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Amateur Radio as a Vehicle for Technology Literacy

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Abstract: Africa faces a shortage of technologically-proficient people who can develop and maintain our ICT infrastructure and drive innovation to facilitate manufacturing and services. Amateur Radio offers a vehicle for technology training that has reaped great rewards for many countries. The barriers to entry are continuously dropping, The article explains the potential of Amateur Radio for technology development, looks at the current state of Amateur Radio in Africa and suggests avenues that might be explored to allow wider access on the continent.

Keywords: amateur radio, technology training, education.

1. Introduction

Technology literacy requires the development of conceptual skills. The process of acquiring these skills is not always easy. A motivating factor is necessary to entice learners into expending the necessary energy to fully master the concepts and vocabulary of their chosen field.

Several initiatives exist to help students acquire a solid basis of electronic knowledge and practical skills. Examples include the FIRST Lego League (FLL) [1] and RoboCup [2], both competitive frameworks within which learners acquire the skills to build and program rudimentary robots. FLL is primarily aimed at primary school level, while RoboCup is mostly aimed at post-graduate students.

Amateur Radio is another arena in which students are encouraged to learn and experiment, expanding their technical skills and simultaneously learning geography and acquiring contacts in the world of technology outside Africa.

The paper presents the current state of African amateur radio, along with some precedents of the impact amateur radio could have.

Several specific activities within amateur radio are described.

Finally, it presents action plans for African telecommunications regulators to establish amateur radio within their countries, including specific sources of help in setting up the necessary regulatory framework.

2. Tangible Benefits of Technology Literacy

The US Department of Commerce publishes a Fact Sheet [3] which outlines the growing requirement for digital literacy in American society. The growth in employment in the IT sector was quoted as being four times the national growth rate (26% in the period 1998 to 2008), with another 22% of growth expected in the following two decades. Given that the almost complete penetration of digital connectivity in that country, it seems reasonable to assume that Africa's growth rate will be more sustained in the immediate future. An

estimate from 2009 is quoted as stating that three million Americans work in Internet-related jobs supported by advertising, with around 40% of these jobs not having existed two decades ago. The same department has a Web portal [4] exclusively dedicated to digital literacy training. It includes numerous resources to aid digital literacy.

In a 2014 report [5], consulting giant Deloitte enumerates the advantages of Internet access on economic development. Chapter 3 discusses benefits such as productivity gains, enterprise establishment, innovation, employment, economic growth and poverty alleviation.

UNESCO's Global Education Monitoring Report for 2016 [6] points out that digital literacy and literacy in a broader context are key determinants of employability. Two of the six "Key Messages" in the report revolve around technology literacy. Chapter 13 describes the impact of ICT (Information and Communications Technology) literacy and ways to measure such literacy levels.

The National Academy Press [7] quotes many direct and indirect advantages of technology literacy. Examples (Chapter 4) show clearly how technology literacy positively influences decision making of normal citizens even on apparently unrelated topics such as the pros and cons of vehicle airbags and the use of genetically-engineered organisms.

3. History of Innovation

Amateur radio has contributed greatly to the development of communications.

After the early work by Marconi and others established commercial radio operations on a sound footing, radio amateurs were given the "useless" frequencies above 1,5 MHz. Amateurs continued to experiment. In 1921, several US stations were heard in Europe, suggesting that shortwave communication may be possible. In 1924, the first daylight shortwave contact spanned the Atlantic. Based on this precedent, Marconi conducted further experiments and started regular commercial use of the short waves [8].

In 1956, two radio amateurs, Art Collins and General Curtis Lemay, demonstrated that reliable communications could be maintained with a heavy bomber on long-distance flights. The demonstration resulted in the large-scale adoption of the then-new Single Sideband technology, replacing the previous obsolete AM systems, and in the adoption of short-wave radio for world-wide communications [9].

In 1961, radio amateurs constructed the first amateur satellite, Oscar 1. This satellite acted as ballast on a military launch, incurring no launch costs. It was launched only four years after the first-ever Sputnik satellite, and was the world's first non-governmental satellite and the first piggyback launch. Over 100 amateur satellites have subsequently been launched, including several with innovative highly-eccentric orbits offering world-wide coverage [10]. An exciting prospect is the launch of the first geostationary amateur transponder in 2017, which will offer round-the-clock communications to amateurs throughout Africa, Europe and west Asia with simple dish antennas [11].

During the 1980s, radio amateurs, including notably Phil Karn of Qualcomm, pioneered the widespread use of packet radio, using a modified protocol known as AX.25 [12]. This protocol uses a loose formation of nodes to establish data communications over long distances, an architecture that mimics the Internet and became one of the first large-scale packet-switched network implementation.

Today, radio amateurs continue to explore new technologies, notably digital speech in congested channels [13] and weak-signal modulation techniques for links with poor signal-to-noise ratios [14].

In the USSR, amateur radio was a government-sponsored activity, specifically intended to create a large pool of technologically-astute individuals who could support the nation's technology aspirations. DOSAAF [15] (the paramilitary sports association in the Union)

provided training and equipment on a regional level, recognising the potential of amateur radio to prepare youngsters for the world of technology.

4. Activities within Amateur Radio

Amateur radio offers a wide scope of activities that appeal to different adherents. The International Telecommunications Union (ITU) defines the purpose of amateur radio as "self-training, intercommunication and technical investigations carried out by amateurs, that is, by duly authorised persons interested in radio technique solely with a personal aim and without pecuniary interest" [16].

Although many participants simply enjoy communicating with others via the radio, the majority of radio amateurs have a technical interest. Technical activities vary from simple self-construction to elaborate scientific studies of radio propagation or solar phenomena. Examples include:

- Contesting, in which participants must maximise contacts and geographical spread over a limited time, typically 24 or 48 hours. The competitive element provides a strong incentive for technical excellence, as well as linguistic versatility and geographic knowledge.
- Low-frequency work, which requires an astute understanding of propagation and antenna techniques to make communications possible at all under very noisy conditions with inefficient antennas.
- Earth-Moon-Earth (EME), where the moon is used as a passive reflector to bounce signals back to earth, for contacts that would otherwise not be possible. EME requires large antennas, good receivers and sophisticated signal processing, all of which offer tremendous scope for technical experimentation and research.
- Awards hunting, where contacts over long distances are pursued to achieve defined goals. A large proportion of amateurs participate in awards hunting, even if only casually. The pursuit provides a good access point for learning the principles of communications and radio propagation, as well as exposure to routine operations of electronic equipment and antennas.
- Satellites, where amateurs build and operate satellites that are accessible and useable by any suitably-licenced and suitably-equipped amateur. Using these satellites engenders a sound understanding of orbital mechanics, ground station design and the management of uplink and downlink phenomena, which can be very useful in commercial and government satellite links.

5. Well-Known Radio Amateurs

More than 190 astronauts and cosmonauts have been licenced radio amateurs [17], including space pioneer Yuri Gagarin.

Technology luminaries (with amateur radio callsigns in brackets) include [18][19] broadcast pioneer Reginald Aubrey Fessenden (1XS), inventor of the machine gun and silencer Hiram Percy Maxim (W1AW), co-founders of the Sony Corporation Masaru Ibuka (J3BB) and Akio Morita (JP1DPJ), co-founder of Hewlett-Packard David Packard (9DRV), aviation pioneer Howard Hughes (W5CY), guitar maven Leo Fender (W6DOE), Atari founder Nolan Bushnell (W7DUK), electronic music pioneer Bob Moog (K2AMH), concert sound pioneer Bob Heil (K9EID), Nobel Physics laureate Joe Taylor (K1JT), former Apple CEO John Sculley (K2HEP), founder of Tandem Computers Jimmy Treybig (W6JKV) and the round-the-world unrefuelled aviation pioneers Dick Rutan (KB6LQS) and Jeana Yeager (KB6LQR).

Other celebrities include King Juan Carlos of Spain (EA0JC), King Hussein of Jordan (JY1), actor Marlon Brando (FO5GJ), King Bumiphol Adulayadej of Thailand (HS1A),

UNICEF Secretary-General Talal bin Abdul Aziz al Saud (HZ1TA), President Carlos Menem of Argentina (LU1SM), prime minister of India Rajiv Gandhi (VU2RG), Japanese Prime Minister Keizo Obuchi (JI1KIT) and Eagles guitarist Joe Walsh (WB6ACU). Closer to home is Mark Shuttleworth (issued with the special callsign ZSRSA for his activity from the International Space Station).

6. Other Benefits of Amateur Radio

Apart from the technology benefits suggested by the introduction, amateur radio offers other tangible benefits.

Amateur radio provides widespread communications capability that is independent of fixed infrastructure. This independence makes it ideal for emergency communications.

A tangible example is the 2004 Southeast Asian tsunami, that devastated large swaths of low-lying land. An amateur radio expedition that happened to be on the Andaman islands provided round-the-clock communications to coordinate rescue efforts [20]. Their actions were praised by the Indian Prime Minister as indispensable.

Many amateurs remain involved in disaster preparedness exercises. In South Africa, Hamnet [21] is the arm of the South African Radio League (SARL) that coordinates such exercises. Hamnet members regularly support endurance sports events, including the Comrades and Two Oceans ultramarathons and the Ironman triathlon, as well as a number of motor rallies. These exercises raise the visibility of amateur radio, while allowing amateurs to develop the skills and equipment that will enable them to provide meaningful communications infrastructure in the case of natural disasters.

In its Smart Sustainable Development Model [22], the International Telecommunications Union refers repeatedly to amateur radio as a unique resource. Quotes include:

- "Amateur Radio is uniquely suited to situations in which other telecommunications networks have been disrupted. Amateur radio is not a commercial service and involves a community-driven response to disasters."
- "The best asset the amateur radio service brings to emergency communications transcends technology. It provides skilled people 'on the ground' who can communicate using whatever technology is available."
- "Amateur radio operators are well suited to respond in times of crisis. They are already "on the ground", have their own equipment and networks and can operate independently of commercial sources. They can provide short term immediate communication relief until such time as a commercial enterprise, such as a satellite operator, can place appropriate longer term communications equipment."

7. Amateur Radio in Africa

Africa suffers from low levels of participation in amateur radio. The world's amateur population [23] is estimated at just over three million, with around 1,3 million in Japan and about 750 000 in the USA. More than 1% of Japan's population members hold amateur radio licences. The countries with the highest percentages are Japan (1,0%), Slovenia (0,32%), Taiwan (0,30%), South Korea (0,29%) and Thailand (0,28%).

The country with the highest participation in Africa is South Africa with approximately 6000 amateurs, or 0,01% of the population. No statistics are readily available for African countries. However, statistics from QRZ.com [24], a voluntary-participation amateur radio database, can provide some suggestion of amateur populations. The fact that 2173 South African callsigns are recorded in QRZ.com suggests a participation rate of about 36%. Normalising the statistics for each African country suggests the following numbers for the biggest amateur populations:

Territory	Estimated licences	Population	Licence rate
South Africa	6000	53 000 000	0,01%
Canary Islands (Spain)	3100	2 100 000	0,15%
Morocco	1100	33 000 000	0,003%
Sudan	911	38 000 000	0,002%
Namibia	588	2 300 000	0,03%
Algeria	436	39 200 000	0,001%
Cabo Verde	425	500 000	0,09%
Cameroon	422	22 300 000	0,002%

Table 1: Estimates of amateur licences in several African countries

Around 8000 African licences are recorded in QRZ.com. Using the estimated participation rate for South Africa, the results suggest that there are around 22 000 licences in Africa. Results probably appear higher than reality due to the fact that rarer countries are more likely to be recorded in the database and are also more likely to have high numbers of transient visitors that obtain licences but are not resident or active in the country. The figures for Morocco, Sudan, Cabo Verde and Cameroon are almost certainly skewed in this way.

Nevertheless, the trend is clear. The only territory with rates comparable to the leading nations is the Canary Islands (an autonomous community of Spain), with a rate about ten times that of others in the table. Cabo Verde shows a comparable rate, but visual inspection of the database shows that more than three-quarters of entries are for temporary visitors.

Some nations in Africa have adopted a collective model, placing restrictions on individual licencing but supporting club stations with collective infrastructure. A prime example is Ethiopia, where club station ET3AA [25] has operated from the Addis Ababa University's Institute of Technology for some years. Individual participants generally have FCC licences (see below), but the only transmitting licence belongs to the club station and its equipment.

8. Means to Improve

During the past decade, there has been considerable standardisation in international licencing. The biggest single initiative has been the adoption of CEPT Recommendation T/R 61-01 [26]. This recommendation by the European Conference of Postal and Telecommunications Administrations [27] prescribes a standard syllabus for the examination for radio amateurs [28].

Administrations that accept and implement T/R 61-01 can issue a Harmonised Amateur Radio Examination Certificate (HAREC) to their licensees. This Certificate, along with the licence issued by the administration, is accepted almost anywhere in the territories of participating countries. Along with most of Europe, other non-European administrations participating in this joint licencing arrangement include the USA, Canada, Australia, New Zealand, Peru and South Africa. When the European nations and the possessions of France, Spain, Holland and the USA are taken into account, over 80 territories in all continents accept CEPT operating licences without any further paperwork.

Several countries in southern Africa already accept the HAREC as a basis for the issuance of their own licences, but only South Africa and the African territories of France and Spain have fully implemented the CEPT recommendation. For most of these countries, examinations are conducted in South Africa under the auspices of the SARL. A HAREC is then issued, after which the applicant can obtain a licence in his or her country of choice. The SARL has approached a number of African countries to extend this arrangement,

offering an attractive mechanism for smaller countries to participate in amateur radio without incurring the overheads involved in administering the examination system.

The Syllabus contained in the HAREC specification provides a clear indication of the level of knowledge and skill that applicants must possess before obtaining the HAREC and being authorised to apply for an amateur licence. Although the syllabus is in no way a professional qualification, it does provide a sound introduction to the world of electronics and communications systems.

In South Africa, the SARL felt a strong need for affordable training towards the HAREC, and commissioned a study guide which was brought into use around 2005. This study guide is self-contained and provides all the material needed to study for and pass the examination to obtain the HAREC. A revised version of the study guide, called *Introduction to Amateur Radio* [9] is available to any prospective radio amateur free of charge. The guide contains numerous sample questions, which can be implemented directly as an examination question pool.

Also in South Africa, the South African Amateur Radio Development Trust (SAARDT) [29] has made available bursaries to sponsor deserving candidates for the HAREC examination. An amount of cash is made available to enable candidates to pay the examination entrance fee, as well as some coaching or lectures. The free study material made available by the SARL can also be printed on paper if required.

Finally, the US Federal Communications Commission (FCC) issues amateur radio licences to non-residents who meet their requirements. Examinations can be taken anywhere on earth. A permanent examination team resides in Pretoria, South Africa [30]. Many nations, including Ethiopia [20], have used this mechanism to licence their operators, guaranteeing a certain level of government-certificated proficiency without having to incur the burden of a home-grown examination system.

9. Hindrances

Some administrations in Africa have traditionally harboured security concerns around amateur radio. For this reason, some nations have prohibited the issuance of licences to visitors. Several other nations have prohibited the issuance of amateur licences to their own residents.

With ever-increasing access to mobile telephony and the Internet, and the prohibition on encrypted communications in amateur radio, most nations have now realised that amateur radio does not pose a threat—it is not a suitable channel for subversive activity, and potential anarchists have access to far more efficient channels. Indeed, the very fact that most major nations represented by CEPT now permit a free exchange of radio amateurs and operating permissions between them is a clear indication that most nations no longer regard amateur radio as potentially subversive.

Another element hampering universal adoption of amateur radio has been the potentially high cost of entry. This factor is no longer regarded as substantial. On the one hand, many suitable dongles and other low-cost receivers have come into use. On the other, many low-cost digital signal processing (DSP) devices are now available, making software-defined radios that are eminently suitable for experimentation relatively cheap. The increasing availability of remote-controlled stations with access provided through the Internet can also address many of the cost concerns, as it is becoming easier and easier to share infrastructure between many users. Finally, the pending availability of Eshailsat 2 [31] will provide an operating platform that will be accessible with TVRO-style dishes and simple transducers. This satellite will provide coverage of all of Africa, along with a portion of Brazil, most of Europe, the entire Middle East and much of southeast Asia. Finally, several open-source DSP platforms that run on generic devices and computers are becoming available, enabling users to experiment with radio communication systems

without a substantial financial layout on hardware. Perhaps the best example of this trend is Linrad [32].

10. Action Plan

Clearly, African telecommunications regulators would do well to facilitate widespread participation in amateur radio.

Help is available from the South African Radio League and the South African Amateur Radio Development Trust to implement training and examination systems. A question pool, along with software to compile examination papers from the question pool, can be made available.

Following the example of several southern African nations, a regulator can also accept the CEPT-compliant HAREC issued by the SARL, and issue a local licence on that basis. The SARL and SARDT can assist in formulating a licencing policy and procedure for nations that do not already have such policies and procedures.

Another option is to assist local citizens to obtain licences issued by the FCC in the USA, and then to recognise those licences locally using existing or new procedures for reciprocal licencing. The advantage of this approach is that the candidate will already have passed through the approval process of a CEPT-compliant regulator, offering the local regulator some assurance of the suitability of the candidate. Again, the SARL and SARDT can assist in conducting examinations and in establishing the necessary policies and procedures. Examinations can be conducted anywhere by an FCC-approved examination team. Such a team is based in Pretoria, South Africa.

Once local amateurs have been licenced and approved, they can start experimenting and learning the practice of telecommunications systems. Indeed, the hope is that Africa will take its place at the forefront of future technology developments, continuing the proud tradition of amateur radio from the earliest days of radio.

11. Conclusions

Amateur radio provides a ready source of trained and equipped individuals with the skills and experience to develop, install and run sophisticated telecommunications infrastructure. They also provide a ready source of emergency communications capability.

The emergence of the HAREC has provided a simple mechanism for nations to train and licence their amateur population, using training material that is freely available on the Web. Support is available to ensure that the examination system does not have to be a burden on the host nation.

An alternative licencing mechanism is also available in the USA's FCC, as this authority will issue licences to non-residents who pass the necessary examinations.

The time is ripe for Africa to reap the rewards offered by Amateur Radio as a vehicle for fostering technology literacy.

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