion total market size. The percentage of value attributable to the unlicensed spectrum is 100%, as unlicensed spectrum is required to use the device (Primary Function test).

B.16. Remote Keyless Entry and Tire Pressure Monitoring Systems

Overview

A small transmitter “fob” on the user’s key ring allows keyless entry into cars and other vehicles. Various known as remote keyless entry (RKE), remote keyless system and keyless entry system; it is also known under descriptive or trademarked names at dozens of vehicle manufacturers. The automotive industry

has created a superset of remote keyless entry called passive entry passive start (PEPS) that is popular on mid-range and higher vehicles. PEPS systems allow hands-free interaction with the car so that the driver may lock and unlock the car and start and stop the engine without directly using a key fob or mechanical key. PEPS systems often use a low frequency localizer and wakeup signal along with a one-way or two-way RF link for communications.

Also covered in this section are tire pressure monitoring systems (TPMS), which use some of the same technologies and frequencies. All vehicles in the United States have been required to include TPMS since 2008 in accordance with the TREAD Act. Although “indirect” TPMS, in which the anti-lock braking system is used to count wheel rotations to sense an underinflated tire, is allowed under the TREAD Act, most cars today use “direct” TPMS that includes a sensor, battery and transmitter in each wheel to continuously transmit tire pressure when the vehicle is moving.

TPMS generally uses 315 MHz in the U.S. Aftermarket TPMS replacement sensors may be equipped with 315 MHz and 433 MHz (popular in Europe) transmitters. RKE and PEPS systems use 315 MHz, 902 MHz and other unlicensed frequencies internationally. Not included in this analysis is emerging “Digital Key” technology in which a smartphone can be used for RKE and PEPS functions. Digital Key standards from the Car Connectivity Consortium currently use NFC and have added Bluetooth LE and UWB to provide PEPS and location aware features.

This category is rather straightforward. The key fob unlocks the car door at a minimum. Other features are trunk unlock, remote car start and panic alarm. In the application space, this category overlaps with RFID and NFC. Remote start is particularly popular in the northern climes.

Tire pressure sensors (TPS) use similar frequencies and circuitry. A transmitter and sensors are included in the valve stem of the tire and transmit pressure and temperature data periodically.

This technology is shipped primarily through new vehicle sales, but aftermarket security systems also

offer RKE features, and aftermarket TPMS sensors are available.

Market Size Determination

Car sales in the United States were seriously hurt in 2020 and 2021 due to the pandemic and chip shortage. For the five years between 2015-2019, car and light truck sales in the United States averaged 17.3 million units per year. Based on this sales figure, a 70% penetration rate for RKE systems and 100% penetration of TPMS, CTA estimates total value of the RKE and TPMS module market to be \$259 million. The percentage of value attributable to the unlicensed spectrum is 100%, as unlicensed spectrum is required to use the device (Primary Function test).

B.17. Smart Meters and Mobile Meter Readers

Overview

This category covers water, power and gas meters that are wireless-enabled to allow utilities, and sometimes customers, to remotely read meter data.

Automatic meter reading (AMR) emerged in the 1980s as a means of collecting electric, gas and water meter readings. AMR meters are generally fitted with short-range radios, commonly but not exclusively 902-928 MHz ISM band, which allow walk-by or drive-by reading. Hand-held or fixed infrastructure devices read data off the meter at a short distance. This makes entering the property — which may be fenced or guarded by dogs — unnecessary.

In the early 2000s, the technology behind advanced metering infrastructure (AMI) emerged. The Energy Information Administration defines advanced meters as “meters that measure and record usage data at a minimum, in hourly intervals and provide usage data at least daily to energy companies and may also provide data to consumers.” AMI combines advanced meters with long-range communications to allow utilities the capability of reading consumption, power quality and other information on a frequent basis as well as sending demand response and other commands to the endpoint devices.

Market Segments and Impact

The main market segment for this group is hardware sales to the utility companies.

Smart meter equipment suppliers include:

- [Aclara Technologies](#) (which bought General Electric's electricity metering business in 2015)
- [Badger Meter](#)
- [Honeywell](#)
- [Itron](#)
- [Kamstrup](#)
- [Landis+Gyr](#)
- [Mueller Systems](#)
- [Neptune Technology Group](#)
- [Sensus](#) and [Sensus RF](#)

Market Size Determination

Over 300 million gas, electric and water meters are installed in the United States. Smart meters have good penetration, more than half of the current installed base and rising. Some market research pegs the U.S. smart meter market, inclusive of products and services, at \$3.73 billion. CTA estimates the value of smart meters sold in the United States at some \$1.03 billion. The percentage of value attributable to the unlicensed spectrum is 15%, as products include an unlicensed wireless feature but can reasonably be treated as having significant utility without the wireless feature (Significant Utility test). The ISV for this category is \$155 million.

B.18. Walkie-Talkies (Family Radio Service)

Overview

Walkie-talkies may be toys, tools for families or equipment for businesses. In all cases, the term refers to a two-way portable voice radio capable of relatively short range. Early consumer products operated on 27 MHz and 49 MHz. In the United States, most such products now operation on Family Radio Service (FRS); this includes toys down to very inexpensive prices. FRS can be combined with General Mobile Radio Service (GMRS), a licensed technology in the same unit, because the two services, FRS and GMRS, share a common spectrum allocation with slightly different channels schemes.

The FCC revised rules for FRS in 2017, permitting power up to 2 watts from the original 0.5 watts previously. However, as of September 2019, the FCC no longer permits hybrid GMRS/FRS products under Part 95 unlicensed rules.

These products were originally introduced for consumers, although small businesses have adopted them for their permissionless operation nature as much as their utility. These small, portable units have similar convenience in size and battery operation as older walkie-talkie technology but with significantly greater range.

Consumers use these radios to keep in touch at theme parks, national parks, ski resorts and the like. Geocaching enthusiasts use these radios to connect at local competition sites. Organizers and staff at events like soccer tournaments also use these radios. There are also FRS radios in use in the military.

Market Segments and Impact

The primary impact of this category comes from hardware sales.

Note that the industry refers to these products typically as “two-way radios” or “walkie-talkies” and includes either FRS or GMRS/FRS in the specifications. Suppliers include:

- [Backcountry](#)
- [Amcrest](#) (Amcrest Industries also owns the Baofeng brand, via Baofengradio US)
- Comvox
- Fayagoo
- [Garmin](#)
- [Icom](#)
- Kidzlane
- [Midland](#)
- [Motorola](#) (Motorola brand by Motorola Solutions)
- Retevis
- [Uniden](#)
- Wouxun

Additionally, amateur radio product is often capable of operating on FRS channels. Amateur radios are not generally marketed as “FRS compatible,” unlike the

more specialized two-way radios listed above.

Market Size Determination

Sales have declined due to the growth in popularity of mobile and smart phones. We conservatively estimate total U.S. sales of about \$10 million. The percentage of value attributable to the unlicensed spectrum is 100%, as unlicensed spectrum is required to use the device (Primary Function test).

Market Size Determination

According to Fortune Business Insights, the North American market for wireless microphones was \$1.84 billion in 2019 with a cumulative annual growth rate of 8.8%. From these numbers, we estimate annual U.S. sales of \$1.081 billion. The percentage of value attributable to the unlicensed spectrum is 100%, as unlicensed spectrum is required to use the device (Primary Function test).

B.19. Wireless Microphones

Overview

These professional tools are the familiar handheld or lavalier audio pickup devices using radio frequency to transmit to an audio system, typically to amplify the voice. Unlicensed types are permitted to operate in the TV band, with restrictions. Unlicensed wireless microphones can operate on other frequency bands under the FCC's Part 15 rules (e.g., the 902-928 MHz band, the 1920-1930 MHz band and the 2.4 GHz band).

They are widely used for concerts, sporting events, churches, etc. At the low end are wireless microphones bundled with inexpensive karaoke systems; at the high end are the headsets worn by professional entertainers in front of huge crowds. Beyond entertainment, wireless microphones are used in warehouses, manufacturing and more as businesses rethink the nature of work.

Market Segments and Impact

The primary impact of this category comes from hardware sales.

Suppliers include:

- [Audio Technica](#)
- [Azden](#)
- [Pyle Audio](#)
- [Shure](#)
- [Sony](#)

Annex C: Non-Quantifiable Categories for U.S. Unlicensed Spectrum Devices

This annex expands on 12 categories of unlicensed spectrum devices included in the preceding report; however, adequately reliable data that are compatible with the analysis methodology were not available. Consequently, no ISV from these categories is computed or included in the total economic value of unlicensed products found in the main body of the report. The inability to determine an ISV for these categories stems from one or more of the following reasons.

Small, Private or Fractured Markets

This group includes small markets where there is not enough sales volume to be tracked. It includes highly fractured markets of private companies, where the ease of integrating unlicensed spectrum makes it possible for many small companies to participate but makes it difficult to quantify sales volumes:

- CB radio
- Enterprise wireless headsets
- Wireless microphones

Service Industry Products

The sale of a single unit in these industries may drive months or years of service activity. Therefore, these products have sporadic data unsuitable for inclusion in this study.

- Cable locating equipment
- Ground penetrating radar
- Stud sensors and wall imaging devices
- Through-wall imaging systems

Merged, Indistinguishable Product Types

Some product types include a subset of products that use unlicensed spectrum. But because no data is available on that subset of products, they could not be included in this study:

- Baby monitors (not using Wi-Fi)
- Field disturbance sensors
- Medical imaging systems
- Surveillance systems (perimeter protection system)

For example, most baby monitors use either Wi-Fi or non-Wi-Fi 2.4 GHz frequency hopping protocols. Reports tracking baby monitor sales, however, typically doesn't separate unit sales by this detail. Wi-Fi-based baby monitors are covered in the CTA-tracked IP/Wi-Fi cameras category. The overall market for baby monitors (both types) is estimated at \$600 million; the overall market for IP/Wi-Fi cameras (including baby monitors of the Wi-Fi type) is estimated at \$977 million. We use only the Wi-Fi value for all camera types, since also including the 2.4 GHz FH types would overcount the Wi-Fi types as being in both IP/Wi-Fi cameras and in baby monitors.

C.1. Baby Monitors

Overview

Baby monitors include a transmitter and receiver that allow audio, video, location and health monitoring of children using wireless technology, typically marketed to parents. Products can be found at 900 MHz ISM (typically audio-only), 1.9 GHz DECT, 2.4 GHz ISM and using Wi-Fi. There is some market still for 49 MHz audio monitors.

This category is treated separately from IP/Wi-Fi cameras that are marketed as baby monitors. Tracking numbers available for baby monitors per se tend to merge both Wi-Fi and non-Wi-Fi types in a single category, thus it is difficult to reliably separate the two times. Since IP/Wi-Fi cameras data is directly forecasted by CTA, this number is considered a reliable estimate of that category.

Consequently, although there are a significant number of products sold as baby monitors that do not use Wi-Fi, we do not attempt an estimate for market value due to the risk of over-counting Wi-Fi products in both IP/Wi-Fi cameras and baby monitors.

Baby monitor is simultaneously the category name and the primary application. These systems use unlicensed spectrum to broadcast audio and possibly video of the child's room to a receiver/monitor. In recent years, the feature set has expanded from basic audio and video.

It should be noted, however, that the consumer category of baby monitors includes both licensed and unlicensed technologies. Products marketed as "analog," "digital," "DECT," "FHSS" and "Wi-Fi" are typically unlicensed devices. "Cellular," "CDMA," "GSM," etc., are terms indicating licensed spectrum.

In recent years, technology innovation and expanded use of unlicensed spectrum has led to market expansion:

- Video capable device sales have gained over audio-only, increasing the ASP.
- New features include IR night vision; breathing, sleep and temperature sensors; video with two-way audio; built-in lullabies; mobile notifications and more.
- Wearable health and location tracking monitors are a new sub-category. These devices — analogous to adult wearable health trackers — may include capability to monitor, report and alert based on location data plus health data (heart rate, oxygen saturation levels, sleep patterns, etc.).
- More capable video monitors also spawn a wireless sensor accessory market, such as wireless motion pads to be placed in the crib and wirelessly connected to the monitor unit.

Finally, there are more brands available now than a decade ago.

Market Segments and Impact

The primary impact of this category comes from hardware sales. Suppliers of baby monitors include:

- AGPtek
- Angelcare Monitor
- Arlo Baby
- Dorel Industries Inc.
- eufy
- Graco
- iBaby Labs
- Infant Optics
- LBtech
- Levana
- Lorex Technology
- Miku
- Motorola
- Nanit
- NETGEAR Inc.
- Panasonic
- Philips
- Safety 1st
- Samsung Electronics
- Snuz
- Summer Infant
- Time Flys
- VAVA
- VTech
- WiFi Baby
- Withings

C.2. Cable Locating Equipment

Overview

This technology entails coupling a radio frequency signal onto cables, pipes, etc., and using a receiver to detect the location of that structure or element. The FCC permits these intentional radiators to operate on any band from 9 to 490 kHz under 47 CFR § 15.213.

These products are used by trained operators to locate buried cables, lines, pipes and similar structures or elements. This equipment is used by utilities prior to digging to service pipes or avoid them. Broadcasters use them to find buried cables and copper ground plane wires. Builders use them to avoid utility pipes and cables.

Market Segments and Suppliers

In this category, hardware sales tell only part of the story. When not owned by large companies (e.g., builders, broadcasters and utilities) this equipment is used by small businesses who are brought in on an ad-hoc basis to the site of interest. These products prevent service disruptions in internet services, electricity, landline phone, gas, water and sewer systems.

Suppliers include:

- [3M](#)
- [Goldak](#)
- [Rycom](#)
- [Vivax-Metrotech](#)

C.3. Citizens Band Radio

Overview

Citizens Band (CB) radio was commonly used in cars and trucks and very popular in the 1970s. Today, this is a shrinking category but still significant to many people. CB radio is authorized through 47 CFR § 95.

CB is used by truckers socially and to communicate information about road construction, accidents and police activity. It has an advantage over mobile phone technology in that it is always local, due to the RF coverage limitations.

Market Segments and Suppliers

The primary impact of this category comes from hardware sales. Radios are the main product, but there is also a healthy market of compatible antennas.

Suppliers include:

- [Cobra](#)
- [Midland](#)
- [Ranger Communications](#)
- [Uniden](#)

C.4. Enterprise Wireless Headsets

Overview

These devices are wireless-enabled headsets used for voice communications in non-consumer applications. Common examples are headsets used in fast food and retail settings to enable employee communications.

Unlicensed wireless headset systems are used in supermarkets, shops, restaurants and drive-thrus. This category uses ISM band (900 MHz, 2.4 GHz) and DECT personal communications service (PCS; 1.9 GHz). Bluetooth-enabled product is covered elsewhere in this report.

Market Segments and Suppliers

The primary impact of this category comes from hardware sales. However, these systems are frequently installed by integrators.

Suppliers include:

- [3M G5 Series](#)
- [Clear-Com DX Series](#)
- [Panasonic Attune II](#)
- [Polycom](#)
- [HME](#)

For further suppliers: [QSR Magazine List of Drive-Thru Headsets/Timers](#)

C.5. Field Disturbance Sensors

Overview

A field disturbance sensor establishes a radio frequency field in its vicinity and detects changes in that field resulting from the movement of persons or objects within its range, possibly with a tag that the sensor is designed to detect. A number of bands are defined under § 15.245.

In addition, in 2016 the FCC modified part § 15.255 to expand the frequency range available from 64-71 GHz to 57-71 GHz. This latter band is considered in [B.5, Consumer Radar Devices](#).

In retail applications, store owners use electronic article surveillance (EAS) systems to control shoplifting. These systems use field disturbance sensors that detect the article leaving the store. These are common in clothing stores, drug stores, liquor stores, “big box” and department stores and supermarkets.

Also, the home, business and automotive security industries use field disturbance sensors to detect motion, indicating unauthorized access. Besides standalone motion detectors, cameras and lights are available with such motion detectors that combine to turn on the camera or light when motion is detected.

Market Segments and Suppliers

The automotive segment is relatively small. However, home and business security systems use large numbers of such units with identifying terms such as “doppler radar motion detector,” “microwave motion detector” and of course “field disturbance sensor.” Products are sold directly to consumers (e.g., motion

detector security lights at big-box hardware stores) and via system installers (e.g., companies that install office security systems). Note that some motion detector products use IR sensing instead of field disturbance sensing.

Retail EAS systems are sometimes sold through systems integrators, as are motion detectors for corporate or industrial security systems. Automotive and home security systems are sold by installers and as components for do-it-yourself projects.

Suppliers include:

- Home and car security and anti-theft (motion detectors)
 - [Bosch](#) (home/business security)
 - [Directed Viper](#) (car security)
 - [Megatronix](#) (car security)
 - [Southwest Microwave](#) (business security)
 - [Utilitech](#) (home security)
- Retail EAS systems (detectors, labels, tags, detachers and deactivators) are available from:
 - [Ketec](#)
 - [Samzai](#)
 - [Sensormatic](#)
 - [Tag Company](#)

C.6. Ground Penetrating Radar

Overview

Ground penetrating radar (GPR) is a radar system designed to operate in close proximity to the ground for the purpose of detecting or obtaining the images of buried objects. GPR is a UWB system authorized under 47 CFR § 15.509. Both metallic and non-metallic materials can be detected and outlined, at depths of 1 m to 100 m for substrates other than sea water (which dissipates the signal) and freshwater ice (which carries it well over 100 m).

GPR is also sometimes known as ground probing radar.

GPR is used for a wide variety of underground and in-structure applications. The following list is adapted from US Radar's [Applications](#) page:

- Utilities: Pipes, conduit, cable, wire, manholes, water boxes, abandoned lines, illegal or unknown connections, fiber optic lines, missing valves
- Structural: Reinforcing, cracking, voids, water infiltration damage in concrete, slab/wall thickness, asphalt thickness
- Geophysical: Strata layers, ground water, root mass, disturbed soil, buried wood, bedrock, boulders or rocks, density changes, fill replacement
- Archeological: Artifact locating, structural mapping, gravesite locating
- Environmental: Buried drums, landfill or rubble limits, high saturation levels
- Military: Unexploded ordnance, bunkers, tunnels, weapons caches
- Law Enforcement: Contraband, objects hidden in walls, buried caches, forensics

Market Segments and Suppliers

Of course, there are hardware sales. As the hardware is expensive and requires training, a service industry of companies does GPR work with their equipment on behalf of customers in all the above applications.

Suppliers and service providers include:

- [3D-Radar](#)
- [GeoTek Services](#)
- [Geophysical Survey Systems](#)
- [Geoscanners AB](#)
- [Ground Penetrating Radar Systems LLC](#)
- [MALÅ](#)
- [Penetradar](#)
- [Proceq](#)
- [Radar Systems](#)
- [Sensors & Software](#)
- [US Radar Inc.](#)
- [UTSI Electronics Groundvue](#)

C.7. Perimeter Security Systems (Field Disturbance Sensors)

Overview

This category defines a system that operates as a “security fence” by establishing a stationary microwave perimeter field and looking for changes in received reflections.

This is primarily a security application. A transmitter emits a frequency modulated microwave carrier; a receiver tracks the reflected signal strength. An intruder moving in the detection zone detector will change the received signal level, triggering an alarm.

FCC rules (47 CFR § 15.245) treat these systems as intentional radiators used as field disturbance sensors. There is an exclusion for “perimeter protection systems;” according to Knowledgebase article 661845, the intent is to exclude devices that rely on buried cables surrounding the protected zone.

Market Segments and Suppliers

This category has significant hardware sales and integration sales, as these systems are widely used for security purposes.

Suppliers include:

- [Advanced Perimeter Systems](#)
- [AVS](#)
- [CIAS](#)
- [Forteza](#)
- [Southwest Microwave](#)

C.8. Personal Locator Beacons

Overview

This category falls under Part 95, Subpart K - *Personal Locator Beacons and Maritime Survivor Locating Devices*. The 406 MHz frequency used is internationally coordinated and recognized. Some devices combine GPS capability so that emergency responders can locate the beacon to as little as 100m. While the spectrum is technically unlicensed, registration of the device is required by the FCC as the information required is used in life-saving operations. A worldwide dedicated search and rescue satellite network operated by the *International Cospas Sarsat Programme*.

As the satellite service is Government-funded, the market impact of these devices is based on hardware sales.

Suppliers include:

- [ACR Electronics](#)
- [Polaris RDF](#) (detectors)
- [RESCUEME PLB1 Personal Locator Beacon](#)

The U.S. Coast Guard website has a full explanation of these life-saving devices. See their [Emergency Position Indicating Radiobeacon \(EPIRB\) webpage](#) for more information.

C.9. Stud Sensors and Wall Imaging Devices

Overview

These are unlicensed spectrum devices designed to detect support beams and fasteners in structures for purposes of consumer or professional use.

Until 2002, stud sensing technologies included ultrasound, magnetic and capacitive sensing. FCC action in 2002 permitted the use of unlicensed UWB RF under certain restrictions. The advantage of UWB is that a relatively inexpensive system can find ferrous and non-ferrous materials in buildings deeper than capacitive technology.

Market Segments and Suppliers

Commercially available stud sensors and wall imaging systems that can find studs and pipes at depths of 2 inches or more.

Suppliers include:

- [Bosch](#)
- [Zircon](#)

Other Resources

An FCC order contains background information on the use of the band 3.1–10.6 GHz for stud sensors and wall imaging. See Robert Bosch, GmbH; Request for Waiver of Part 15 Ultra-wideband Rules for a Wall Imaging Device, DA 11-899, Order, ET Docket No. 10-253 (2011).

C.10. Through-Wall Imaging Systems

Overview

These systems use UWB to determine the position or movement of persons or objects that are located on the other side of structures such as walls. These systems are authorized under 47 CFR § 15.510.

The use of these systems is limited to law enforcement, fire and rescue organizations. Law enforcement includes the Department of Homeland Security, and these systems are considered candidates for anti-terrorism work. There are also military applications.

In dangerous environments, including places where explosives may be in use, “stand-off” systems are preferred. These systems can be used at a short distance from the outer edge of the volume of interest.

Suppliers include:

- [Akela](#) (2.9 GHz to 3.6 GHz)
- [Camero](#)
- [NovoQuad](#)
- [RETIA](#) (1.9 to 3.7 GHz)

Annex D: Acronyms and Definitions

ADA	Americans with Disabilities Act
AHAM	Association of Home Appliance Manufacturers
AM	amplitude modulation; specifically, the AM broadcast band in the United States
AMI	advanced metering infrastructure
AMR	automatic meter reading
AMTS	Automated Maritime Telecommunications System
ANT	A low-power short-distance wireless technology (also ANT+)
AR	augmented reality
ASHE	American Society for Health Care Engineering
ASP	average sale price
AVIS	automatic vehicle identification system
C-V2X	cellular vehicle-to-everything
CBRS	Citizens Broadband Radio Service
CDMA	code-division multiple access
CTA	Consumer Technology Association
DECT	digital electronic cordless telephone, the digital cordless access technology standardized by ETSI and used worldwide
DSLR	digital single-lens reflex
DSRC	dedicated short-range communications
EAS	electronic article surveillance
EIRP	effective isotropic radiated power
ESU	electrical surgical unit
ETSI	European Telecommunications Standards Institute
FCC	Federal Communications Commission
FHSS	frequency hopping spread spectrum
FM	frequency modulation, may refer to: 1) The FM broadcast band in the United States 2) Frequency modulation when applied to carriers in other bands for applications other than FM broadcast
FRS	Family Radio Service, an unlicensed Part 95 Personal Radio Service for consumer walkie-talkie use
GDO	garage door opener
GHz	gigahertz; 1,000,000,000 Hz
GMRS	General Mobile Radio Service
GPR	ground penetrating radar
GSM	Global System for Mobile Communications
HAAT	height above average terrain
HVAC	heating, ventilation and air conditioning
Hz	international standard symbol for hertz, a unit of frequency
ICD	implantable cardioverter-defibrillator
IoT	internet of things
IIoT	industrial internet of things

IP	the Internet Protocol
IR	infrared
ISM	industrial, scientific and medical; a reference to the 900 MHz and 2.4 GHz unlicensed spread-spectrum bands
ISP	internet service providers
ITS	intelligent transportation systems
ISV	incremental sales value
kHz	kilohertz; 1000 Hz
LAN	local area network
LPRS	Low Power Radio Service, a Part 95 service permitted for auditory assistance
MedRadio	FCC-defined service for medical device radiocommunications services for wearable and implantable products
MHz	megahertz; 1,000,000 Hz
MICS	Medical Implant Communication Service (since superseded by MedRadio)
MRI	magnetic resonance imaging
MURS	Multi-Use Radio Service, an unlicensed Part 95 Personal Radio Service for private, two-way, short-distance voice or data communications service for personal or business activities of the general public
NFC	near field communication, a very short-range data communications technology
NII	National Information Infrastructure, not a specific piece of infrastructure or single piece of legislation, but more the concept of the U.S. internet infrastructure and legislation pertaining to it
Part 15	Code of Federal Regulations, Title 47, Part 15 (47 CFR 15); part of the FCC rules and regulations regarding unlicensed transmissions
PC	personal computer
PCS	personal communications services, category name of digital wireless services that provide advanced cellular and paging
PEPS	passive entry passive start
PMP	point-to-multi-point
PSAP	Personal Sound Amplification Products (sometimes Personal Sound Amplification Devices) is a category defined by the U.S. Food and Drug Administration for wearable non-prescription products that amplify sound for those who are hard of hearing or otherwise have limited hearing; they are distinct from the hearing aid category.
PTP	point-to-point
RCRS	Radio Control Radio Service
RF	radio frequency
RFID	RF (radio frequency) identification, technology to uniquely identify something by a data code read wirelessly
RKE	remote keyless entry
SLR	single-lens reflex
sUAS	small unmanned aircraft systems (drones under 25 kg/55 lbs)
TEM	transmission electron microscope
TPMS	tire pressure monitoring system
TPS	tire pressure sensor

TVWS	TV white spaces
U-NII	(also UNII) Unlicensed National Information Infrastructure, spectrum set aside by the FCC for wireless access to the NII
UAS	unmanned aircraft systems (aka, drones)
UAV	unmanned aerial vehicle
UCS	unified communication systems
UWB	ultra wide band, a signaling system that uses very low power combined with a wide swath of spectrum, typically more than 500 MHz
VoIP	voice over IP (Internet Protocol)
VR	virtual reality
WiSP	wireless internet service provider
WMTS	Wireless Medical Telemetry Service, an unlicensed Part 95 Personal Radio Service for the healthcare industry
WPAN	wireless personal area network

Annex E: Permissionless Frequencies

For source information on allocations, see the FCC Online Table of Frequency Allocations (47 CFR § 2.106), available at <https://transition.fcc.gov/oet/spectrum/table/fcctable.pdf>.

Some categories use spectrum allocated for the indicated purpose; some use unlicensed; and some use both. In the table below, “Spectrum Band(s)” indicates both allocated and unlicensed spectrum (i.e., that which is in current use by products):

Category	Description	Spectrum Band(s)
AM Broadcast	Low-power broadcast of AM signals.	535-1705 kHz
Auditory Assistance Device	Used to provide wireless audio to help those who have difficulty hearing at places of public gatherings such as churches, theaters or sporting events; also for supplemental information including simultaneous translation at such events.	49 MHz 72-76 MHz 216-217 MHz 902-928 MHz 2400-2483.5 MHz
Automatic Vehicle Identification Systems (AVIS)	Used to automatically identify vehicles, especially those used in transportation. Also used to track and position trains, and for vehicle fleet management.	902-928 MHz 2400-2483.5 MHz 2.9-3.26 GHz 3.267-3.332 GHz 3.339-3.3458 GHz 3.358-3.6 GHz
Baby Monitors	Transmitter and receiver that allows monitoring of children by parents using wireless technology.	49 MHz 902-928 MHz 1910-1920 MHz 2400-2483.5 MHz
Bluetooth	Short-range wireless technology that allows devices to interact at a range of up to 30 feet. Used primarily to connect mobile devices to cars, headsets and computers.	2400-2483.5 MHz
Cable Locating Equipment	Used by trained operators to locate buried cables, lines, pipes and similar structures or elements. Entails coupling a radio frequency signal onto the cable, pipes, etc., and using a receiver to detect the location of that structure or element.	9-490 kHz
Citizens Band Radio	A short-range voice communication service commonly used in cars and trucks	26.965-27.405 MHz
Commercial Phone Systems	Phones that do not require a wired connection between the handset and the base station.	902-928 MHz 1910-1920 MHz 2400-2483.5 MHz
Drones	Unmanned aerial craft, often with video camera capability.	902-928 MHz 2400-2483.5 MHz 5725-5875 MHz
Field Disturbance Sensors	A device that establishes a radio frequency field in its vicinity and detects changes in that field resulting from the movement of persons or objects within its range. Common implementation are the sensor tags used in department stores to prevent theft.	902-928 MHz 2435-2465 MHz 5785-5815 MHz 10500-10550 MHz 24075-24175 MHz
FM Broadcast	Low-power broadcast of FM signals.	88-108 MHz

Category	Description	Spectrum Band(s)
Garage Door Openers	Unlicensed device that allows remote opening of garage doors.	Typically in 100-400 MHz with the most common being 310 MHz, 315MHz, 318MHz, 360 MHz, 390 MHz and 433 MHz; over Wi-Fi as well See also [1] for all references to <i>Intermittent Control Signals</i>
Ground Penetrating Radar	A radar system designed to operate near the ground to detect or obtain images of buried objects.	Varied spectrum bands depending upon depth of penetration required. Typically 25 MHz to 2 GHz.
Home Security Systems	Wireless link from various entry points, appliances, lights and HVAC systems in the consumer's residence to a central hub in the home.	Intermittent Control Signals spectrum (see [1]) 902-928 MHz 2400-2483.5 MHz
Intelligent Transportation Systems (ITS)	A variety of solutions intended to reduce traffic congestion and increase safety on the roadways.	2400-2483.5 MHz 5725-5875 MHz 5.85-5.925 GHz
ISM Part 18 Devices	The industrial, scientific and medical (ISM) radio bands are radio bands (portions of the radio spectrum) reserved internationally for the use of radiofrequency (RF) energy for industrial, scientific and medical purposes other than communications. Examples of applications in these bands include radiofrequency process heating, microwave ovens, and medical diathermy machines.	Specific allocation is made for 6.765-6.795 MHz 13.553-13.567 MHz 26.957-27.283 MHz 40.660-40.700 MHz 902-928 MHz 2400-2483.5 MHz 5725-5875 MHz 24.0-24.25 GHz 61.0-61.5 GHz 122.0-123.0 GHz 244.0-246.0 GHz; however, any frequency above 9kHz is acceptable except for a few bands prohibited in 18.303
Low-Power Radio Service	A private, one-way service permitted for auditory assistance, translation, tracking of persons or stolen property and certain healthcare and education related applications.	216.0-217.0 MHz
Medical Imaging Systems	X-ray: Under 47 CFR 15.513, limited to use by medical practitioners, use of ultrawideband technology to produce body imaging. These rules also define a frequency of 3100-10600 MHz, therefore x-ray. MRI: Operates under ISM rules, 47 CFR 18, with RF coils under 300 MHz.	5MHz to 300 MHz 3100-10600 MHz
Medical Devices	Includes MedRadio and WMTS. Used by healthcare professionals to communicate with wearable or implantable devices that monitor, regulate or, in some cases replace, critical human biological functions.	(Some limited or legacy use of 175 kHz) 401-406, 413-419, 426-432, 438-444, 451-457, and 2360-2400 MHz (MedRadio); 608-614, 1395-1400, 1427-1432 MHz (WMTS) Bluetooth and Wi-Fi are also used in their bands

Category	Description	Spectrum Band(s)
Multi-Use Radio Service	Low-powered two-way walkie-talkies often used in buildings and on construction sites	151 and 154 MHz
Near Field Communications (NFC)	Near field communication (NFC) is a set of standards for smartphones and similar devices to establish radio communication with each other by touching them together or bringing them into close proximity, usually no more than a few centimeters. Present and anticipated applications include contactless transactions, data exchange and simplified setup of more complex communications such as Wi-Fi. Communication is also possible between an NFC device and an unpowered NFC chip, called a “tag.”	13.56 MHz
Point-to-Point and Point-to-Multi-Point	Direct wireless communications between fixed (installed, not mobile) antennas for infrastructure purposes.	902-928 MHz 2400-2483.5 MHz 3.55-3.78 GHz 5.2-5.8 GHz, 5.9-7.1 GHz 24 GHz 37-37.6 GHz, 37.6-40 GHz 57-64 GHz, 64-71 GHz
Radio Controlled Hobby Craft	Distinct from drones, these are small-scale cars, planes and boats that can be controlled remotely.	26.995 MHz-27.255 MHz 72-73 MHz, 75.4-76 MHz 2400-2483.5 MHz Also (less often) under RCRS (Part 95): 72.0-73.0 MHz, 75.4-76.0 MHz, 26.995 MHz-27.255 MHz
Radiofrequency ID (RFID)	RFID is used for a variety of monitoring and tracking applications in logistics. Typical applications include access control, asset management and supply chain management. Systems consist of a small transponder with encoded information, an antenna, and a transceiver equipped with a decoder. The antenna emits a radio signal to read or write data from or to the tags attached to the items to be tracked.	125-148 KHz, 13.56 MHz, 433 MHz, 860-930 MHz, 2.45 GHz - 5.8 GHz
Remote Keyless Entry and Tire Pressure Monitoring Systems	Allows keyless entry into cars and other vehicles; wirelessly reports air pressure in tires.	315 MHz, 433 MHz, 902-928 MHz; Emerging RKE application of Bluetooth Low Energy
Smart Meters and Mobile Meter Readers	Water, power and gas meters that are wireless enabled to allow utilities, and sometimes customers, to remotely read meter data	902-928 MHz
Stud Sensors	Unlicensed devices designed to detect support beams in structures for purposes of consumer or construction use.	3.1 - 10.6 GHz
Perimeter Security Systems (Field Disturbance Sensors)	A system that operates as a “security fence” by establishing a stationary RF perimeter field and detecting the intrusion of persons or objects in that field. Limited to law enforcement, fire and rescue organizations, public utilities and industrial entities.	902-928 MHz 2435-2465 MHz 5785-5815 MHz 10500-10550 MHz 24075-24175 MHz

Category	Description	Spectrum Band(s)
Through-Wall Imaging Systems	Systems designed to detect the location or movement of persons or objects that are located on the other side of structure such as a wall. Limited to law enforcement, fire and rescue organizations.	1.9 to 3.7 GHz Permitted: 960-1610 MHz 1610-1990 MHz 1990-3100 MHz 3100-10600 MHz Above 10600 Typically approximately 1.4 GHz is used
Toys	Broad category that includes toys that are wireless enabled and not covered elsewhere in this report.	Typically 27 MHz or 49 MHz
Unlicensed PCS/ DECT	UPCS is a band allocated by the FCC for unlicensed short-range phones; DECT is widely used on this band for cordless phones and some headsets. Wireless Private Access Branch Exchange (PABX). See "Commercial Phone Systems".	1920-1930 MHz
Walkie-Talkies	Personal handheld devices that allow wireless communications between two transmitters and receivers.	27 MHz 49 MHz 462 MHz and 467 MHz
Wi-Fi/Wireless LANs	Wi-Fi allows for wireless network access for computers, devices and peripherals through short-range communications.	2400-2483.5 MHz 5.15-5.25 GHz 5.25-5.35 GHz 5.47-5.725 GHz 5.725-5.825 GHz
Wireless Headsets	Wireless enabled headsets used for voice communications. Common examples are headsets used in fast food and retail settings to enable employee communications.	Most commonly DECT 1.9 GHz and ISM 2.4 GHz spread spectrum
Wireless Microphones	Handheld wireless devices used to amplify the voice. Widely used for concerts, sporting events, churches, etc.	174-216 MHz, 470-663 MHz, 902-928 MHz, 940-960 MHz, 1920-1930 MHz, 2400-2480 MHz, 5000-5800 MHz

Supplemental Documents:

(1) Understanding the FCC Regulations for Low-Power, Non-Licensed Transmitters

https://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet63/oet63rev.pdf

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