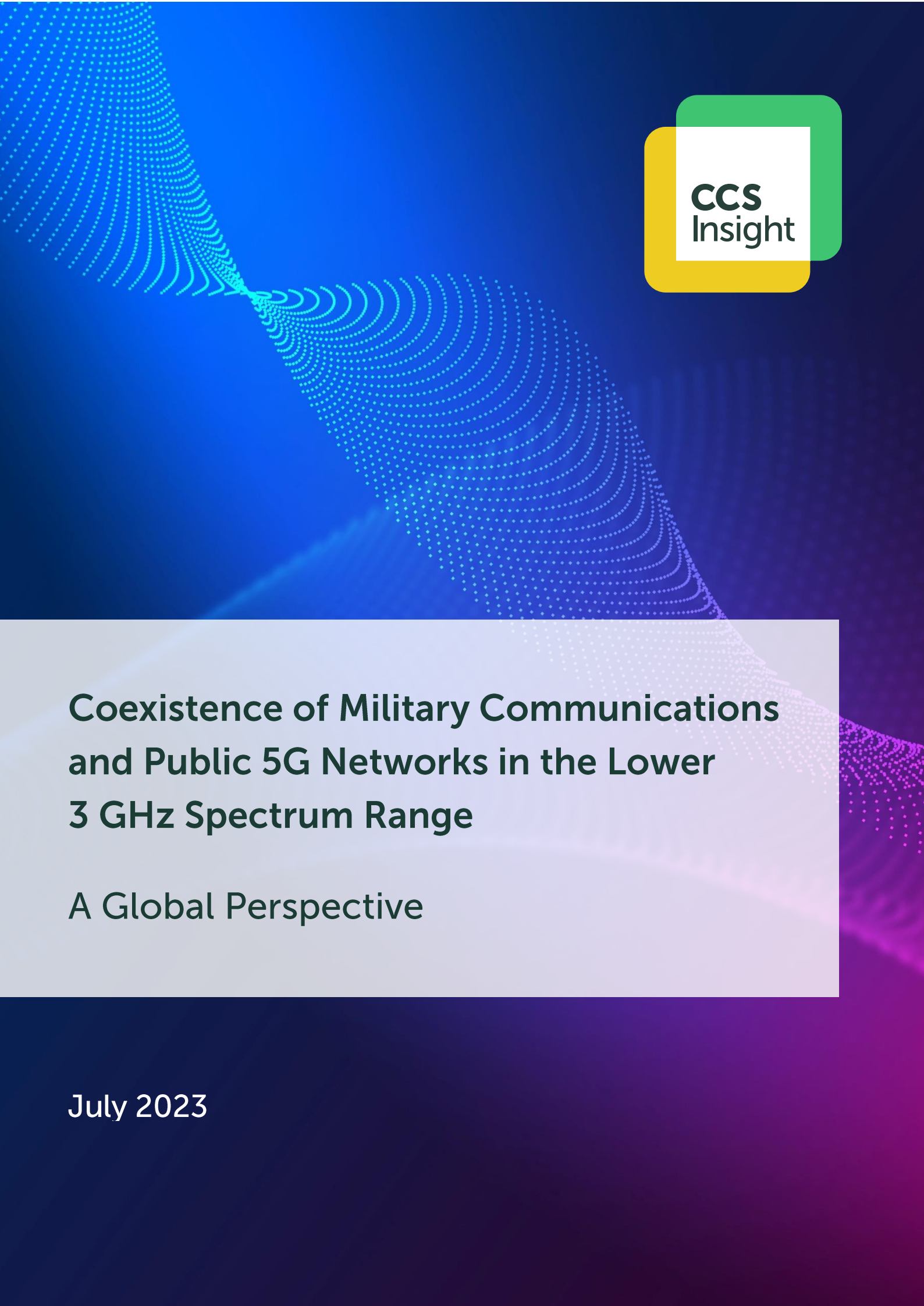


Coexistence of Military Communications and Public 5G Networks in the Lower 3 GHz Spectrum Range

A Global Perspective

July 2023

Contents

Executive Summary

Spectrum is the lifeblood of all radio communications, and 5G, which comprises the broadest ever range of possible applications and uses, requires a commensurately broad range of spectrum to fulfil its potential.

For many of these applications, high capacity, low latency and mobility are critical. Although fixed-line fiber and Wi-Fi have valuable merits, only 5G combines all three characteristics, making it very much the "Swiss army knife" of communications technologies. This means that nationwide, high-performance 5G networks are vital to drive digital transformation in industry and retain economic competitiveness.

Around the world, nations have adopted 3.3 to 3.45 GHz spectrum for optimization of commercial 5G networks. Often, these 5G systems coexist in the lower 3 GHz band with military and NATO systems operating in the same or adjacent spectrum. There is a 150 MHz opportunity in the US using proven coexistence techniques.

Given the critical need for more dedicated mid-band spectrum in the US, it is important for all domestic stakeholders to consider the methods developed in other countries for spectrum coexistence and collaboratively investigate options for clearing, tuning or coordination in the lower 3 GHz band. For the US to maintain a world-leading role in commercial 5G deployment, adoption and innovation, it is imperative to investigate all options for coexistence in the lower 3 GHz band without delay.

This report considers the following:

- Mid-band spectrum is vital to ensure mobile network operators have the fullest opportunity to support a new wave of mobile applications over 5G networks to benefit the economy and society
- Countries with suboptimal usage and sharing of mid-band spectrum for 5G network deployment are likely to be at a disadvantage compared with other nations
- 3.3 GHz and 3.45 GHz spectrum bands are accessed by military as well as civilian users through public network operators in a host of countries, many of them NATO member states
- There are proven methods being used around the world for coexistence
- By creatively exploring these options, it should be possible to identify a workable solution for sharing lower, 3 GHz mid-band spectrum in the US while still prioritizing military usage

In assessing lower 3 GHz spectrum coexistence, the primary concern is not about maximizing the profitability of mobile operators, but giving the full extent of mobile services and applications — many of which will yield societal benefits and economic stimulus — the best chance to flourish. It is about ensuring that the critical communications infrastructure of 5G networks is available as a utility for public use, at the same time as protecting prioritized military use of the same spectrum.

This report offers a region-by-region inventory of countries where this coexistence is already in effect, providing examples of how coexistence of military and 5G usage of mid-band spectrum can be achieved.

This study has been undertaken by telecom and technology industry analyst firm CCS Insight using a combination of publicly available resources and original primary research conducted specifically for the purposes of this report.

This report was commissioned by CTIA, with research undertaken independently by CCS Insight.

List of Abbreviations Used in This Report

AWACS: airborne warning and control system

CBRS: Citizens Broadband Radio Service

CSIC: Coordination of the Information and Knowledge Society

DHS: Department of Homeland Security

DoD: Department of Defense

FCC: Federal Communications Commission

G/ATOR: Ground/Air Task Oriented Radar

GSA: Global mobile Suppliers Association

GSMA: GSM Association

IFF: identification, friend or foe

IFT: Instituto Federal de Telecomunicaciones, or Federal Telecommunications Institute

IMT: International Mobile Telecommunications

ITU: International Telecommunication Union

NATO: North Atlantic Treaty Organization

NTIA: National Telecommunications and Information Administration

SKE: station-keeping equipment

WRC: World Radiocommunication Conference

Spectrum Overview: Optimizing Usage for Future 5G Demand

There are various spectrum ranges potentially accessible for 5G. Lower-band 5G spectrum in the sub-1 GHz ranges has capacity limitations, whereas high-band 5G spectrum in the 24 to 40 GHz range, also known as millimeter waveband, is limited in physical range, making it more suitable for high-capacity localized applications such as fixed wireless access or dense high-traffic environments needing additional capacity.

Because of this and its ability to balance coverage and capacity, mid-band spectrum is viewed as the key to realizing the promises of 5G. It is broadly defined as being in the 1 to 6 GHz range, but more typically used in the global band allocation called n77 from 3.3 to 4.2 GHz, along with n78 from 3.3 to 3.8 GHz. Although 5G networks will ultimately require a combination of low-, mid- and high-band spectrum, optimizing mid-band usage is essential for pulling together a cohesive 5G platform in any given country.

Mobile telecommunications industry body GSMA describes spectrum in the 3.2 to 3.8 GHz range as ideal because it offers coverage and capacity with good propagation characteristics.

Mid-Band Spectrum Overview in the US and Globally

Many regions around the globe are using 3.3 to 3.8 GHz or 3.4 to 3.8 GHz as prime mid-band spectrum for 5G network deployments. Band allocations n77 and n78 are used extensively throughout the world for 5G services, with the potential to provide hundreds of megahertz of spectrum for capacity coupled with good coverage range and propagation characteristics. Coexistent use of 3.3 to 3.4 GHz spectrum by military radars and 5G networks is not only possible but is also deployed and fully operational in a growing number of countries.

Several of these are countries with close military ties to the US. For example, Mexico, the Philippines and Taiwan all have 5G licenses awarded for 5G deployment in 3.3 to 3.4 GHz ranges. We look at numerous such examples in more detail below.

In China, 100 MHz has been allocated in the 3.3 to 3.4 GHz band for commercial indoor wireless use alone, in the form of three licenses for 100 MHz of spectrum awarded to mobile operators China Telecom, China Unicom and China Broadcasting Network. This is predominantly for use in private 5G networks for industry customers, but also indoor coverage and capacity in public facilities such as business and entertainment venues.

To date, the US has pursued a different path, establishing the Citizens Broadband Radio Service (CBRS), based on the 3.55 to 3.7 GHz range. US spectrum regulators reached an agreement in which federal government users retain primary access and commercial users share the spectrum at low power levels. The regulatory and technical rules for CBRS enable dynamic spectrum sharing among three tiers of federal and commercial users with corresponding levels of rights to access the spectrum. This approach relies in part on software-based spectrum access systems to notify and control commercial use when federal shipborne radars are operating nearby.

As a result of these sharing and power restrictions, the CBRS band delivers less capacity and coverage than licensed bands with full power, placing the US at a disadvantage relative to countries where telecom operators have a more equitable shared access to critical mid-band spectrum.

Carriers such as AT&T, T-Mobile and Verizon spent the past couple of years installing mid-band radios to the cell towers they lease. T-Mobile covers about 260 million Americans with its mid-band 5G network and expects this to increase to 300 million. Verizon covers 200 million and expects to reach 250 million by the end of 2024.

Although US carriers are also planning to redeploy some spectrum currently taken by 3G services — such as 1800 MHz — for 5G, major providers will inevitably need more mid-band spectrum to support 5G adoption, enhanced connectivity performance and delivery of new mobility applications.

It is not simply the growing number of connections that needs to be accommodated, but also the demand for more bandwidth per connection to support emerging technologies such as cloud-native networking, edge computing, quantum computing and the rapid proliferation of artificial intelligence-based applications.

This increased demand for 5G is pushing the mobile telecommunications industry to seek spectrum from 3.1 GHz upward, widely considered necessary to ensure US leadership in 5G. Access to 150 MHz of additional capacity in the 3.3 to 3.45 GHz range would be a significant step in supporting current and future capacity demand for public 5G networks and services. A more moderate allocation like 50 MHz is unlikely to be fully adequate.

However, the 3.1 to 3.55 GHz band is critical to the US Department of Defense (DoD) and Department of Homeland Security (DHS), and specifically their radar operations for national defense and domestic

security. The DoD operates high-powered defense radar systems on fixed, mobile, shipborne and airborne platforms.

Uses for Radar and Radiolocation in the US

Radiolocation service has primary allocation status throughout the lower 3 GHz band for government operations and is secondary for non-government operations in the US. In the lower portion of the 3 GHz band, also known as S band, the US government operates several radar systems using frequencies for national defense purposes.

The military services have radiolocation operations throughout the band in support of airbase and tactical airfield search and surveillance by air traffic control; aircrew bomb scoring; airborne search and surveillance; battlefield weapons-locating; Doppler radar; air defense radar systems for shipborne fleet (search and surveillance, tracking, fire control and more); aircraft carrier precision approach control; and point area defense for small surface ships and patrol craft. Other radiolocation radars support non-military functions at the many national and agency test ranges for search radars, ensuring range safety by detecting unauthorized transiting aircraft and ships.

Some of the most popular systems are:

- Land-based radar operations: key mobile tracking radars used by the Army and Marine Corps include the AN/TPQ-53, AN/TPS-80 and Ground/Air Task Oriented Radar — known as G/ATOR — S-band systems
- Maritime radar operations: naval ships with air and surface search radar such as the AN/SPY-1
- Airborne radar operations: airborne warning and control systems (AWACS) such as the E-3 Sentry, and navigational station-keeping equipment (SKE)

In the US, a portion of 3 GHz spectrum allocated for commercial use is the 3.45 to 3.55 GHz band auctioned in 2021. This band was created as licensed spectrum with full power, but the government established protection zones around military radar locations, with coordination zones to protect existing systems. For example, the DoD uses the 3.45 GHz band for radar operations along with testing and training activities, operating five major types of system in this band:

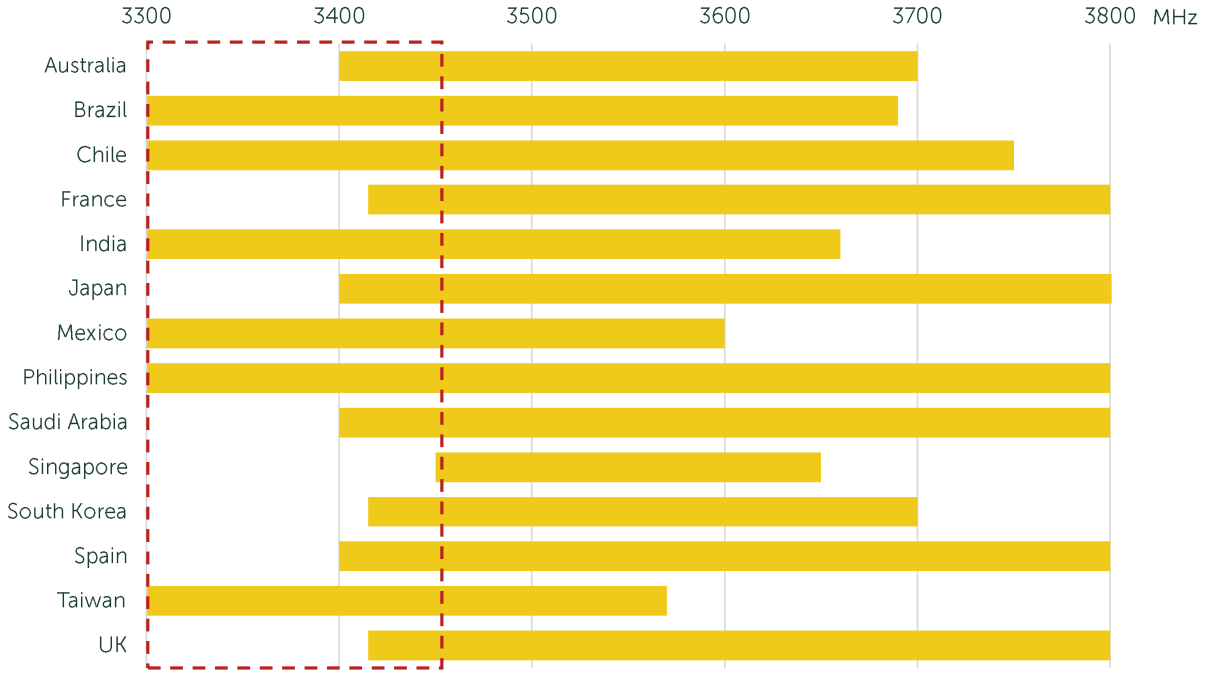
- Army ground-based radar
- Marine Corps ground-based radar
- Air Force airborne radar
- Navy shipboard radar
- Testing and training infrastructure and activities

Around the globe, the presence and operation of US radar systems to protect vital interests is a cooperative one. There are bases in Europe that are part of NATO where the same radar systems are deployed. A prime example is NATO's AWACS — the organization's "eye in the skies" — with a fleet of 14 aircraft based in Germany. In Asia, the US military has bases in Japan and South Korea to defend interests in the area and regularly conducts exercises in and around these countries.

The US military also relies on hundreds of C-130J Super Hercules for transportation missions. Many other countries have acquired C-130 Hercules aircraft variants with AN/APN-243 SKE, which operate from 3.3 to 3.6 GHz according to the Leonardo DRS brochure and have also allocated or plan to allocate 5G services based on 3.3 GHz spectrum. They include Brazil, India, Mexico, the Philippines and Taiwan.

Figure 1 depicts the coexistence of US radar systems with spectrum allocations used for 5G around the world. The red outline indicates spectrum between 3.3 and 3.45 GHz, highlighting a 150 MHz opportunity in the 3GPP global band designation.

Figure 1. Global spectrum allocations (MHz)



Source: CCS Insight

Low 3 GHz spectrum ranges are used by the military in other countries but often have also been allocated for public 5G network use, as shown in Table 1.

Table 1. Foreign Military Sales for popular US S-band military radar systems

Type	Military System	Foreign Military Sales
Ground-based radar	AN/TPQ-53	Saudi Arabia, Singapore
Shipborne radar	AN/SPY-1, used in the Aegis Combat System	Australia, Japan, Norway, Spain, South Korea
Airborne radar	AWACS Boeing E-3 Sentry	Chile, France, NATO, Saudi Arabia, UK
Airborne radar	AN/APN-243 (SKE) 2000, used in C-130J Hercules aircraft	Too many to list

Source: CCS Insight

Coexistent use of 3.3 to 3.4 GHz spectrum by military radars and 5G networks is not only possible but, as the next section shows, is also deployed and fully operational in a growing number of countries.

ITU Region 1: Europe, Middle East and Africa

Overview

3.3 to 3.4 GHz

Europe has 5G deployments in the 3.4 GHz range: radiolocation systems are defined as the sole user in the latest draft of the International Telecommunication Union (ITU) regulations. Many European countries have allocated[1] or plan to allocate[2] spectrum for 5G from 3.4 GHz upward, including NATO members Belgium, Estonia, Germany, Latvia, Lithuania, Macedonia, Montenegro, Portugal, Slovakia, Slovenia and Spain. Germany is a good example of coexistence, having deployed 5G in 3.4 GHz spectrum with a fleet of AWACS performing missions every day.

In the Middle East and Africa, as of the ITU's World Radiocommunication Conference 2019 (WRC-19), many countries have made spectrum allocations in lower 3 GHz ranges to fixed and mobile services on a primary basis: 12 nations in the Middle East and 36 in Africa. Despite this, according to the Global mobile Suppliers Association's (GSA) GAMBoD database tracking spectrum assignment, only five African countries have assigned spectrum for international mobile telecommunications (IMT) in this range so far — to 4G services — although South Africa, Uganda and Zambia have planned 5G auctions in this range for 2023 to 2024.

Allocated: Angola, Cote d'Ivoire, Ghana, Kenya, Mauritius

Ongoing or planned assignment: Serbia, South Africa, Uganda, Zambia

3.4 to 3.45 GHz

According to ITU regulation, the 3.4 to 3.45 GHz band has "mobile" as a primary user, in addition to fixed and fixed-satellite services with certain coordination conditions. As such, this has been a popular allocation for 5G services in Europe, which has been an early adopter of mid-band spectrum for commercial mobile networks. This includes major European powers Germany and the UK.

This band is also popular in much of the Middle East and Africa, with Bahrain, Nigeria and Saudi Arabia allocating this spectrum for 4G and 5G services. The latter has acquired military systems in lower 3 GHz spectrum as mobile operators have launched 5G networks using 3.4 GHz frequencies. According to GSA, 47 countries and territories have existing IMT allocations in the 3.4 to 3.45 GHz band, with some also dedicating spectrum in this range for private network use by enterprises.

An additional six countries have plans to or are in the process of assigning spectrum in this range, including countries of significance to the US military such as Kosovo, Ukraine and new NATO member Montenegro. In fact, of the 47 countries across the region allocating spectrum here, more than half are NATO members and include major US arms and radar system customers. This includes radars operating in the 3.4 GHz band including AN/TPQ-53 in Saudi Arabia, AWACS in France, Germany and the UK, C-130 SKE, and AN/SPY-1 in Norway and Spain.

[1] "Allocated" indicates that a country has issued commercial licenses for IMT services in a specific spectrum band.
[2] "Ongoing or planned assignment" indicates that a country is in the process of, or has a stated intention to, issue IMT licenses in a specific band.

Allocated: Aland Islands, Andorra, Angola, Austria, Bahrain, Belgium, Congo, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Ghana, Greece, Hungary, Iran, Ireland, Isle of Man, Italy, Cote d'Ivoire, Kenya, Latvia, Lithuania, Luxembourg, Malta, Mauritius, Mayotte, Montenegro, Nigeria, Norway, Oman, Portugal, Reunion, Romania, Rwanda, Saudi Arabia, Slovakia, Slovenia, South Africa, Spain, Sweden, Tanzania, Tunisia, UK

Ongoing or planned assignment: Guernsey, Iceland, Jersey, Kosovo, Netherlands, Ukraine

Examples

Below are European examples where US military radars coexist with lower 3 GHz spectrum.

Germany

In Germany, 5G has been deployed extensively in the lower 3 GHz band, yet still houses and exercises military equipment, which operates within similar frequency ranges.

In 2019, being one of the first in Europe to do so, Germany awarded 5G-capable mid-band spectrum between the range of 3.4 and 3.7 GHz. As a result, all four major network operators received portions of the mid-band spectrum and quickly moved to roll out 5G services nationwide. According to Deutsche Telekom, 5G coverage has been expanded to 94% across the country and some network operators have also deployed standalone 5G. Compared with some other nations, it is justifiable to rank Germany as a leading market for 5G services.

Militarily, Germany is also a major force in the NATO alliance and its geographical position on the border of Western and Eastern Europe means that it retains many NATO facilities within its borders. For example, Air Base Geilenkirchen is the main operating base of NATO's E3-A aircraft fleet, which provides airborne surveillance for major events and military operations.

In addition to NATO bases, Germany is also host to a large number of US military facilities founded after the Second World War but remaining principal locations for airborne activities and ground-based exercises today. The Grafenwoehr training ground, for example, is the largest permanent training area in Europe, and Ramstein Air Base, near Kaiserslautern, is a major launching base for activities across Europe and the Middle East.

Many of these military bases are therefore host to equipment and transport that engage the same military radars used by the US Army. For example, the Ramstein Air Base holds C-130J transport aircraft, which use the AN/APN-243 SKE radar; AWACS is a vital component of the E-3A surveillance unit in Air Base Geilenkirchen; and the 41st Field Artillery Brigade uses the AN/TPQ-53 ground base radar in its exercises at the Grafenwoehr training area. All these are examples of S-band radar systems that operate in the same lower 3 GHz frequency band that 5G is also deployed in, but 5G coverage is extensive and commercially available both across and near these sites.

Coexistence is established through a combination of coordination procedures and techniques, often between regulators, military and network operators. An example of similar agreements can be drawn from DFS Deutsche Flugsicherung, outlined in a presentation about the civil–military cooperation in Germany for civil air traffic control and radar systems. In the document, DFS claims that to improve radio frequency load reduction, operational German Mode S radars, both civil and military, are operated in clusters and coordinated within the European interrogator code allocation process.

In addition, specific rules for the use of "identification, friend or foe" systems, also called IFF, equipment and military exercises have been implemented including proofs of concept to stop harmful interference immediately. Although relating to air traffic control, it is likely that similar practices, committees and techniques are being used to increase civil–military cooperation, leading to benefits of understanding, efficiencies and effective joint management of limited-resource radio frequency.

UK

In 2021, as preparations for 5G network roll-outs started, mobile network operators in the UK were required to evaluate the impact of their proposed 5G base stations on existing spectrum-using military and civil aviation infrastructure, such as S-band primary surveillance radars and air traffic control radars. They were required to identify 5G sectors potentially causing interference and undertake suitable mitigation techniques, using the interference criteria set out by national spectrum regulator Ofcom for the management of potential conflict in radio usage.

This process resulted in two requirements.

- Principally, holders of 3.4 GHz licenses — commercial mobile network operators — have a duty of care under their licensing conditions to protect existing radars operating in the 2.7 GHz band from potential harmful interference from the deployment of networks in the 3.4 GHz band within 7 km of S-band radars. To ensure this, operators are obliged to apply coordination procedures, detailed below.
- Additionally, as part of the award process for the 2.6 GHz spectrum band, a cross-government radar remediation program ensured that radars active in the 2.7 GHz band — from 2700 to 3100 MHz — were modified to be more resilient to interference from the 3.4 GHz band — ranging from 3410 to 3600 MHz.

With regards to the first outcome, when planning 5G network deployment, all mobile network operators with a 3.4 GHz spectrum license had to calculate the communication signals and out-of-band noise at the relevant protected radar locations. Protected radars included civil and military radars, with the latter being protected within the airfield boundary and not just a specific position.

As part of their duty of care, licensees of 3.4 GHz spectrum must monitor the protection thresholds and ensure they are not exceeded. If potential interference was identified, adjustments had to be made before deployment. Mobile network operators deploying 5G networks based on spectrum in the 3.4 GHz band were required to comply with these stipulations before network deployment could proceed.

UK operators undertook studies to identify and understand the impact of sectors that could compromise the performance of air traffic control radars and the safety of air-traffic operations and navigation systems at airports and military bases in the UK. Mitigation measures were recommended to avoid interference in line with the methodology and interference criteria set out by Ofcom in its 2018 coordination procedure.

Note that there are no specific requirements for mobile networks to adjust to lower power performance, although in some instances they may elect to do so as a means of limiting possible interference.

Protection thresholds and coordination procedures apply to all radars listed at the time a new 5G network is deployed based on 2.6 or 3.4 GHz spectrum. Monitoring of all relevant 5G network sites for potential interference continues for all civilian and military aeronautical radars in the UK, at more than 80 locations, and remains an ongoing obligation for mobile operators. Ofcom ensures diligence in this activity.

ITU Region 2: Americas

Overview

3.3 to 3.4GHz

ITU Region 2, which includes North and South America, has radiolocation as the primary user of 3.3 to 3.4 GHz spectrum, although unlike other ITU regions it also has amateur, fixed and mobile use as secondary. As of the ITU's WRC-19, a total of 13 countries, including parts of Central and Southern America such as Mexico, Argentina, Brazil and Chile, also now have mobile use promoted to primary user, subject to coordination agreements.

As a result, 10 countries including Brazil, the Dominican Republic and Mexico hold licenses or have launched commercial services in this band. Another two countries are planning its allocation.

Allocated: Argentina, Bolivia, Brazil, Chile, Colombia, Dominican Republic, Guadeloupe, Mexico, Suriname, Uruguay

Ongoing or planned assignment: Costa Rica, Ecuador

3.4 to 3.45 GHz

As with Europe, IMT is identified as a primary user of the 3.4 GHz band, with coordination conditions. A total of 13 countries and territories have 5G licenses here, including Brazil, Chile, Colombia and Peru. An additional five countries are considering auctioning this band over the next couple of years.

Although the US military is less active in parts of Central and South America, Mexico, which operates 5G services in the lower 3 GHz band, shares a border with the US and it is therefore possible that some spectrum coordination will be required along border areas.

Allocated: Argentina, Bermuda, Bolivia, Brazil, Chile, Dominican Republic, French Guiana, Guatemala, Martinique, Mexico, Peru, Saint Barthelemy, Saint Martin, Saint Pierre and Miquelon, Suriname, Uruguay

Ongoing or planned assignment: Colombia, Costa Rica, Ecuador, Honduras, Mexico

Example

Mexico

Mexico has been using the lower 3 GHz band for commercial 5G services, specifically 3.35 to 3.45 GHz spectrum. This portion of the band was originally allocated to older fixed wireless access services in 1998, but consultations on its migration for new usage began in 2018. In 2022, its use was approved for 5G services and shortly after America Movil (Telcel) launched Mexico's first commercial 5G network throughout the country in this band, after relocating most of its regional concessions from its previous allocation of 3.45 to 3.55 GHz where it operates fixed wireless access services.

In addition, the 3.30 to 3.35 GHz portion of the band is also being considered for 5G services, as Mexico's Federal Telecommunications Institute, or IFT, prepares future allocation. Previously, the 3.30 to 3.35 GHz band was licensed to the Coordination of the Information and Knowledge Society (CSIC), which used 50 MHz of spectrum for older microwave multipoint systems needed for government purposes.

As of 2023, the CSIC has been persuaded to relocate these licenses to another band, paving the way for this valuable 5G-suitable spectrum to be auctioned. It is expected that 50 MHz of spectrum will

be auctioned later in 2023 or in 2024, with America Movil stating its intention to acquire more for its 5G service.

Mexico has been deploying the lower 3 GHz band without any major problems presented by military radar systems operating in this range, despite several US military installations including Fort Bliss being located near the border, and there have been no reported issues with interference from ground-based radars.

As with many neighboring countries, Mexico's geographical location on the southern border of the US presents challenges for both governments to coordinate on topics such as spectrum interference. This demands careful policy, and certain processes must be established and followed by multiple parties.

In 2012, the US Federal Communications Commission (FCC) signed spectrum coordination agreements with Mexico on the rebranding of spectrum allotments to alleviate interference to public safety licensees in the band caused by commercial cellular licensees. Similarly, in 2016 this was followed by a successful meeting between the FCC and the IFT, which led to an agreement to develop a work plan addressing coordination in several frequency bands including between 3.4 and 3.7 GHz.

There are currently no specific coordination requirements on the use of 3300 to 3400 MHz spectrum between Mexico and the US, but research suggests that simple coordination procedures such as geographic exclusion zones could be used in such situations.

ITU Region 3: Asia–Pacific

Overview

3.3 to 3.4 GHz

In ITU Region 3, which corresponds to Asia–Pacific and Oceania, radiolocation is the primary user of 3.3 to 3.4 GHz spectrum, with amateur use secondary. However, as of WRC-19, many countries in this region are also permitted to allocate fixed and mobile services on a primary basis, including leading influencers in the region such as China, Japan, South Korea and New Zealand.

Unlike in ITU Region 1, eight Asian countries have already deployed 4G and 5G services in the 3.3 GHz band, including China, India and the Philippines and special administrative regions Hong Kong and Taiwan. It must be noted, however, that China has opted for 3.3 GHz 5G spectrum for indoor use only to accelerate 5G adoption in enterprise environments.

Allocated: China, Hong Kong SAR, India, Indonesia, Kazakhstan, Maldives, Philippines, Taiwan

Ongoing or planned Assignment: Macao SAR, Pakistan

3.4 to 3.45 GHz

According to ITU regulation, and different from the other two regions, the 3.4 to 3.5 GHz band is only identified as a secondary user of IMT, with fixed and fixed-satellite usage positioned as primary. However, WRC-19 saw 16 countries promote IMT services to primary uses including Japan, New Zealand and South Korea. As such, it is also now a popular allocation for 5G services.

There are 14 countries in which operators hold commercial licenses for IMT use in 3.4 to 3.45 GHz and another four are considering or planning its allocation. These 18 countries consist of the same list as in the 3.3 to 3.4 GHz band but also include parts of Oceania such as Australia, New Zealand and Papa New Guinea.

Countries with allocations in the lower 3 GHz band in Asia–Pacific include several with close military ties to the US. Specifically, Japan, the Philippines, South Korea and Taiwan are all host to many international US military bases, operations and exercises. US military radars deployed in these countries are able to coexist with 5G, with extensive 5G coverage and services operating in the 3.3 GHz and 3.4 GHz bands.

Allocated: Australia, Azerbaijan, Bangladesh, China, Hong Kong SAR, India, Japan, Kazakhstan, Republic of Korea, Maldives, Pakistan, Papua New Guinea, Philippines, Taiwan

Ongoing or planned assignment: Macao SAR, New Zealand, Sri Lanka, Thailand

Examples

Below are examples where US military radars are able to coexist with lower 3 GHz spectrum.

Japan and South Korea

The Ministry of Internal Affairs and Communications in Japan allocated 3.4 to 3.9 GHz spectrum to all four of the country's network operators. 5G systems were subsequently launched by operators in 2020, with new equipment suppliers such as Rakuten able to deploy greenfield networks across the country. South Korea also auctioned spectrum at a similar time, allocating licenses in lower 3 GHz spectrum to its three main operators and launching services. Both countries have now established extensive 5G networks, taking advantage of the mid-band's coverage and capacity benefits for 5G services.

Yet, like the example highlighted in Germany, Japan and South Korea are host to a large number of stationed US military forces, resulting from historical strategic placement in the mid-20th century but remaining relevant amid increased provocation in the region in recent years. These bases are particularly relevant for the US Navy, which has established facilities in the Busan Naval Base in Korea and Yokosuka in Japan, strategically positioned near the South China Sea.

Recent years have witnessed several joint military exercises between the US and its allies — for example, Operation Keen Sword in 2022, Iron Fist in 2022 and Sea Dragon in 2023 — putting both amphibious forces and aircraft into action. The naval frigates and aircraft used in such exercises are all equipped with the same US military radars that operate in the S-band frequency of the lower 3 GHz spectrum, including the AN/SPY-1 in the navy and AWACS in the air force.

Despite these high levels of military activity and stationed equipment, 5G is still able to coexist in this band and the coverage and capacity advantages of the highly valued mid-band are received by the population and enterprises.

China and Hong Kong

Allocating spectrum in the 3.3 GHz band opens even more possibilities for coverage and capacity. China, in 2020, officially moved to reserve a large block of 3.3 to 3.6 GHz spectrum for 5G services, which was assigned to the country's three state-owned operators.

Since then, coordinated investment into telecommunications infrastructure by existing radio access network providers has put China's 5G services among the most developed in the world, achieving extensive coverage and speeds. According to a recent GSMA report, 5G connections in China are set to top 1 billion by as early as 2025, far in advance of other countries.

China is also committed to the development of applications for 5G in industrial settings and has dedicated the 100 MHz block of 5G spectrum between 3.3 and 3.4 GHz to indoor use. This approach is unique to China, and although some coordination with radiolocation systems may be necessary, allocating additional spectrum in this way aims to avoid the bulk of interference while still providing some core benefits of 5G.

Hong Kong is also taking the same route, able to allocate the whole 3.3 to 3.45 GHz spectrum, with mobile operators achieving high levels of coverage for their 5G services.

Taiwan

Taiwan, an area of significant concern in the geopolitical landscape given the recent assertions by China, has authorized and deployed 5G in 3.3 GHz spectrum bands with several operators. Four Taiwanese telecom providers received spectrum in the 2020 auction:

- Taiwan Star Telecom: 3300 to 3340 MHz
- Far EasTone Telecom: 3340 to 3420 MHz
- Chunghwa Telecom: 3420 to 3510 MHz
- Taiwan Mobile: 3510 to 3570 MHz

In anticipation of an invasion by China, Taiwanese network operators are expected to continue to operate full-power 5G networks during naval and airborne training and exercises involving radar systems using the same spectrum ranges.

India

India, now the world's most populous country, has begun to launch 5G services following a highly anticipated multispectral band auction in 2022. As part of the auction, the lower 3 GHz band was

identified for the launch of 5G services and sold at a regional level to India's three main operators. Reliance Jio, Bharti Airtel and Vi (or Vodafone Idea) won significant allocations between 3.350 and 3.650 GHz, enabling them to launch commercial services in these bands.

Prior to this allocation of 3.3 GHz spectrum, India faced similar restrictions as the US and other countries in relation to existing military radiolocation radars operating in this band, including ownership of a C-130J Hercules with SKE equipment. Importantly, several military radars on its shores were using the S band in lower 3 GHz spectrum that would conflict with any IMT services launched. The Telecom Regulatory Authority of India, or TRAI, oversaw coordination consultations with the military leading up to the auction in 2022. With some negotiation, the military agreed to reduce its spectrum usage to operate in the 3.2 GHz band instead.

Some radiolocation sites remain operational in the 3.4 to 3.42 GHz band, primarily for the Indian Regional Navigation Satellite System. However, commercial IMT services and spectrum in this band were still able to be auctioned thanks to coordination procedures which led to geographical restrictions and guard bands being put in place at the few sites where this is applicable.

As a result, India's 5G auction went ahead and sold $19 billion of spectrum to the government. In addition to the increased revenue opportunity, the resulting benefit of faster speeds and bandwidth to India's population will yield greater innovation and connectivity benefits.

This example provides sufficient evidence that when similar potential obstacles for spectrum competition arise, sometimes all that is necessary is simple coordination and consultation to achieve mutually beneficial outcomes from spectrum policy.

Summary Exhibits

3.3 to 3.4 GHz

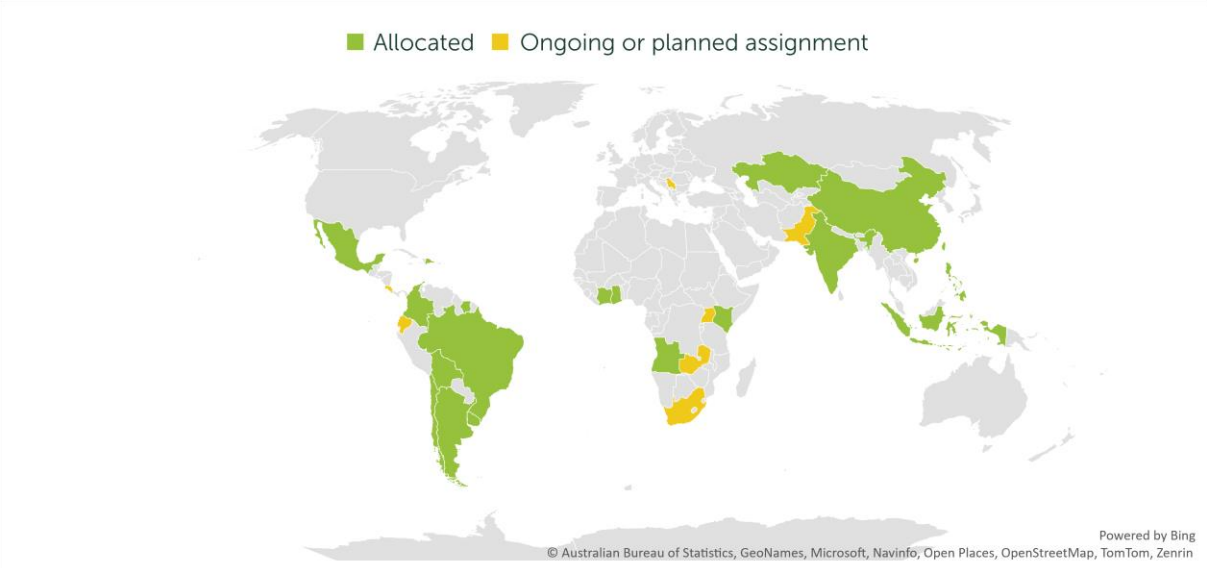
Table 2. Summary of 3.3 to 3.4 GHz spectrum licenses by ITU region

	ITU Region 1	ITU Region 2	ITU Region 3
ITU mobile primary use	No	No, mobile secondary	No
ITU mobile primary use: additional allocation (WRC-19)	48	13	13
Commercial IMT licenses*	5	10	8
Considering or planning IMT licenses*	4	2	2

* According to GSA GAMBoD Spectrum Assignment Database (https://gambod.gsacom.com/spectrum_assignment)

Sources: CCS Insight and GSA

Figure 2. Commercial IMT allocation of 3.3 to 3.4 GHz spectrum



Source: GSA

3.4 to 3.45 GHz

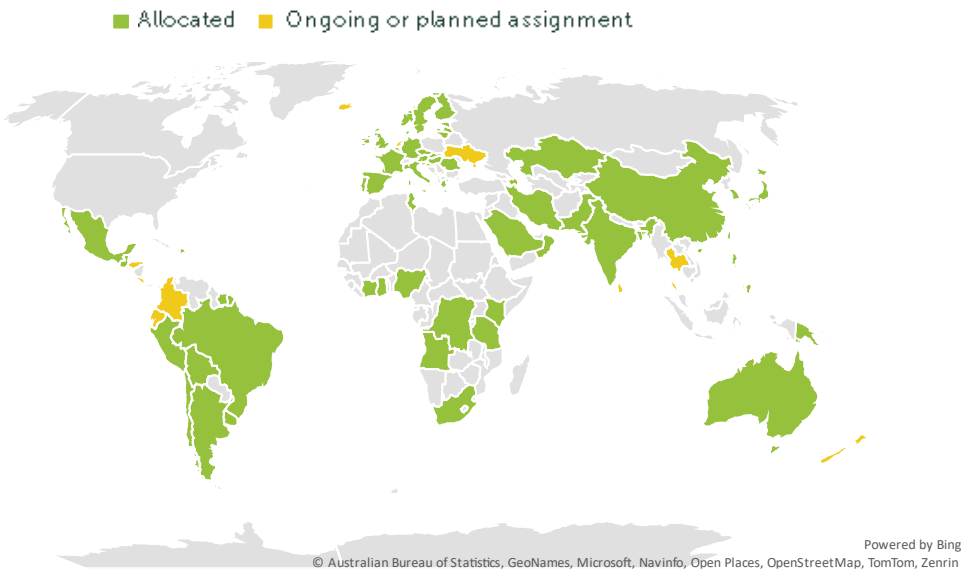
Table 3. Summary of 3.4 to 3.45 GHz spectrum licenses by ITU region

	ITU Region 1	ITU Region 2	ITU Region 3
ITU mobile primary use	Yes	Yes	No, mobile Secondary
ITU mobile primary use: additional allocation (WRC-19)	N/A	N/A	16
Commercial IMT licenses*	47	14	14
Considering or planning 5G licenses*	6	4	4

* According to GSA GAMBoD Spectrum Assignment Database (https://gambod.gsacom.com/spectrum_assignment)

Sources: CCS Insight and GSA

Figure 3. Commercial IMT allocation of 3.4 to 3.45 GHz spectrum



Source: GSA

Methods of Coexistence

There are several possible mechanisms for constraining commercial 5G network operations to ensure they do not cause harmful interference with prioritized military spectrum usage. For example:

- Relocation: relocating to alternative spectrum — effectively, vacating current spectrum band to allow it to be reallocated to a different licensee or usage
- Tuning: using the tuning range of radar systems to operate in portions of frequency bands away from other systems. For example, radars have been tuned to lower portions of the band to allow commercial users of spectrum above certain levels and maintaining the ability to operate up to full power
- Compression: radio signal compression facilitates transmission, reception and processing of large volumes of data and conserves valuable storage and transmission resources. This enables less spectrum to be used as well as greater efficiency, allowing "neighbors" to occupy adjacent spectrum
- Coordination areas: examples include cooperative planning areas and periodic use areas as defined by the National Telecommunications and Information Administration (NTIA). These are not spectrum usage exclusion zones, but defined geographical areas where military systems require protection from harmful interference from new non-federal operations
- Guard bands: for frequency separation — a narrow frequency range that separates two ranges of wider frequency to ensure simultaneously used channels do not experience interference; a disadvantage is that it is not effective for co-channel usage and bandwidth remains unused
- Interference mitigation mechanisms: several techniques and algorithms that can be used in radio communication systems to mitigate interference, including radio frequency power reduction; incorporation of filters in communication channels whose characteristics are known, or equalizer, if the channel characteristics are unknown; and transmission at different places or different times. They may also include 5G radio site measures like restrictions in the design or operation of base stations, such as antenna height and radiation pattern restrictions
- Indoor restrictions: for scenarios where radar locations are unknown and power reduction and penetration loss are helpful to mitigate interference; however, this can severely hinder the performance and coverage
- Interference protection and rejection: diminishes the interference impact of neighboring users in the spectrum band. Radar systems can be designed to employ signal processing to suppress or cancel predictable sources of interference, and inherently more resilient to interference
- Anti-jamming: jammers attempt to disrupt communications or radar systems. To the extent possible, radar systems should be designed to be jam-resistant, using the detection of, and countermeasures against, jamming activity

Coexistence of military radio communications and 5G networks in the low 3 GHZ spectrum range is achievable, as countries outside the US demonstrate. It can be a straightforward process of negotiation; sometimes it is not but can be achieved by being creative with the mechanisms outlined above, and do not necessarily incur high overheads.

Failure to accommodate a mutual existence puts US-based carriers at a disadvantage when compared with their international peers, and, consequently, aspects of society that will increasingly rely on high-performance 5G networks to support their digital transformations: industry, healthcare, education and so on.

5G networks provide growing opportunities for mobile-related uses for the military. In military bases, airfields and other facilities, this is likely to be through private mobile networks, potentially built and operated by the military itself to support secure, on-campus communication.

But for several uses requiring wide area communications and mobility, such as supply chain and intelligent transportation, it is unrealistic to implement military-only 5G network infrastructure because of the magnitude of the required investment. Using commercial 5G networks, possibly within a private, secure network slice, will become a necessity. Therefore, it is also in the military's interest to support the optimization of public 5G network infrastructure across viable spectrum bands to maximize available capacity.

Conclusion

To optimize 5G network capabilities and service opportunities, 3.3 to 3.45 GHz spectrum has been adopted around the world, often coexisting with military and NATO systems operating in in the lower 3 GHz band or adjacent spectrum, using proven coexistence techniques.

There is a critical need for more dedicated mid-band spectrum in the US. Within the 3.3 to 3.45 GHz range there is a 150 MHz opportunity that is not being exploited. This puts the US at a disadvantage to the growing list of countries that have developed creative and collaborative methods for spectrum coexistence, by clearing, tuning or coordinating spectrum in the lower 3 GHz band.

For the US to maintain a world-leading role in commercial 5G deployment, adoption and innovation, it is imperative for all domestic stakeholders to investigate all options for coexistence in the 3.3 to 3.45 GHz spectrum band without delay.

Appendix

The following table shows the status of deployment of lower 3 GHz spectrum by country and ITU region.

ITU Region	Country	Spectrum	Status
1	Angola	3.3 to 3.4 GHz	Allocated
1	Cote d'Ivoire	3.3 to 3.4 GHz	Allocated
1	Ghana	3.3 to 3.4 GHz	Allocated
1	Kenya	3.3 to 3.4 GHz	Allocated
1	Mauritius	3.3 to 3.4 GHz	Allocated
1	Serbia	3.3 to 3.4 GHz	Ongoing or planned assignment
1	South Africa	3.3 to 3.4 GHz	Ongoing or planned assignment
1	Uganda	3.3 to 3.4 GHz	Ongoing or planned assignment
1	Zambia	3.3 to 3.4 GHz	Ongoing or planned assignment
1	Aland Islands	3.4 to 3.45 GHz	Allocated
1	Andorra	3.4 to 3.45 GHz	Allocated
1	Angola	3.4 to 3.45 GHz	Allocated
1	Austria	3.4 to 3.45 GHz	Allocated
1	Bahrain	3.4 to 3.45 GHz	Allocated
1	Belgium	3.4 to 3.45 GHz	Allocated
1	Congo	3.4 to 3.45 GHz	Allocated
1	Cote d'Ivoire	3.4 to 3.45 GHz	Allocated
1	Croatia	3.4 to 3.45 GHz	Allocated
1	Cyprus	3.4 to 3.45 GHz	Allocated
1	Czech Republic	3.4 to 3.45 GHz	Allocated
1	Denmark	3.4 to 3.45 GHz	Allocated
1	Estonia	3.4 to 3.45 GHz	Allocated
1	Finland	3.4 to 3.45 GHz	Allocated
1	France	3.4 to 3.45 GHz	Allocated
1	Germany	3.4 to 3.45 GHz	Allocated
1	Ghana	3.4 to 3.45 GHz	Allocated
1	Greece	3.4 to 3.45 GHz	Allocated
1	Hungary	3.4 to 3.45 GHz	Allocated
1	Iran	3.4 to 3.45 GHz	Allocated
1	Ireland	3.4 to 3.45 GHz	Allocated
1	Isle of Man	3.4 to 3.45 GHz	Allocated
1	Italy	3.4 to 3.45 GHz	Allocated
1	Kenya	3.4 to 3.45 GHz	Allocated
1	Latvia	3.4 to 3.45 GHz	Allocated
1	Lithuania	3.4 to 3.45 GHz	Allocated
1	Luxembourg	3.4 to 3.45 GHz	Allocated
1	Malta	3.4 to 3.45 GHz	Allocated
1	Mauritius	3.4 to 3.45 GHz	Allocated
1	Mayotte	3.4 to 3.45 GHz	Allocated
1	Montenegro	3.4 to 3.45 GHz	Allocated
1	Nigeria	3.4 to 3.45 GHz	Allocated
1	Norway	3.4 to 3.45 GHz	Allocated

ITU Region	Country	Spectrum	Status
1	Oman	3.4 to 3.45 GHz	Allocated
1	Portugal	3.4 to 3.45 GHz	Allocated
1	Reunion	3.4 to 3.45 GHz	Allocated
1	Romania	3.4 to 3.45 GHz	Allocated
1	Rwanda	3.4 to 3.45 GHz	Allocated
1	Saudi Arabia	3.4 to 3.45 GHz	Allocated
1	Slovakia	3.4 to 3.45 GHz	Allocated
1	Slovenia	3.4 to 3.45 GHz	Allocated
1	South Africa	3.4 to 3.45 GHz	Allocated
1	Spain	3.4 to 3.45 GHz	Allocated
1	Sweden	3.4 to 3.45 GHz	Allocated
1	Tanzania	3.4 to 3.45 GHz	Allocated
1	Tunisia	3.4 to 3.45 GHz	Allocated
1	UK	3.4 to 3.45 GHz	Allocated
1	Guernsey	3.4 to 3.45 GHz	Ongoing or planned assignment
1	Iceland	3.4 to 3.45 GHz	Ongoing or planned assignment
1	Jersey	3.4 to 3.45 GHz	Ongoing or planned assignment
1	Kosovo	3.4 to 3.45 GHz	Ongoing or planned assignment
1	Netherlands	3.4 to 3.45 GHz	Ongoing or planned assignment
1	Ukraine	3.4 to 3.45 GHz	Ongoing or planned assignment
2	Argentina	3.3 to 3.4 GHz	Allocated
2	Bolivia	3.3 to 3.4 GHz	Allocated
2	Brazil	3.3 to 3.4 GHz	Allocated
2	Chile	3.3 to 3.4 GHz	Allocated
2	Colombia	3.3 to 3.4 GHz	Allocated
2	Dominican Republic	3.3 to 3.4 GHz	Allocated
2	Guadeloupe	3.3 to 3.4 GHz	Allocated
2	Mexico	3.3 to 3.4 GHz	Allocated
2	Suriname	3.3 to 3.4 GHz	Allocated
2	Uruguay	3.3 to 3.4 GHz	Allocated
2	Costa Rica	3.3 to 3.4 GHz	Ongoing or planned assignment
2	Ecuador	3.3 to 3.4 GHz	Ongoing or planned assignment
2	Argentina	3.4 to 3.45 GHz	Allocated
2	Bermuda	3.4 to 3.45 GHz	Allocated
2	Bolivia	3.4 to 3.45 GHz	Allocated
2	Brazil	3.4 to 3.45 GHz	Allocated
2	Chile	3.4 to 3.45 GHz	Allocated
2	Dominican Republic	3.4 to 3.45 GHz	Allocated
2	French Guiana	3.4 to 3.45 GHz	Allocated
2	Guatemala	3.4 to 3.45 GHz	Allocated
2	Martinique	3.4 to 3.45 GHz	Allocated
2	Mexico	3.4 to 3.45 GHz	Allocated
2	Peru	3.4 to 3.45 GHz	Allocated
2	Saint Barthelemy	3.4 to 3.45 GHz	Allocated
2	Saint Martin	3.4 to 3.45 GHz	Allocated
2	Saint Pierre and Miquelon	3.4 to 3.45 GHz	Allocated
2	Suriname	3.4 to 3.45 GHz	Allocated
2	Uruguay	3.4 to 3.45 GHz	Allocated

ITU Region	Country	Spectrum	Status
2	Colombia	3.4 to 3.45 GHz	Ongoing or planned assignment
2	Costa Rica	3.4 to 3.45 GHz	Ongoing or planned assignment
2	Ecuador	3.4 to 3.45 GHz	Ongoing or planned assignment
2	Honduras	3.4 to 3.45 GHz	Ongoing or planned assignment
3	China	3.3 to 3.4 GHz	Allocated
3	Hong Kong SAR	3.3 to 3.4 GHz	Allocated
3	India	3.3 to 3.4 GHz	Allocated
3	Indonesia	3.3 to 3.4 GHz	Allocated
3	Kazakhstan	3.3 to 3.4 GHz	Allocated
3	Maldives	3.3 to 3.4 GHz	Allocated
3	Philippines	3.3 to 3.4 GHz	Allocated
3	Taiwan	3.3 to 3.4 GHz	Allocated
3	Macao SAR	3.3 to 3.4 GHz	Ongoing or planned assignment
3	Pakistan	3.3 to 3.4 GHz	Ongoing or planned assignment
3	Australia	3.4 to 3.45 GHz	Allocated
3	Azerbaijan	3.4 to 3.45 GHz	Allocated
3	Bangladesh	3.4 to 3.45 GHz	Allocated
3	China	3.4 to 3.45 GHz	Allocated
3	Hong Kong SAR	3.4 to 3.45 GHz	Allocated
3	India	3.4 to 3.45 GHz	Allocated
3	Japan	3.4 to 3.45 GHz	Allocated
3	Kazakhstan	3.4 to 3.45 GHz	Allocated
3	Republic of Korea	3.4 to 3.45 GHz	Allocated
3	Maldives	3.4 to 3.45 GHz	Allocated
3	Pakistan	3.4 to 3.45 GHz	Allocated
3	Papua New Guinea	3.4 to 3.45 GHz	Allocated
3	Philippines	3.4 to 3.45 GHz	Allocated
3	Taiwan	3.4 to 3.45 GHz	Allocated
3	Macao SAR	3.4 to 3.45 GHz	Ongoing or planned assignment
3	New Zealand	3.4 to 3.45 GHz	Ongoing or planned assignment
3	Sri Lanka	3.4 to 3.45 GHz	Ongoing or planned assignment
3	Thailand	3.4 to 3.45 GHz	Ongoing or planned assignment

References

In researching this topic, resources, reports and spokespeople were referenced from the organizations listed below.

Telecommunications Industry Policy Bodies

- 3GPP
- CTIA (formerly Cellular Telecommunications Industry Association)
- European Telecommunications Standards Institute (ETSI)
- Global mobile Suppliers Association (GSA)
- GSMA
- International Telecommunications Union Radiocommunication Sector (ITU-R)
- UK Telecoms Innovation Network (UKTIN)

Regulatory and Advisory Bodies

- US Federal Communications Commission (FCC)
- UK communications regulator Ofcom
- US National Telecommunications and Information Administration (NTIA)
- Telecom Regulatory Authority of India (TRAI)
- International Civil Aviation Organization (ICAO)

Military

- US Defense Information Systems Agency (DISA)
- US Department of Defense (DoD)
- US Defense Security Cooperation Agency
- UK Ministry of Defence
- NATO Cooperative Cyber Defence Centre of Excellence (CCDCOE)

Network Operators

Multiple mobile network operators across all regions, including BT/EE in the UK, China Mobile, KT and SK Telecom in Korea, Deutsche Telekom in Germany and Reliance Jio in India.

Network Solution Providers

Multiple providers of commercial and military radiocommunications equipment and services, principally: ADTi, Booz Allen, DFS Deutsche Flugsicherung, Ericsson, Leonardo DRS, Lockheed Martin, Nokia, Northrop Grumman, Qorvo and Qualcomm.

About CCS Insight

CCS Insight is a specialist market intelligence and advisory firm serving customers with original research, data, insight and consulting, across the global telecommunications industry. It has over 30 years' experience in providing insight and data to customers in the telecom and technology industry.

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