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A Review: The Past, Present and Future of Radio Frequency Spectrum in Nigeria, Canada, United Kingdom, Ghana

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Abstract - *Since the time of inception of cellular analogue telephony in 1985, there has been an unending improvement taking shape from the first generation to the second generation and now the fifth generation. The cellular mobile concept has been a major transformer of the human existence from the time of Stone Age to the Bronze Age. But this cellular mobile concept needed a system that would enable its technology to be readily accessible, the radio frequency spectrum. With the advancement in the wireless communication, the need for proper sharing of the RF spectrum became an issue since it is limited. The possibility of being able to share this spectrum to house all the forms of wireless communication ranging from mobile telephony, radio and TV broadcasting, broadband links etc. become a top issue in the research work. With this paper, we tend to study the past, the present and the future work done towards achieving a better radio frequency spectrum usage and make some recommendations for future growth.*

Key Words*: *Spectrum, Radio frequency, Mobile telephony, TV broadcasting

1.I NTRODUCTION

The radio frequency spectrum is an article of trade owned by the national regulatory bodies established by different countries which must cooperate with one another through the international organizations to ensure the national spectrum regulations provide the means for interoperability and that there is no harmful interference between countries. The international telecommunication union (ITU) is in charge of the spectrum management with each of the world countries having their own organization collaborating with ITU. In the year 2004, the International Telecommunication Union (ITU) propelled a regional project with collaboration with the European Union, to support the founding of an integrated ICT market in the Western part of Africa. This project launched following several requests by the West Africa countries government for assistance on the regulatory reform which was aimed to speed up the development of the telecommunication sector in the region. This project had five important components namely: the interconnection, licensing, numbering plan and frequency spectrum management, universal access and model policy and legislation.

2. Radio Frequency Spectrum

In this paper, we refer to the radio frequency spectrum as that portion of the electromagnetic spectrum that is used to perform telecommunication operations such as the radio broadcasting, television broadcasting, mobile telephony, radars, satellites, and so on [1].

Generally, the radio frequency spectrum has been set by convention to run from 8.3 kHz to 3 000 GHz and it is divided into several frequency bands which are then allocated to several telecommunication services [2]. The table below shows the uses and the properties of the frequency bands in the radio-frequency spectrum [3].

TABLE 1: Uses and the Properties of the Frequency Bands in the Radio-Frequency Spectrum [3]

Band	Frequency range	Range	Common use	Bandwidth	Interference
VLF (myriametric waves)	3-30 kHz	1 000 km	Long-range radionavigation	Very narrow	Widespread
LF (kilometric waves)	30-300 kHz	1 000 km	Long-range radionavigation	Very narrow	Widespread
MF (hectometric waves)	300-3 000 kHz	2-3 000 km	Long-range radionavigation	Moderate	Widespread
HF (decametric waves)	3-30 MHz	Up to 1 000 km	Fixed point-to-point, Global broadcasting	Wide	Widespread
VHF (metric waves)	30-300 MHz	2-300 km	Broadcasting, Mobile, WAN	Very wide	Confined
UHF (decimetric waves)	300-3 000 MHz	< 100 km	Broadcasting, Mobile, Satellite	Very wide	Confined
SHF (centimetric waves)	3-30 GHz	30-2 000 km	Fixed, Broadcasting, Mobile, WAN, Satellite communications	Very wide up to 1 GHz	Confined
EHF (millimetric waves)	30-300 GHz	20-2 000 km	Broadcasting, Fixed point-to-point, Mobile, Satellite communications	Very wide up to 10 GHz	Confined

Source: ITU 2011 ICT Regulation Toolkit. Radio Spectrum Management. Module 5, p. 12 (www.ictregulationtoolkit.org/en/home).

Also, viewing the RF spectrum in economic terms, it is a resource needed for the continuous production of communication which is scare and which cannot also be stored and readily traded off [4]. By technologically, this

scare resource, spectrum can be well utilized by dividing it into frequency bands as shown in the Table 1 and its scope of action controlled by regulating transmitter power and antenna radiation patterns clinically [1]. That is, before assigning this spectrum to users, the frequency spectrum managers must set the frequency band, geographic coverage and maximum authorized radiated power [1].

3. Radio-Frequency Spectrum Management Objectives

According to ITU-D10 [5], modern spectrum management is aimed towards utilizing n=and optimizing the available RF spectrum which is now been sought after by both public and private authorities for several reasons. This optimization technique involves maximizing the attainment of three objectives: economic efficiency, technical efficiency and social benefit [1][5].

The principle of economic efficiency stipulates that a frequency band must be only allocated to telecommunication services that produce greater economic value that must be more digital dividend if it must be allocated to one telecommunication services before the other [1][5].

The second objective is technical efficiency which holds that following the scarcity of the spectrum, it must only be allocated provided there would be maximum utilization. This objective is to ensure that interference is managed, which would cause degradation in the quality of communication when the residual transmission intercepts neighboring frequencies [1][5].

The third objective that is clinically pursued is maximizing social benefit which is recognizing that telecommunications are a service for the public good and the effective spectrum management enables service providers to access the spectrum in an environment of healthy competition [1][5].

4. Nigeria as a Case Study:

4.1 The Past of Radio Frequency Spectrum in Nigeria

Radio frequency spectrum due to its direct application in telecommunication, broadcasting, military operations, scientific researches and a host of other socioeconomic activities was, is and will continue to be one of Nigeria's key natural resources of great economic value. As a result, many industries in Nigeria have been, are and will continue to be dependent on the efficient utilization of radio frequency spectrum.

The Government agency in charge of the management of the radio frequency spectrum is the Nigeria communication commission (NCC) which was created under decree number 75 by the federal military government of Nigeria on the 24th of November 1992. The decree has since then been revoked and replaced with the Nigerian communication acts (NCA) which came about in 2003. (Nigerian Communications Commission, 2018).

The agency was created to be a subsidiary of the Federal ministry of communication in Nigeria and is a member of the international government organization ITU (International Telecommunication Union). Nigeria became a member state of ITU on the 11th of April 1961 and has since then participated in ITU programs around the globe. (List of Member States, 2018).

As of 2003, after the replacement of the degree number 75 by the federal military government of Nigeria, the NCC was empowered to make and publish regulations on matters such as permits, assignments and written authorizations, develop comprehensive frequency management policies, conduct studies and produce reports on the telecommunication industry set up a uniform numbering scheme to be used by operators to set up calls, etc. and this has helped in the substantial growth of communication in Nigeria over the years. (regulations, 2018).

4.2 The Future of Radio Frequency Spectrum in Nigeria

Rapid evolution in technology of wireless communication in the past few years has adversely affected the demand on wireless services which brought a wave of spectrum scarcity. Although diverse communication and broadcasting licenses has been granted since 1992, Nigeria is without a doubt the leader in spectrum deregulation and licensing. This drastic increase in broadcasting stations in Nigeria has been fueled by the Nigerian government which has made the local environment a fertile ground for both local and foreign investors hence resulting in the domino effect of increased job opportunities, improved business opportunities in the foreign market, more effective and easily accessible means of communications and much more benefits. Nigeria posing to be a fertile ground has attracted more offers from companies offering their services which will definitely increase pressure and scarcity of frequency spectrum in Nigeria. This congestion and scarcity has affected the quality of communication and broadcasting throughout Nigeria. Although there is a communication explosion in Nigeria, the masses (those in the rural and remote areas) benefit little due to limited accessibility and high costs. Although radio frequency spectrum is an important asset in the digital age and Nigeria has a great future in it, management and utilization have to be reevaluated in order to solve the problem of scarcity and hence maximize the useable radio spectrum bands.

5. Ghana as a Case Study:

5.1 The Past & Present of Radio Frequency Spectrum in Ghana

NCA which is National Communications Authority is in charge of spectrum allocation and it grows about 46% of its

funding from spectrum fees. They are also in charge of supervising broadcasting spectrum. They have lasting management strategy and planning to regulate and occasionally update the current and forthcoming requirements for the numerous radio communications services. Their job is to also allocate, allot and control the use of frequencies for operations in land mobile, terrestrial, marine and other associated amenities in conformism with international requirements, code of behavior or agreement in which Ghana is a party to. It is in charge of protecting the country's radio's communication system from probable interference from another country's assignment. NCA is also responsible for imposing fines and punishments for any defilement of spectrum instructions in order to uphold discipline. Radio monitoring is also a key responsibility. The authority is in charge of carrying out assessments of installations to guarantee that stations and companies conform with the appropriate provisions of NCA Act 524, NCA regulations, Ghana telecommunication policy which are indicated in terms of license. Note that, the spectrum costs are imposed but the structure is unknown. The priority is also unknown, almost like spectrum scarcity is an issue.

5.2 The Future of Radio Frequency Spectrum in Ghana

Choices such as frequency for urban areas, rural areas should be considered choices involving the determination of coverage radius of public, broadcasting services for both commercial and community.

In this light future spectrum planning is a policy decision that will affect services available to viewer and listener in the art of digital broadcast engineering. The plan is for **NMC** (National Media Commission), **NCA** (National Communication Authority) to work hand in hand on this exercise making frequency spectrum re-use, international and technical recommendation do not interfere with non-broadcast spectrum users.

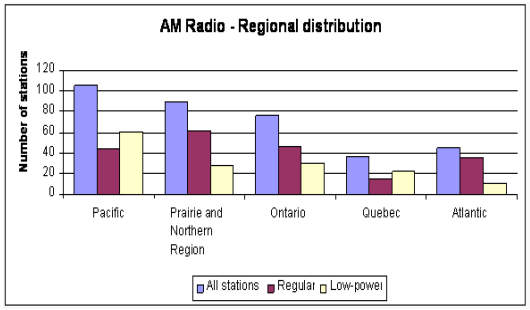
A plan for the use of radio frequency spectrum assigned for broadcasting in Ghana national frequency plan which would include future digital broadcasting, joint planning between NMC and NCA is essential. This would increase understanding, review of implementation of spectrum planning, consultation on broadcast radio spectrum planning.

6. Canada as a Case Study

6.1 The Past of Radio Frequency Spectrum in Canada

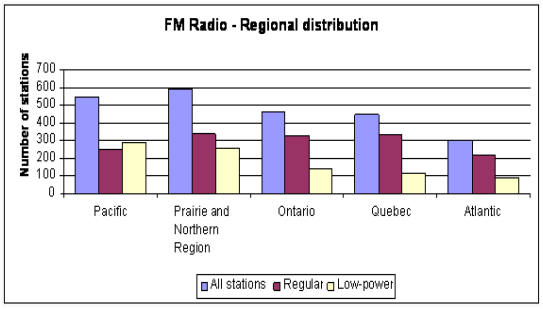
One of the ancient methods of broadcasting is the AM radio. After AM, FM radio was created many decades later. FM has a better signal reception quality, this made it more famous than AM. FM radio functions in Very High Frequency (VHF) band which lies between 88 to 108 MHz with 200 kHz channels. Newer services such as Multipoint Distribution service (MDS) and digital radio broadcasting (DRB) were introduced in Canada in the late 1990s. MDS functions using big blocks of 6 MHz channels for provision of data and video communication to users. DRB functions in a system of co-channel transmitters which delivers a multiplex service to a digital service area.

In June 2010, 353 AM stations were fully in operation in Canada. Part of the Subscribers were CBC/Radio-Canada (143 stations), Astral Media (22 stations) New cap (26 stations)



FM radio (88-108Mhz) Source: [20]

In June 2010, 2,349 FM stations were in operation in Canada.



Source: [20]

6.2 The Present of Radio Frequency Spectrum in Canada

Frequency spectrums are used by organizations like television stations to send information over the air, also to broadcast signals to our homes. It is also used by radio stations to send audio streams to cars, and the telecommunication sector use spectrum to connect us to one another. Although these uses of spectrum are very important and they have great impact in our daily life, if frequency spectrum is limited. In this section, the focus will be on how radio spectrum has succeeded to impact Canada's past, present and also future [6]. On the 29th of July1939, the Canadian AM station, CBK in Waterous, Saskatchewan became operational operating at a medium frequency between 525 and 1705 KHZ with a 10KHZ channel [7]. The FM radio was later introduced decades later. FM became more popular when compared to AM due to qualities like better signal reception especially in urban areas. The FM radio operates at VHF (Very High Frequency) band of about 88-108 MHZ with 200 KHZ channels. Television stations transmit signals over the air at VHF and UHF bands [7].

Currently the primary aim of the Canadian Spectrum Policy Research is the sub- 300 GHz radio frequencies which is used for public mobile communications [8].

For the future of frequency spectrum in Canada and other parts of the world, taking into account the Federal Communication Commission (FCC) release of about 11GHZ of high frequency spectrum in the support of 5G. 5G will be the future of telecommunications. Also, the recent testing of the 3.5 GHZ mid-band spectrum which has been approved for a shared spectrum model. The shared spectrum model which as unlicensed spectrum as its core is been tested in order to provide a solution to issues like limited, unusable, or unavailable spectrum [10].

6.3 The Future of Radio Frequency Spectrum in Canada

The range interest for Television in Canada is moderately flat. In any case, inside the DTV Allotment design, few extra channels are accessible for development. It is noticed that blockage of FM Radio range exists in vast markets, for example, the Greater Toronto Area. There will be proceeded with weight as AM stations try to change over to FM broadcasting. The utilization of IBOC computerized broadcasting inside existing FM channel assignment may offer a path forward to grow the utilization of the FM band. In any case, it is conceived that the FM radio range will remain the absolute most congested band of any of those appointed to the High-Value Services, over the time of the Study, and there is restricted justification for anticipating that this should change in the subsequent years.

7. Uk as a Case Study

7.1 The Past of Radio Frequency Spectrum in U.K

The UK's flourishing space segment contributed £4.1billion in Gross Value Added in 2011, on a standard with the commitment from the UK film and broadcast business. In 2011 there were 234 organizations in the UK space industry, running in estimate from sole brokers to extensive multinational organizations, and utilizing 28,9009. The normal development rate from 2006-2012 and through the retreat has been a strong 7.5% for each year. At the present rate of development, we anticipate that the space business will have multiplied in measure inside the following 10 years. While broadcasting and telecommunications right now command the space economy, the essential open great territories of science, particularly Earth Observation, ought not by under-evaluated. Expanded interest for spectrum is normal over all space parts, from telecommunications to remote detecting

7.2 The Present of Radio Frequency Spectrum in Uk

The range interest for Television in Canada is moderately flat. In any case, inside the DTV Allotment design, few extra channels are accessible for development. Additionally, inside the ATSC computerized channel of 19.3 Mbps, there are open doors for supporters to offer a blend of HDTV, SDTV and versatile TV programming inside a doled out 6 MHz OTA TV broadcasting channel. The interest for range will stay at 270 MHz and development will happen inside the designated 6 MHz channels. It is noticed that blockage of FM Radio range exists in vast markets, for example, the Greater Toronto Area. There will be proceeded with weight as AM stations try to change over to FM broadcasting. The utilization of IBOC computerized broadcasting inside existing FM channel assignment may offer a path forward to grow the utilization of the FM band. In any case, it is conceived that the FM radio range will remain the absolute most congested band of any of those appointed to the High-Value Services, over the time of the Study, and there is restricted justification for anticipating that this should change in the subsequent years. The quantity of SDTV is assessed to develop from 951 to 1532 projects from 2010 to 2015. Likewise, the quantity of HDTV develops from 162 to 494 projects. In 2010, around 800 MHz (orbital-MHz units) is required for what might as well be called under two DTH satellites. [11]

8. Using U.S.A as a Case Study

8.1 The Past of Radio Frequency Spectrum in U.S.A

The radio spectrum is a segment of the radio frequency electromagnetic spectrum. In the USA, the radio spectrum's administrative obligation is part between the Federal Communications Commission (FCC) and the National Telecommunications and Information Administration (NTIA). The FCC which is a free administrative body, controls spectrum for non-Federal utilize, the NTIA, a working unit of the Department of Commerce, is responsible for administration of spectrum for Federal utilize. In any case, inside the FCC, a division called the OET (Office of Engineering and Technology) gives guidance on specialized and strategy issues relating to spectrum designation and utilization [11]. Edwin Armstrong is known to be the author/engineer of the USA's FM, toward the apocalypse War II, the FCC moved to institutionalize frequency portion, in this way apportioning around one hundred FM stations from 88– 108 MHz, and allocated the previous FM band to 'non-government settled and versatile' (42– 44 MHz), and TV station (44– 50 MHz), evading the subject of the impacts of tropospheric and Sporadic E spread on those administrations. A while later, a time of allowing existing FM stations to communicate on low and high groups took after, as late as 1947, in Detroit, there were just 3,000 FM according to collectors being used for the new band, and 21,000 for the old band [12]. At midnight, January 8, 1949, the double band change period finished at which time any low band transmitters must be closed down, formally making out of date 395,000[13]. Following this, beneficiaries that had just been bought by general society for the first band. In spite of the fact that converters permitting low band FM sets to get high band were fabricated, they at last ended up being entangled to introduce, and regularly as (or increasingly) costly than purchasing another high band set

by and large [14]. The more prominent cost was to the radio stations themselves that needed to remake their stations for the new FM radio band. FM radio as an industry did not recuperate essentially from the difficulty until the upsurge in high devotion hardware in the late 1950s [15].
Toward the finish of the 1970s 50.1% of radio audience members were tuned to FM, finishing AM's authentic predominance. By 1982, FM told 70% of the worldwide gathering of people and 84% among the 12-to 24-year-old statistic [16]. The move in ubiquity of FM radio over AM in United States amid the 1970s has been called by record maker Steve Greenberg "a seismic mechanical move that had torn separated the general thought of the mass gathering of people whereupon pop hits depended" (AM radio would recuperate by moving its concentration to talk radio, which would be deregulated in the late 1980s after the annulment of the Fairness Doctrine) [17].

8.2. Present Radio Frequency Spectrum in USA

In the United States of America, the NTIA (National Telecommunications and Information Administration) manages the spectrum for the legislature. The Communications' Act, which was set up in 1934 however allows full rights for spectrum use to the Office of the President (47 USC 305). The FCC (Federal Communications' Commission) administers and controls residential (non-state) use as indicated by the manages of the 47 USC 301 [18]. The tenets that represent the utilization of the spectrum in the United States of America can be found at http://wireless.fcc.gov/index.htm?job=rules_and_regulations. At present, just frequency groups that lie in the vicinity of 9khz and 275khz have been assigned for earthbound and satellite administrations [19].

9. Conclusion:

We have fully analyzed the past, present and future of radio frequency spectrum in Nigeria, Canada, UK, Ghana. This analysis has provided an overview of the subject area using the selected countries as a case study, it was observed that there is a rapid growth in this aspect of communication and the future is brighter than present in all the countries selected.

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