ATU-R RECOMMENDATION

RELATING TO

Spectrum Audit

NUMBERED

ATU-R Recommendation 001-0

DATED

March 2021

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Contents

PART A: EXECUTIVE SUMMARY

Radio frequency spectrum audit aims to have a clear picture of how the radio spectrum is used in each member state. It will determine which companies hold licenses for which spectrum, and for what purpose. A national spectrum audit should form an integral part of the Spectrum Management Process of a country to serve the following functions:

i. Helping governments to determine how spectrum can be used more efficiently
ii. Aid in locating frequency that is not being used.
iii. Support the updating of the national Table of Frequency Allocations (Band Plan).
iv. Re-farming the spectrum
v. Introduce new services in under-utilized spectrum bands.
vi. Frequency planning and assignments, including providing information on spectrum occupancy, applying spectrum reuse, development of band-sharing strategies, as well as band clearing efforts.
vii. Avoiding incompatible usage with license conditions and technical standards, and identifying sources of harmful interference.

By publishing the results of spectrum audits, including databases of spectrum usage (e.g., a database of fixed point-to-point links), regulators can help accelerate network deployment and enhance coexistence between incumbent and emerging technologies. Moreover, these databases can facilitate innovation in spectrum management which in turn can promote more efficient spectrum audit in the future.

There is therefore, a need to ensure spectrum audit is carried out periodically (e.g. annualy / bi-annualy) in the interest of Regional harmonisation at the least, with National Frequency Allocation table of African countries updated regularly, especially after each World Radiocommunication Conference, and in conformity with the international regulations governing radio spectrum use, and the international/regional agreements acceded to by each country. The harmonised spectrum audit recommendation is very important for the member states particularly on the uniformity of the methodologies and where possible, in conducting the spectrum audits.

PART B: SPECTRUM AUDIT ISSUES FOR CONSIDERATION

One of the tools for spectrum audit is spectrum monitoring, which aims to identify the use of the spectrum and to ensure the use of the spectrum is restricting to the licensed frequencies. To achieve this goal, spectrum monitoring should be operating on a continuous base. Although, spectrum inspection should be working along with the monitoring to verify and ensure the efficient use of the spectrum. A national spectrum audit therefore, should answer the following questions, amongst others:

- Which frequency bands are licensed and/or in use (in the case of unlicensed access such as with Wi-Fi)?
- Number of licences by service type in each frequency band?
- Amount of frequencies still available for licensing in each band?
- Level of usage of each frequency band by service type, and location?
- Geographical coordinates of ground equipment (e.g., fixed service links, gateways, satellite terminals)?
- Technical parameters of ground equipment (e.g., transmitter power, antenna gain, beamwidth, polarization, installation elevation, antenna elevation angle)]?
- Is there any technology or system that requires additional spectrum to cater for growth?
- Is more (or less) spectrum required for any specific radiocommunication service based on current usage and forecasts?
- Is the current licensing or usage of a frequency band in the country's best socio-economic interest?
- Is the measured spectrum usage (via field measurement/spectrum monitoring) in line with license records and expectation?
- How spectrum is currently being used in African member states taking into account, the RR in force?
- Which national policies and regulations are being complied with, by member states in line with relevant regulations on the regionally determined bands of interest?
- Is spectrum used flexibly (i.e., on different platforms and technologies) across the nation?
- Is there a balance betwen license-exempt, lightly licensed, and licensed spectrum? Is there sufficient license-exempt spectrum to support licensed use cases (via offload or backhaul)?
- Is there any spectrum that can be released for use immediately? Is there spectrum that is under-utilized that could be shared with different tiers of users?
- Can spectrum be made available to enhance network capacity and coverage? Can rural operators gain access to under-utilized spectrum? Is spectrum available to allow for enhanced capacity and backhaul use cases?

In addition, spectrum audit assists spectrum managers in:

- Frequency planning and assignments, including providing information on spectrum occupancy, applying spectrum reuse, development of band-sharing strategies, as well as band clearing efforts.
- Avoiding incompatible usage with license conditions and technical standards, and identifying sources of harmful interference.

PART C: COLLATION OF PRACTICES

Tanzania National Experience:

Tanzania Communication Regulatory Authority (TCRA), conducts spectrum audits on yearly basis, using the following approach/methodologies in carrying-out the spectrum audit exercises:

- Identification of the radio frequency bands for audit.
- Verification of radio frequency spectrum assignments - Prior to fieldwork, the frequency spectrum assignments in the aforementioned bands are verified.
- Collect the network technical data of the operators.
- Site Visit - monitoring of the utilization of radio frequency spectrum.
- Using the radio frequency Mobile Monitoring Station (MMS) - The radio spectrum occupancy is measured at various locations for all radio channels in the respective frequency bands. The measurements are made as per ITU-R SM.2256-1 (08/2016) recommendation.

Uganda Communications Commission (UCC) National Experience:

UCC currently runs a network of seven strategically located remote fixed and two mobile monitoring stations in addition to a number of handheld equipment. These equipment combined are capable of monitoring radio frequency activities in the range of 9KHz to 43GHz, in order to identify and monitor the existing operators against the licensed database and help mitigate a number of undesirable outcomes including harmful interference, unauthorised operations and underutilization.

Guniee National Experience:

Guniee has performed frequency band occupancy measurements ranging from 30 MHz to 5 GHz for all services, in accordance with the frequency assignment databases, and have succeeded to identify unassigned channels in the 88-108 MHz, 138-460 MHz, 3.4 GHz, 3.6 GHz and 5 GHz bands. In addition to, inspections and compliance checks carried out in 2019, out of 87 networks inspected, 61 used unassigned spectral resources or did not comply with the authorized amount in terms of bandwidth.

Côte d'Ivoire National Experience:

Côte d'Ivoire process of audit at a national level

a. Before the audit:
1. Establish a national frequency allocation table which is in line with the international frequency allocation table (Art 5, RR)
2. Make frequency assignment in conformity with the national frequency allocation table
3. Develop a frequency assignment database recording all users and the technical conditions of use of the frequencies
4. Establish a program of spectrum audit

b. During the audit
1. Make an administrative assessment of the databases to sort out the occupancy of the frequencies being audited
2. Conduct an on-site control to assess the real occupancy of the frequencies and the conformity with the licensing
3. Conduct an on-site inspection of sites and stations to check their conformity with the specifications set at their initial roll-out.

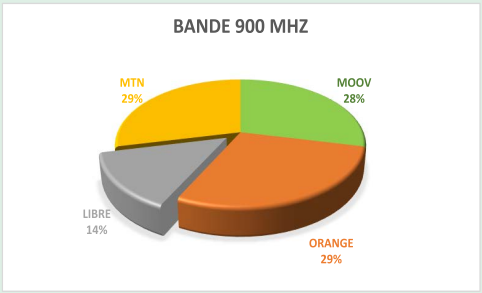
The Agence Ivoirienne de Gestion des Fréquences Radioélectriques (AIGF) audit of access networks frequency bands:

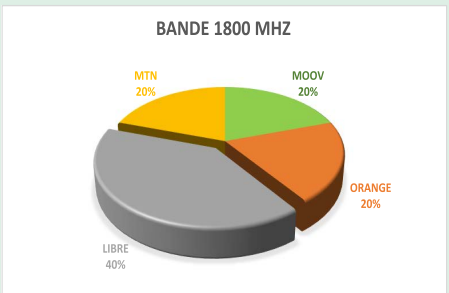
Occupancy of bands used by mobile services:
1. 900, 1800 and 2100 MHz bands

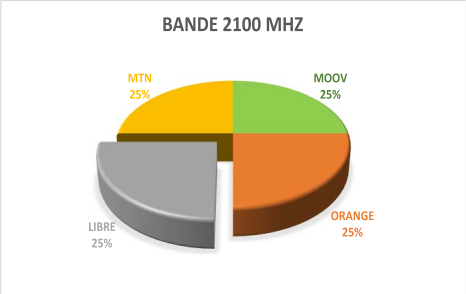
a. Features

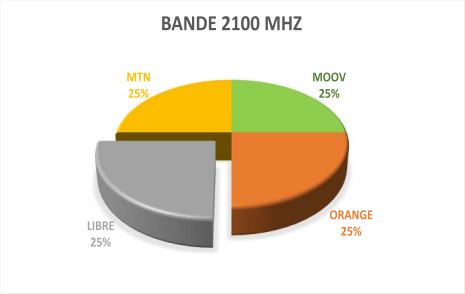
The 900 MHz (880-915/925-960 MHz) and 1800 MHz (1710-1785/1805-1880 MHz) bands with 200 KHz channelling and FDD duplexing are used for mobile services based on GSM technologies. The 900 MHz band can be used for UMTS technology and the 1800 MHz band for LTE technology, with 5 to 20 MHz channelling and FDD duplexing mode. The 2100 MHz band (1920-1980/2110-2170 MHz) is used with UMTS technology, with 5 MHz channelling in FDD mode.

a. The occupancy status is shown below:







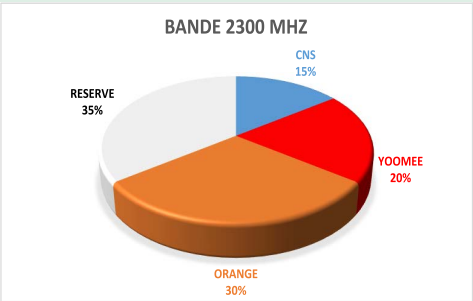


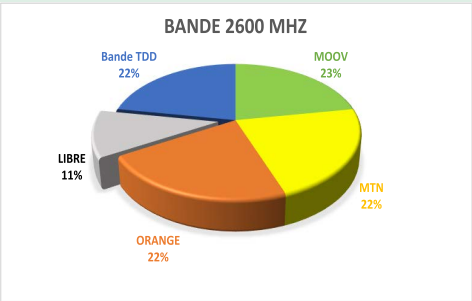
NB: All the free portions in the different frequency bands are reserved for a potential operator in the mobile telephony landscape in Côte d'Ivoire.

1. 22300 and 2600 MHz TDD band

a. Features:The 2300 MHz (2300-2400 MHz) and 2600 MHz TDD (2570-2620 MHz) bands, with channelling from 5 to 20 MHz and TDD duplexing, are used for broadband services based on WiMAX and LTE technologies. To achieve higher speed, carrier aggregation between these two bands is possible.

b. The occupancy status is shown below:





It should be noted that the frequency sub-bands 2315 - 2335 MHz and 2355 - 2370 MHz (which represent the reserved band on the 2300 MHz band graph) will be assigned to two Internet Service Providers for which the licensing process by the Government is currently under way.

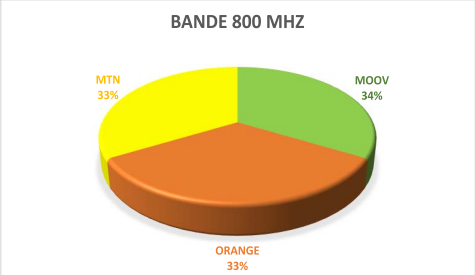
The free portion of the 2600 MHz band is also reserved for a potential operator in the mobile telephony landscape in Côte d'Ivoire.

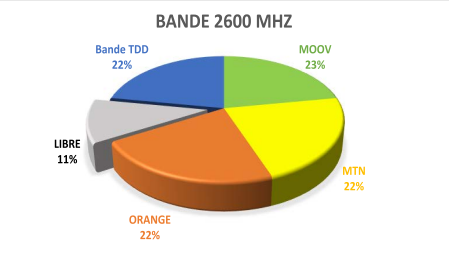
1. 800 and 2600 MHz FDD band

a. Features

The 800 MHz (791-821/832-862 MHz) and 2600 MHz-FDD (2500-2570/2620-2690 MHz) bands, with channelling ranging from 5 to 20 MHz and FDD duplexing, are used for mobile services based on LTE technology.

a. The occupancy status is shown below:





1. 700 MHz band:

This frequency band has not yet been made available to the assignment authority. However, in view of its characteristics in the Radio Regulations, the planned operating conditions are set out below:

a. Features:

The 700 MHz band (703-733 / 758-788 MHz) with a channelling ranging from 5 to 20 MHz and FDD duplexing mode, is dedicated to mobile services based on LTE technology and above (5G).

b. Occupany status

The 700 MHz frequency band is currently free.

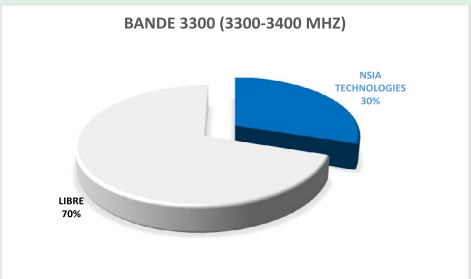
1. Bands 3.3 GHz TDD - 3.5 GHz FDD - 5.2 GHz TDD and 5.8 GHz TDD

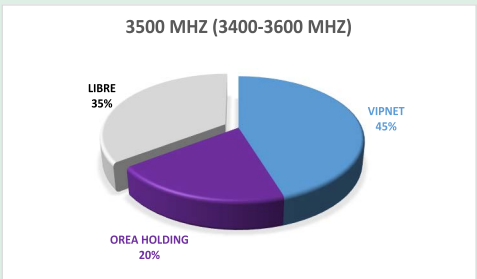
a. Features:

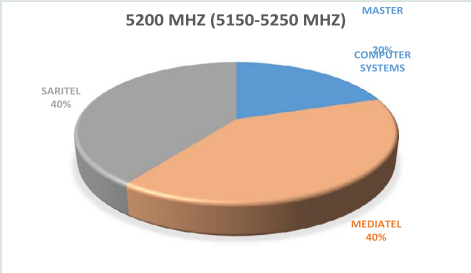
The 3300 MHz bands (3300-3400 MHz) in TDD duplexing mode, and 3500 MHz in FDD duplexing mode (3400-3500 / 3500-3600 MHz) with a 5 MHz channel, are dedicated to WiMAX and LTE technologies.

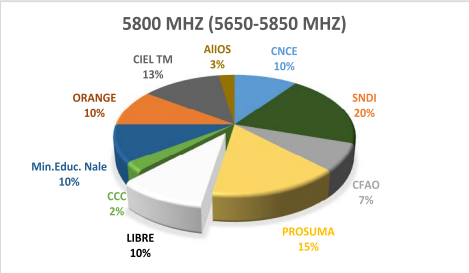
a. The 5.2 GHz (5150-5250 MHz) and 5.8 GHz (5650-5850 MHz) TDD bands with 5 MHz channelling are dedicated to wireless radio access or site interconnection services.

The occupancy status is shown below:









Synthetic table of the band occupancy rate for mobile phones

Frequency bands	700 MHz	800 MHz	900 MHz	1800 MHz	2100 MHz	2300 MHz	2600 MHz	3300 MHz	3500 MHz	5500 MHz	5800 MHz	3500 MHz
Occupancy rate	0%	100%	86%	60%	75%	65%	89%	30%	50%	60%	90%	65%

Frequency band occupancy rates for IMT at WRC-19

The bands 24.25-27 GHz, 37-43.5 GHz, 45.5-47 GHz, 47.2-48 GHz and 66-71 GHz were identified for IMT at the previous WRC-19.

All these bands are free except for band 37-43.5 GHz, which is partially occupied by an FH link.

Frequency bands	24.25-27.5 GHz	37-43.5 GHz	45.5-47 GHz	47.2-48 GHz	66-71 GHz
Occupancy rate	0%	2.8%	0%	0%	0%

United Kingdom Case Study:

The UK has conducted an independent Audit of spectrum holding by Prof. Martin Cave that covers over twenty key bands in the Audit's range of study (up to 15 GHz). In the process, the public sector spectrum management regime was examined, and an alternative framework set out. The audit has focused on four main thematic areas:

i. The extension of market mechanisms to the public sector;
ii. A more comprehensive approach to the application of Administered Incentive Pricing (AIP) as a tool for incentivising more effective spectrum management;
iii. Encouraging increased band-sharing as a beneficial activity for both incumbents and sharers; and
iv. Specific recommendations to individual departments, focusing on their spectrum management processes.

With regard to market mechanisms, the Audit concludes that the application of market mechanisms to spectrum management in the commercial sector is likely to have profound impact on the framework for managing spectrum in the public sector. New spectrum requirements will need to be met through the market in all but exceptional circumstances, as this is where the majority of spectrum available for use will lie in the future. Public bodies will also be able to benefit from the gains of trading where they chose to engage with the market.

Regarding to AIP, the Audit recommends that the application of AIP should be widened, to take account of areas which have previously not been subject to pricing. Pricing mechanisms are suggested for the valuable radar bands. It is also suggested that pricing should be applied to a previously unpriced NATO managed band used by the MoD. Changes to the overall AIP structure are also suggested. A review should be carried out of the pricing rates applied, with the view to addressing the current 'cliff edge' effect whereby those bands deemed 'fixed' and those classified as 'mobile' are charged vastly different rates which may be unrepresentative of potential alternative use. The Audit also suggests that Ofcom should ensure that the regular reviews of AIP rates are informed by both information about market values and by the effectiveness of AIP in practice.

Regarding band sharing, geographic, temporal or technological reuse of bands is an attractive way to maximise use of the spectrum, particularly where the primary use is not continuous or nationwide. A significant amount of bandsharing already takes place in public sector spectrum, and the Audit is keen that this is enhanced and increased. This report examines two ways of doing this. Firstly, building on existing sharing techniques and arrangements by incentivising the bodies managing the bands to admit more sharers, for example by reducing their AIP charges commensurate with the value of sharing permitted, or allowing the bodies to keep the income generated from sharing arrangements agreed through the market. The second approach is to examine new technology-based opportunities for enabling sharing, perhaps in bands previously viewed as no-go areas for sharing. The Audit's aim in this case is to address potential barriers to such technology emerging, by, for example, the spectrum regulator facilitating a testing programme.

Regarding band specific audit, the audit has looked at just over twenty bands managed by the Civil Aviation Authority and the Ministry of Defence. Examining current and potential future use, the Audit has taken a view, based on the information made available. Basing on the scope in each of these bands, the audit suggests that it would be essential to either release spectrum to alternative use or admit additional services into the band on a shared basis, and equally, traffic light marking should be given accordingly.

Selected fixed links bands have also been examined, and the Audit has concluded that there is no conclusive case for any immediate regulatory intervention, for example through clearance projects, to improve management in these bands. However, a number of bands examined pose significant spectrum management challenges. As the market develops it will become clearer whether the nature of licensing in Fixed Links bands is likely to inhibit trading and liberalisation in these areas and whether there is therefore a case for regulatory intervention to ensure efficient spectrum usage.

The Audit also recommends that Ofcom should run a one-off "Spend on Technology to Save on Spectrum" scheme. The Audit found that it is little known that Spectrum Efficiency Scheme funds, held by Ofcom, can be used to fund grants to promote efficient management and use of the spectrum, if the benefits outweigh the costs, so suggests actively seeking bids as a means of promoting this.

Regarding Spectrum Management Processes, the Ministry of Defence was engaged in a process to improve its internal spectrum management, and the Audit commented on how this process can be used to improve coordination on spectrum issues within the department, and how spectrum requirements are taken account of in the procurement process. Reporting of progress against the MoD's planned actions is suggested, as is the possibility of the application of targets at the next Spending Review to ensure that management of the MoD's valuable spectrum resource is given appropriate priority if the incentives regime suggested in this report does not lead to a change in spectrum management behaviour.

The Audit was of the view that there needs to be both more of a focus on spectrum policy for the Emergency and Public Safety Services, and that there needs to be included a role for a band manager in managing the spectrum associated with these services. To achieve this, it is recommended that the role of the Public Safety Spectrum Policy Group should be recast to address these areas.

The Audit team has engaged with a wide range of stakeholders over the course of the project. In some cases this engagement has been with those who are the subject of our review – for example the Ministry of Defence and the Civil Aviation Authority – and we are grateful for the considerable input they have provided. In other cases our contacts have been with those who may be interested in engaging with the public sector and their spectrum, for example, commercial spectrum users. In all cases the Audit team found discussions valuable and informative.

Below are some of the recommendation by the UK spectrum audit conducted in 2005.

Market Mechanisms

1. The Audit recommends that there should be a presumption that new public sector spectrum needs should be met through the market in all but exceptional cases.

2. The Audit recommends that, where there is an exceptional case where new spectrum needs cannot be met through the market, a process (set out in chapter 2) should be followed for assessing, through UKSSC, and against set criteria, the case for administrative assignment. Where this case is met Ofcom should be directed to make that spectrum available. Any costs involved should be met by the body or bodies responsible for generating the need.

3. Public sector spectrum should be considered for its trading potential and in principle be made tradable on a comparable basis to commercially held spectrum. Decisions will need to be made on a case-by-case basis depending on the suitability for trading of each RSA agreed.

4. Income generated from spectrum trading activities (including short term leasing and sharing arrangements) can be retained by departments, subject to capping arrangements. Departments should discuss this treatment with their Treasury spending team.

5. Ofcom should work with key public sector spectrum users to introduce RSA, beginning with priority bands where there is most necessity for usage to be recognised. Charges should be attached, based on AIP. The presumption should be that RSA should be tradable and convertible unless there is a good case otherwise.

6. UKSSC should produce a 'Forward Look' for public sector spectrum, every two years, including, for each of the public sector spectrum users who attend UKSSC: description of current spectrum use; changes to be made to allocations; changes to spectrum management; and quantitative predictions and justifications for future spectrum needs.

7. Ofcom should build on the analysis done in the demand study commissioned by the Audit team, and take forward future work as appropriate to gather background information on likely future spectrum demand and market developments.

8. Ofcom should seek to incorporate information about public sector spectrum usage and tradability in its public registers/databases.

There should be a review of the impact of the introduction of market mechanisms on public sector spectrum management in five years. Ideally, this should be independently led, but working with UKSSC. If the effect of the introduction of market mechanisms is not as envisaged by this Audit, the Government may wish to consider implementing a more interventionist approach, for example setting up an overarching spectrum management organisation for the public sector.

UK- 5G Base Stations

The UK has conducted recently an audit to the 5G base stations in operation. The target areas were likely to be high levels of mobile phone use, including in and around major transport hubs and shopping centres. The base stations that were measured, all support a range of mobile technologies in addition to 5G, including 2G, 3G and 4G

The measured EMF exposure level is done by using a field strength analyser (SRM-3006) connected to an isotropic (E-field) probe mounted on a tripod at a height of 1.5m above ground level. By using an isotropic probe, the measurement result is not affected by the direction of signal arrival and the polarisation of the measured field

The highest level measured EMF levels from 5G-enabled mobile phone base stations was just 0.039% of the reference levels. At all locations, the largest contribution to the measured levels in all mobile bands comes from previous generations of mobile technology (2G, 3G, 4G) with the highest level recorded being approximately 1.5% of the reference levels.

Australia Case Study

The Australian National Audit Office (ANAO) conducted an audit of the Spectrum Reallocation to Support the Deployment of 5G Services in 2020.

The issue could be traced back to December 2017 when the ACMA made a recommendation to the Minister for Communications and the Arts (minister) for the reallocation of spectrum in the 3.6 GHz band through an auction process. The 3.6 GHz auction process was designed for the sale of 125 MHz of spectrum in 14 sectors covering metropolitan and regional areas of Australia. A total of 350 lots were available for sale at the auction. The auction commenced on 20th November 2018 and concluded on 6 December 2018. The auction outcomes were publicly announced by the ACMA on 10 December 2018.

The objective of the audit was to examine the effectiveness of spectrum reallocation to support the deployment of 5G services. The audit examined the following high-level criteria:

- Whether the department and the ACMA effectively prepared for the reallocation of spectrum in the 3.6 GHz band; and
- Whether the ACMA effectively administered the reallocation of spectrum in the 3.6 GHz band.
- In order to examine this criterion, the audit reviewed:
- Auction conduct — This included the management of bidder application and eligibility requirements, the establishment of systems to facilitate the auction and the undertaking of activities to manage emerging risks, which were viewed as important elements in effectively supporting the execution of the auction process;
- Auction outcomes — This recognised the idea that the alignment of auction outcomes and relevant legislative and policy objectives is important in evaluating the effectiveness of the auction process; and
- Lessons learnt — This was set in motion considering that auctions will continue to be a key method for the reallocation and allocation of spectrum, and relevant learnings can provide valuable input into the future processes.

The Audit concludes that the reallocation of spectrum in the 3.6 GHz band to support the deployment of 5G services was largely effective: preparation processes largely followed requirements, but the assessment of options for the use of the band did not integrate coverage of all relevant policy requirements; and auction processes were executed in line with preparations, but the arrangements were inflexible in responding to changes in market conditions.

More specifically, the department and the ACMA were largely effective in preparing for the reallocation of spectrum in the 3.6 GHz band. The design of the process was informed by international practice and previous auction experience. Reallocation preparation processes were largely consistent with legal obligations, policy and guidance and were sufficiently transparent.

While options for the future use of the 3.6 GHz spectrum were identified based on public consultation, the methodology used to assess each option did not integrate coverage of all relevant legislative objects and government policy. The incorporation of existing spectrum holdings in an adjacent band into auction allocation limits was completed late and did not demonstrate sufficient consideration of differences in spectrum utility between the two bands.

Moreover, activities to administer the reallocation of spectrum in the 3.6 GHz band were largely effective. Auction guidance, application and eligibility requirements were developed and implemented. The outcome of the auction process was largely consistent with objectives outlined in the relevant legislation, policy and guidance material. Unexpected market changes impacted on the competitive environment for the auction and had material consequences in relation to the level of revenue achieved. Both entities are implementing relevant learnings into preparation processes for future reallocations.

The auction of the 3.6 GHz band was the first spectrum reallocation targeted at the deployment of 5G services, and the department and the ACMA are preparing for future 5G spectrum releases. Therefore, an audit was needed to assess the process of assigning spectrum for 5G and to draw lessons for future assignments.

Two recommendations were stated namely:

1. The department and the ACMA agree an approach for cooperation and coordination in undertaking respective responsibilities in the process for future spectrum reallocations; and ensure that appropriate probity management principles are applied in a timely and consistent manner to future reallocation activities.

2. For future reallocation processes, the ACMA implement a methodology for the highest value use assessment that provides for appropriate coverage of efficiency and public benefit objectives, and integrates cost-benefit analyses with all policy objectives and guidance.

PART D: PRACTICES AND ASSOCIATED IMPLICATIONS

Spectrum audit best practices can be divided into three phases as shown below:

1. Pre-audit preparation best practices,
2. Audit best practices, and
3. Post-audit best practices.

As best practices, we may note the following before the audit:

1. Establish a national frequency allocation table which is in line with the international frequency allocation table (Art 5, RR)
2. Make frequency assignment in conformity with the national frequency allocation table
3. Develop a frequency assignment database recording all users and the technical conditions of use of the frequencies
4. Establish a program of spectrum audit

National spectrum audits should have the following features:

- Conducted at regular intervals e.g. every four to five years in the middle of a WRC cycle
- There should be wide public consultation
- The national spectrum audit report and ascociated databases should be made publicly available e.g. on the NRA website

With respect to the technology review, the audit should focus on considering technology and associated spectrum to address persistent and developing needs and on best socio-economic use of each spectrum band.

With regard to spectrum licensing and enforcement, there should be a desktop audit to compare NRA[1] records with those of licensees, and to review the type and scale of radio frequency interference complaints to estimate the extent of unauthorised usage. There should also be field measurement/monitoring to compare actual usage with license records and to identify possible unauthorised usage.With regard to spectrum planning, the audit should consider a roadmap of spectrum release timeframes and proposed spectrum use changes.

Based on the findings, the regulator takes appropriate steps in line with license conditions including imposition of penalties for non-compliance. This way, unauthorised operations could easily be identified and dealt with as soon as possible;

1 National Regulatory Authority

Output of spectrum audit should ensure the following:

- That radio spectrum is used in the best interest of Africa as well as for African economic development
- That an updated National/African frequency spectrum database is maintained

Capacity Building should be part of the spectrum audit to support provision and acquisition of new skills given that it is one of the key areas that deserves every member state's attention if governments must keep up with the rapidly changing technology. Otherwise many member states might have to rely on foreign expertise in future monitoring and compliance issues.

Spectrum Inspection:

Inspection has many approaches that can be taken by administrations to achieve its goals. Inspection of radio facilities could be divided into five groups:

v. **"All stations" inspections:** This is the inclusive inspection procedure for verifying the license compliance. This type of inspection may need more than one year to be completed based on the manpower and the measurement devices available. Due to the large number of licensed stations we may limit the inspection to the following ways: inspecting only "newly licensed" stations or inspecting stations at least once during their licence term (which could be more than one year)

vi. **Triggered inspections:** These type of inspections are based on special event. These events could be interference complain event, major events or unknown transmissions discovered by field survey.

vii. **Sampling:** This type of Inspection depends on creating samples of the radio stations. These samples could be changed every year to achieve all stations inspection after few years. These samples could be also depending on the level of compliance of the radio stations, therefore the high compliance radio stations may be excluded from these samples. selection by sampling is based on statistical measures. In its simplest form, by inspecting a small sample of all stations, the overall compliance can be inferred by the compliance rate in the sample.

viii. **"Limited" inspections:** These may check only a limited number of radio stations which are in the interest area of the regulatory authority. Also, some administrations may limit their inspection to those radio stations which operate in specific bands. This type of inspection could be made without visiting the radio station itself but rather, it is done through the monitoring activities, like field survey, by measuring the essential parameters like frequency, bandwidth, frequency deviation and e.i.r.p.

ix. **"Risk-based" inspections:** This type of inspection is mainly concentrating on the radio stations that have a potential risk to create an interference to other radio stations. The stations under inspections may be radio stations adjacent to safety services (which should be protected all the time).

The inspection process is affected by several factors which could lead to failure of the process. Some of these factors include, the availability and readiness of:

- The inspection equipment;
- Inspection forms and inspection guidance documents;
- Travel requirements;
- Pre-inspection records check (e.g. licence record, location, compliance record);

A brief example of an inspection programme structure, plan and decision priority, as mentioned in ITU-R report SM.2130, is shown below, to illustrate a way that many of the factors above may be applied:

Administrative guidelines for inspections planning

- Inspect at least 15% of the radio base stations of the mobile personal services (SMP), trucking and paging.
- Inspect at least 15% of the transceivers used by the public switched telephone networks (PSTN) and SMP.
- Inspect at least 15% of the fixed and mobile stations of the radio taxi services.
- Inspect 100% of the scientific research services.
- Inspect at least 15% of the satellite earth stations.
- Inspect 100% of the authorized stations used for fixed and mobile services whose licences are expired or will expire in the current year.
- Inspect at least 20% of the technical parameters of fixed and mobile stations.
- Accomplish, in a maximum of 30 days before licensing, the inspection of new or modified stations.
- Inspect, or check for continuing operation, at least 15% of all stations whose licences have expired/been removed from the national database system
- Terminate operations of, in a maximum of 45 days, providers operating without licences.
- Inspect, quarterly, at least 4 companies that manufacture, distribute or trade telecommunication products subjected to compulsory certification.

In the above example, we can see that the sample sizes are different for different categories of stations. This may be due to several factors, including the number of stations authorized in the service, past compliance history, or administration goals or policies in the specific radio service class.

The following is the list of the most commonly equipment used during a radio station inspection:

- Frequency meter
- Power meter/directional couplers
- Spectrum analyser/measurement receiver
- Antennas / Antenna supports/tripods.
- Cables, connectors, accessories.

The following is the list of the most commonly technical parameters that need to be checked during inspections.

- Frequency
- output power
- Geographical coordinates
- Harmonics, intermodulation products and spurious emissions
- Electric, magnetic and electromagnetic field strength
- Bandwidth
- Height, and azimuth of the antenna

Spectrum Monitoring:

The goals of spectrum monitoring are:

- Resolve the interference issues;
- Guaranty of an acceptable quality of radio and television reception by the general public;
- Provide the actual use of frequencies and bands, verify the technical characteristics of transmitted signals, guaranty of license compliance, detection and identification of illegal transmitters and potential interferers.

Fixed, remote, unmanned and mobile monitoring stations can be combined to provide a network of integrated tools for spectrum audit; Those can also provide greater flexibility in the design of national and regional monitoring systems.

As the monitoring equipment is very complex and expensive, trade-offs should be considered and administrators have to decide what spectrum segments are most important to audit, in order to make efficient use of existing equipment and capabilities. Spectrum audit cooperation between countries is recommended on bilateral agreements to avoid potential spill over or mutual interference.

Pubic Spectrum Audit

- The new public sector spectrum needs should be met through the market in all but exceptional cases.
- Public sector spectrum should be considered for its trading potential and in principle be made tradable on a comparable basis to commercially held spectrum.
- Income generated from spectrum trading activities (including short term leasing and sharing arrangements) can be retained by the public sector, subject to capping arrangements.
- Regulators should incorporate information about public sector spectrum usage and tradability in its public registers/databases.
- Assignment Process

Following any assignment process by auction, the following steps should be audited.

- Auction conduct — the management of bidder application and eligibility requirements, the establishment of systems to facilitate the auction and the undertaking of activities to manage emerging risks were important elements in effectively supporting the execution of the auction process;
- Auction outcomes — the alignment of auction outcomes and relevant legislative and policy objectives is important in evaluating the effectiveness of the auction process; and
- Lessons learnt —relevant learnings can provide valuable input into the future processes.

Base Stations Audit

An audit should be conducted to base stations in operation for the measured EMF exposure levels to check if the stations are aligned with the license conditions in terms of OOBE and EMF levels.

PART E: RECOMMENDATIONS

ATU recommends Member States to:

1. **Ensure** effective utilization of the spectrum and the level of compliance of the licencsees. Member States should conduct spectrum audit on a regular basis, at least once in each WRC cycle. Member states should also ensure accurate and regularly updated database. This would support a comparative analysis between the collected field data during the audit exercise and information already in the database.
2. **Publish** databases of spectrum licensing, usage, and technical information on a publicly accessible website, as appropriate.
3. **Identify** opportunities to leverage innovations in spectrum management (e.g., self-coordinated light-licensing databases) to enable more efficient and cost-effective spectrum audits.
4. **Audit** in accordance with ITU RR to ensure that the licensing of radio frequency spectrum, results in effective and efficient utilization of spectrum, in support of national interests and protecting existing services.
5. **Undertake** independent audit following spectrum assignment and re-farming to ensure that the processes are in line with country's general policy, and to asses effectiveness of these process and lessons for future assignments.
6. **Assess** the EMF exposure measurements of radio systems should be undertaken to monitor the overall trends in the long term. Therefore, an audit should be conducted to all radio systems in operation for the measured EMF exposure levels to check if the stations are aligned with the license conditions in terms of OOBE and EMF levels.
7. **Establish and use** spectrum monitoring tools, which aims to identify the use of the spectrum and to ensure the use of the spectrum is restricted to the licensed frequencies. To achieve this goal, spectrum monitoring should be conducted periodically to provide the actual use of frequencies and bands, verify the technical characteristics of transmitted signals, guaranty of license compliance, detection and identification of illegal transmitters and potential interferers.
8. **Inform** a national regulator of the opportunities to make more spectrum available in the different frequency bands, all of which will be important to a variety of use cases.
9. **Ensure** there is a balance of license-exempt, lightly licensed, and licensed spectrum available.
10. **Provide** the national regulator with greater insights into spectrum use in all geographical areas.

11. **Undertake** periodic audit of the public sector spectrum, other than being used for sensitive uses. Regulators should incorporate information about public sector spectrum usage and tradability in its public registers/databases.
12. **Ensure** adequate training and skills development of personnel to perform spectrum monitoring and audit in the view of the new radio environment
13. **Invest** adequately in robust spectrum licensing and occupancy database systems.
14. **Support** the development and maintainnce of a spectrum occupancy database which could reflect the occupancy of frequency in every member state. This would help develop statistics and also assist in regional preparations for the World Radiocommunication Conference.

PART F: ABOUT THIS RECOMMENDATION

Development: This recommendation was developed by an ATU Task Group on Spectrum Recommendations from July 2020 to February 2021. This group was led by the following:

Name (Country)	Role
Dr Mohamed EL-MOGHAZI (Egypt representing North)	Chair – Task Group
Wilson BOKATOLA (Congo representing ECCAS)	Rapporteur – Recommendation 001- 0
Alfred Joseph BOGERE (Uganda representing EACO)	Rapporteur - Recommendation 002- 0
Gabriel KOFFI (Cote d'Ivoire representing ECOW-AS)	Rapporteur - Recommendation 003- 0
Dick SONO (South Africa representing SADC)	Rapporteur - Recommendation 004- 0

Validation: This recommendation was validated in a validation forum that was held from 4th to 5th March 2021. The forum was led by the following bureau:

Chair: Valéry Hilaire OTTOU (Cameroun representing ECCAS)

Vice-Chair: Ahmed BORAUD (Niger representing ECOWAS)

Rapporteurs: Stella BANYENZA (Tanzania representing EACO/SADC)

Mohamed ABDELHASEEB (EGYPT representing North)

Official Launch: This recommendation was officially launched on 22 April 2021 by the Minister of Posts and Telecommunications of Cameroun, **Mrs LIBOM LI LIKENG née MENDOMO AWOUMVELE Minette**

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