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Avances tecnológicos en sistemas y equipos de comunicaciones militares

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Resumen—En este artículo se presenta una revisión sistemática que aborda el desarrollo de tecnologías que han impulsado a la comunicación de carácter militar, se describe la evolución de equipos y protocolos de comunicación empleados a través de la historia. Este trabajo se realizó a partir de la revisión de 80 artículos relacionados con el ámbito de las comunicaciones militares, a partir de los cuales se extrajeron los fundamentos sobre las diferentes tecnologías, equipos y medios de comunicación. Se concluye que el avance tecnológico ha mejorado la velocidad de respuesta en las señales digitales, ha propuesto nuevos métodos y protocolos de encriptación de la información transmitida y a más de ello ha optimizado la eficiencia energética de los equipos, que ahora poseen autonomía suficiente para completar extensas misiones sin recargas de energía con el uso de dispositivos más compactos y livianos.

Palabras clave: comunicaciones militares, protocolos de comunicación, transmisión de información, tecnologías.

Technological advances in military communications systems and equipment

Abstract—- This article presents a systematic review carried out around the development of technologies that have driven military communication, describing the evolution of communication equipment and protocols used throughout history. This work was carried out from the review of 80 articles related to the field of military communications, from which the fundamentals of the different technologies, equipment and means of communication were extracted. It is concluded that technological progress has improved the speed of response in digital signals, has proposed

new methods and protocols for encrypting the transmitted information and has also optimised the energy efficiency of the equipment, which now has sufficient autonomy to complete long missions without recharging energy with the use of more compact and lighter devices.

Keywords: military communications, communication protocols, transmission of information, technologies

I. INTRODUCTION

Communications in the military field are an aspect of vital importance for the coordination and control of operations, sending information (voice, data, video), which are necessary to acquire an adequate perception of the environment and the situation. Communication is required by military personnel, at all levels and through different environments such as underwater, on land, air and in space. Military communications must be characterised by having flexibility, adaptability, and controllability of characteristics such as frequency, bandwidths, speed of transmission of information, and response times and guarantee the continuity of communications despite variant environments that may arise [1].

Faced with the needs of modern deployments in the military field, it is necessary to develop new technologies to fill current technological gaps, in the same way, that we are participants in the evolution of mobile communication technologies, better ranges, data transmission speeds, information security are required, equipment autonomy, more compact technologies, etc. The present work describes in the Development section, a description of the standardized technologies implemented in the military communications systems of land, naval and air defense in the armies of greater technological advance in the world. The Methodology section describes the considerations taken in the realization of this comprehensive review document, finally in results, relevant findings and data found in the analysis of the information are presented.

II. COMMUNICATION SYSTEMS OF MILITARY FORCES

The military forces have their reach in continental, maritime and air territory, most countries have this structure

A.Military Ground Communications

The safety and efficiency of communication are very important, and in the military field, they must contemplate catastrophic situations, interference, failures in energy systems and collapse of local communication networks. The Warfighter Information Network-Tactical (WIN-T) created by General Dynamics (US) and implemented in 2002 in the US Army, has a structure in the form of a network of servers, routers, and switches that work in vehicles or mobile stations (Figure 1). The technology is peer-to-peer (Technical Operations Center-TOC) communication radios and lower level connectivity [2].

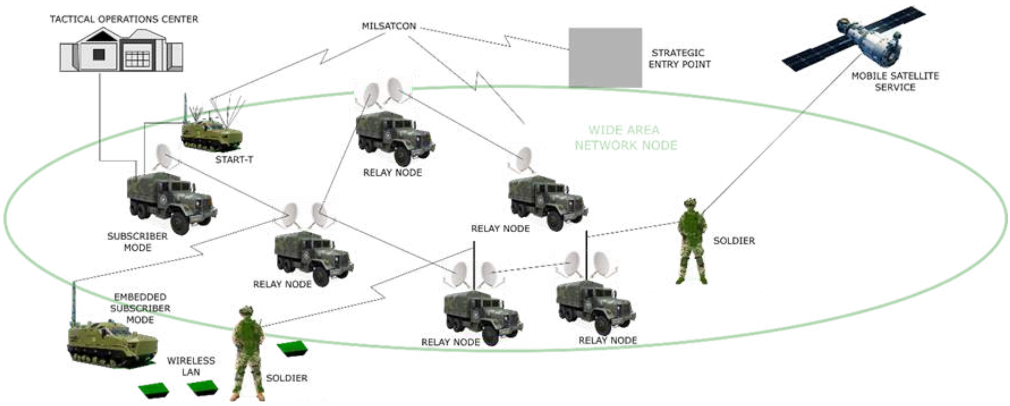

Fig 1. Arquitecture Warfighter Information Network-Tactical (WINT-T)

The WINT-T architecture presented in Figure 1 illustrates a series of mobile and fixed stations that allow the transmission of communications without requiring fixed network communication stations, which allows consistent communication to sets of mobile fighters, vehicles, improved stations, and satellite communication through technologies that use cables and of a wireless nature. The architecture of a tactical communications system considers mobile infrastructure for operations in multiple locations and has some components based on the technology of the type Communication and Networking Riser (CNR), technology owned by the INTEL® brand.

Due to the limitations of Communication and Networking Riser (CNR) systems, WINT-T was developed to support communication as a logical network that allowed voice and data to be transferred with the flexibility of implementation in its physical part. At the lower level, combat troops carry a device that acts as a network node and access terminal. Battery power and the need for small omnidirectional antennas mean that ranges and capacities are limited. At the upper level, the trunk communications systems have been designed to possess a semi-mobile structure. Since these systems operate in remote locations, they employ generators for their power supply. Large capacity antennas are deployed on braced masts in vehicles or fixed stations to provide coverage with reasonable ranges.

To extend the range of communications, an alternative is to raise the position of the antennas, which has been solved with a repeater or satellite-based switch, significantly increasing the ranges between network nodes. A satellite-based solution is not considered desirable in all cases due to its inability to meet the requirements of a minimum organic communications system and whose transmission security may be altered; therefore, an airborne subsystem is required to support long-range flights to increase the Lower-level tactical communications capability by eliminating range restriction at high frequencies that can provide additional capacity from small to omnidirectional antennas. A Tactical Communications System may provide a basic level of service. It should be able to be extended, where possible, with overlapping communications systems, such as the public telephone network, satellite-based communications systems, personal communications systems, etc. These overlapping systems cannot be guaranteed availability and therefore cannot be included in the basic tactical system, yet a significant advantage can be gained from their use. To simplify the user interface of the multiple subsystems used in the WINT-T system, a switching level is required; thems have various forms, including a set of vehicles, mobile stations an a local area networksk around the brigade headquarters.

Within the architecture of the WINT-T tactical communications system, a few systems and subsystems allow its operation. In figure 2, the four fundamental systems are appreciated: Eoverlaid Communications, Tactical Communications and Supported, in addition to this and for security reasons the strategic communications system is added. The subsystems in which WINT-T is supported are Combat Radio, Tactical Data Distribution, Tactical Trunk, Tactical Airborne, and Local to simplify the user interface with the other communications subsystems and the communications systems.

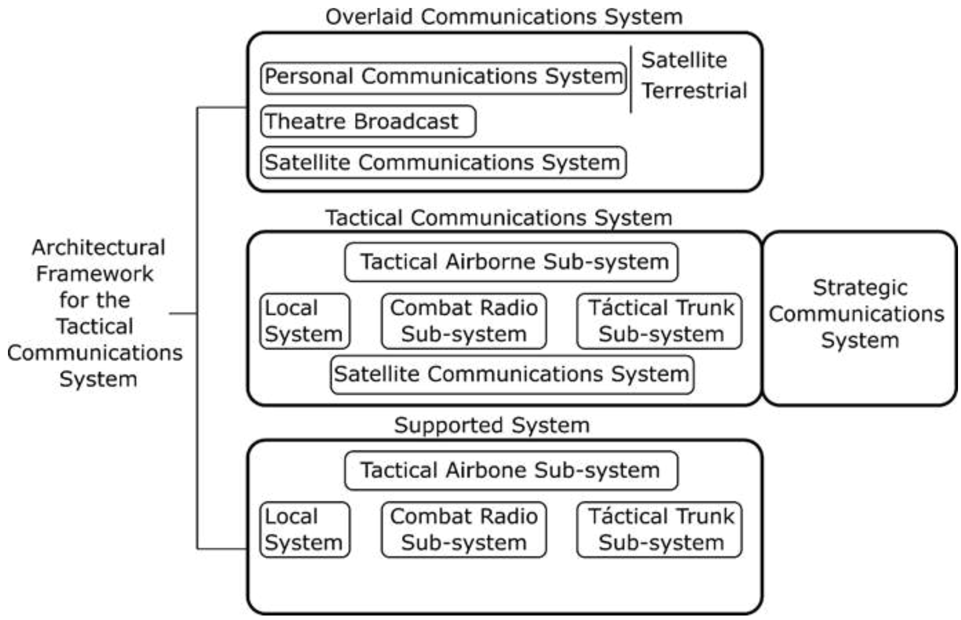

Fig 2. Architecture for the Tactical Communications System

B.Maritime and Aeronautical Communications of a military nature

The communications of the armed forces, both dedicated to the maritime and air aspects share similar technical and operational characteristics that depend on the distances at which they are from other aircraft or ships, as well as from fixed communication stations. Figure 3 illustrates an outline of the technologies used for the aeronautical and maritime aspects, supported by a set of satellites that triangulate the position obtaining and transmitting the positions through the use of the GPS Global Positioning System.

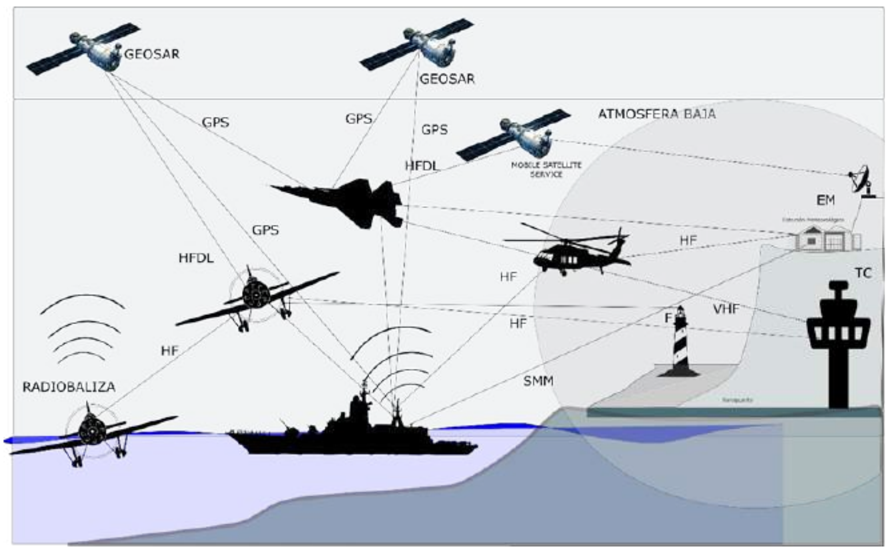

Fig 3. Outline the use of communication technologies in Aeronautical and Maritime communications.

C. Aeronautical Communications

For the positioning of the ships, whether these are combat aircraft, helicopters, light aircraft and even commercial aircraft, these systems are linked by satellites that correspond to GEOSAR technologies, which from a triangulation of the signal between three or more satellites, manage to obtain the position of the aircraft and helicopters. The operations and communications carried out between the aircraft and the ground stations use an Aeronautical Service of communications S.A., while to support the mobile telephony inside the plane are companies such as Onair and AeroMobile, which provide the Aeronautical Mobile Service. The frequency bands most used are two of HF (High Frequency) and VHF (Very High Frequency). The HF frequency, known as shortwave, is used for international radio communications in frequency ranges from 2.8 to 22 MHz and corresponds to the upper sideband in which the emission types J3E (voice communication used by users of the aeronautical area), A3E (used in AM broadcasting in low and medium frequency) are located.

The audio frequencies used in aeronautics are made in audio frequencies from 300 to 2700 Hz, with which large coverages are achieved and a propagation that can vary according to the seasons of the year and activity of the Ionosphere; through the use of HF, you can have direct communication between aircraft and ground stations, even if they are long distances.VHF frequencies are useful for the duration of flights and short distances, useful in operations such as takeoff or landing and operate on frequencies from 117.9 to 136 MHz, which is why they are used in the vicinity of airports. For the military field, the bands used are from 136 to 143 MHz, with a modulation greater than 85%. In cases of emergencies or disasters, communications are broadcast at frequencies above 2182 kHz and 121.5 MHz. For take-off and landing situations, the aircraft rely on the services of air terminals, and support stations such as: Weather aid stations, fixed take-off stations and fixed landing stations, each with its own technologies and communication protocols.

D. Maritime Communications

The Maritime Mobile Service (SMM) allows communication between coastal stations and vessels, allows the detection of rescue devices and radio beacons. In addition to this, there is the Maritime Stations Service (SRM) that regulate maritime traffic in accordance with regulations and regulations imposed with international conventions. Figure 3 illustrates the ships' communications with ground stations, aircraft, and satellites operating in low and high levels of the Earth's atmosphere. Maritime communications in the past contemplated semi-duplex communications in which communication was carried out in only one direction at a time, however, new technologies already allow duplex communication and that correspond to the same HF and VHF technologies that are used by aircraft with a different band and respecting the legislation of each country.

The frequencies for maritime communications are given in two main groups: long-range operating in bands from 4 to 30 MHz with a worldwide coverage and in HF, the second frequency corresponds to short range in bands from 156 to 174 MHz in VHF. Ships and mobile communications also have their classification due to the size of the vessels, this is for communications between vessels and coastal stations. There are two types of communication bands that are: inshore which includes ships of up to 1600 tons, and the band for large transoceanic; for these last two cases frequency ranges of 4 kHz to 25097 KHz are used.

In the case of shipwrecks or dangerous situations, the beacons (frequency of 406 MHz) can communicate with the SARSAT-COSPAS system that corresponds to a set of search and rescue satellites (SAR) through which and by triangulation can locate signal emissions managing to locate the source of the signal and at the same time transmitting to aircraft and stations on the ground. Some international organizations related to maritime defence and civil aviation recommend that ships and aircraft possess Emergency Position Indicating Radio Beacon (EPIRB) and Emergency locator transmitter (ELT), respectively. EPIRB allows localisation in case of accidents, while ELT facilitates location in emergencies. For personal location, in the water and on land, Personal Locator Beacons (PLB) are used. The satellites that operate with SARSAT-COSPAS technology and that allow the communication of the vessels are of two types, those that operate in low orbit called Low Earth Orbit (LEO) and those that operate in higher orbits called Geostationary Earth Orbit (GEOSAR).

E. Advances in the Communication Systems of military forces

Although in the previous sections the communications of a military nature, whether land, air and sea, referred to technologies for the transmission of voice, files and static images; currently, the concept of real-time applications of videos and data between teams is already being addressed, dynamic maps that provide information to identify risk areas. Communications today seeks to generate solutions as a unified entity allowing greater availability of information and accessibility for more military members.

Advances in Military Ground Communications

The use of Software Defined Radio or SDR has been proposed as an alternative due to its robustness, scalability and conditions for rapid deployment. This technology makes it possible to create an efficient and automatic communication network without the need for any prior infrastructure or frequency planning. An example of this type of solution is formed by the BNET family of radios of the multinational Rafael Advanced Defense Systems, which acts as the backbone of a communications network and offers key advantages by offering broadband, low delay and reliability in connectivity. An SDR radio communication option has different patented features that allow forces deployed in the field, mounted in vehicles or in the air, to operate even if the geographical and operational scenarios are highly complex.

BNET technology allows multi-band communications, IP-based network link (Internet Protocol), multichannel reception, and Mobile ad hoc Network (MANET) network management; these possibilities added to the low delay, scalability to more than a thousand terminals and its high level of integration, provide facilities to the user to configure their communications din complications and safely. High data speed and reliability provide a competitive advantage to battlefield actors. This technology has been adapted for the foot soldier (BNET -HH), for a useful backpack in tactical controls (BNET -MPS) and for fixed installations and vehicles (BNET-V).

Evolution of Tactical Communications Technologies.

Very Small Aperture Terminal (VSAT) Networks enable mobile, secure and real-time relays of information via satellites over commercial or government frequencies or a combination of both. Satellite antennas, modems and other related equipment have become smaller, lighter and more mobile, meeting the ideal requirements of size, weight and power (Shared Wireless Application Protocol, SWaP) to meet the demands of military users. Inmarsat Global Government, ViaSat, Hughes Government Solutions, Harris CapRock and Newtec are the major players in the field of VSAT service solutions, providing ever-higher specification offerings to an extremely competitive and fast-moving market.

Ethernet and VoIP networks have evolved in tactical scenarios increasing the need to integrate digital voice over IP (VoIP), file transfer, image and video transmission, and field web-based applications. The ICC-201 IP-based digital intercom system and the PRC-525 tactical combat network radio meet the needs mentioned above, simultaneously improving connectivity, interoperability, flexibility and mobility. The EID tactical network provides equipment that the C4I technology customer needs to increase command, control and communications capability seamlessly, providing solutions to aid the deployment of state-of-the-art IP-based tactical networks, from simple cable-to-fibre-to-fibre Ethernet converters and vehicular power supplies to sophisticated, rugged servers, rugged routers/switches, radio access points, and radio-VoIP gateways. The ICC-201 digital intercom system is an IP-based concept that enables the integration and deployment of a robust, compact and seamless system.

A revolutionary technology is 3D printing and synthetic telepathy, whose technology employs a "brain-computer" interface, or "synthetic telepathy", which are emerging technologies after research in synthetic telepathy by scientists over the years. American researchers successfully demonstrated the use of one person's brain signals to control another person's hand in 2014. From signals obtained by electroencephalography (EEG) and enhanced by transcranial magnetic stimulation (TMS), these signals were delivered to the brain of a second subject. Synthetic telepathy could propose new communication alternatives if subsequent developments achieve applicability and solid evidence of the advantages of its use within the military.

According to the latest advances in physics and quantum computers of the current generation, quantum communications can be transmitted at reasonable distances on Earth and, according to the theory, much greater distances in space. The fact that the information has a different state at each moment and that when obtaining the information it can change makes quantum communications one of the safest anti-hackers. The only way to observe the photon is for it to interact with an electron or electromagnetic field, which would cause the photon to decohesion or interfere with it in a way that would only be apparent to the intended recipient in possession of the encryption key. The advantages of quantum communications in the military field will allow to quickly give orders to soldiers on the battlefield without fear that anyone will hack the information and manage to securely transmit the information to the headquarters for analysis without the possibility of enemy interference.

Advances in Aeronautical and Maritime Communications

BNET technologies also have solutions for the aeronautical field with the incorporation in aircraft with the BNET-AR version. However, there are new alternatives that allow widespread communication to air and sea-land systems; below are some of the most recent developments and projects in development.

Wireless Communication Technologies

The future of aeronautical communications is being developed around a new alternative called Free-Space Optical Technology (FSO) which corresponds to the type of Optical Wireless Communication (OCW). The two terms mentioned above and that are similar refer to the use of optical media in visible bands, infrared (IR) and ultraviolet (UV); for this, laser light or light-emitting diodes are used. This technology in development can provide better response times to sound communications and electromagnetic spectra. However, its use is still debated due to the variability of atmospheric conditions and distortions that can affect light patterns.

OCW technologies have five alternatives: ultra-short range, short-range, long-range and ultra-long-range OCW. These alternatives support not only aircraft without including people on foot, vehicles, aircraft, submarines and even satellites [O1]; an illustration of the interactions of OCW technology can be seen in Figure 4.

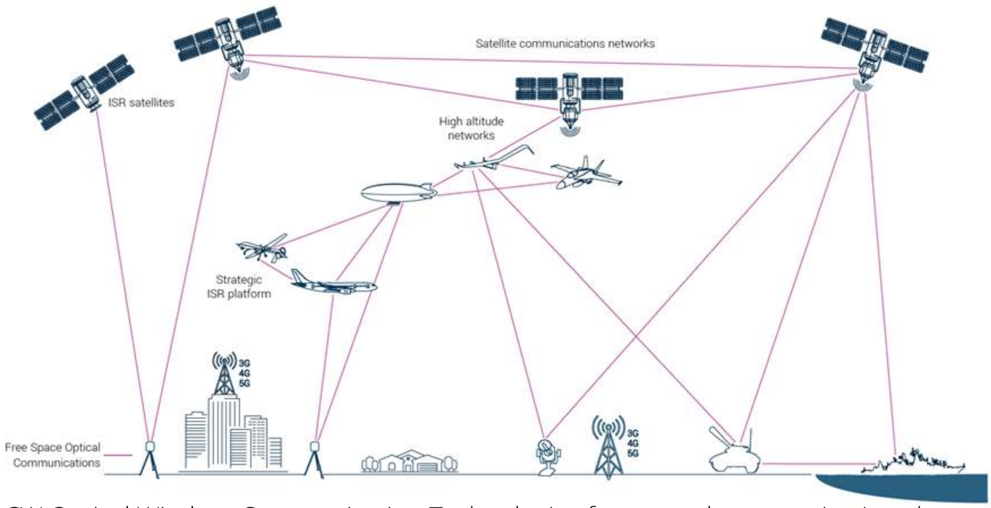

Fig 4. OCW Optical Wireless Communication Technologies for general communications between land, aeronautics and maritime.

Tropospheric Dispersion Communications

Although these communications have been used for years by military organizations for long-distance communications at multiple frequencies and in remote areas, they are currently considered to be used to use the lack of homogeneity in the troposphere to send signals transmitted to a receiver that uses high-gain antennas and that at the same time allow transmission in high powers of the order of 100 W and that commonly are mobile. The interest in the use of the dispersion of the troposphere considers the creation of more precise channels and multiple inputs and outputs (MIMO) transmission techniques which would improve reliability. The use of dual antenna is foreseen to avoid interruptions allowing the transmission of several dozen data in Mbps.

Many factors have been tried to solve for the application of this technology in the aeronautical field, such as the influence of altitude that decreases the density of the troposphere, presenting variations in altitude in the tropics and areas near the poles. The reason why, these technologies will be used in limited situations, but despite this, their information transmission speeds will prevent this technology from falling into disuse for a considerable time.

Near Vertical Incidence Skywave Communications (NVIS)

This type of communication works from the launch of waves in a high frequency spectrum HF in frequencies of 0.5 and 10 MHz, signals are sent with angles above 80° with respect to the horizontal direction and depending on the time of day and the variation of the refraction of the ionosphere, to take advantage of its refraction and provide ranges of hundreds of kilometers. Figure 5 illustrates the rebound effect of electromegenetic waves in the ionosphere for when they are sent at angles greater than 80° (NVIS) and when they are performed with smaller angles in which case transmissions are achieved at longer deistances but with lower fidelity for frequencies used by NVIS.

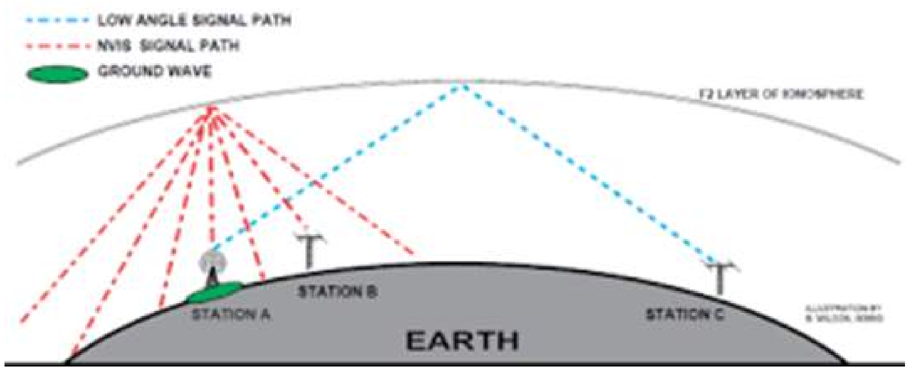

Fig 5. Tecnologías de comunicación Skywave de Incidencia Casi Vertical (NVIS)

The rebound with the almost vertical angle provides the communications system with a suitable alternative for regional aviation especially for reception, and this technology can also be used in drones through HF type modems that are adaptable to the changing conditions of the refraction of the ionosphere. If it is short messages of regional volume, NVIS offers a useful alternative for some air systems.

Orbital Angular Momentum (OAM) Transmission

Analogous to the use of electric field polarisation, angular momentum transmission gained attention more than a decade ago when the scientific community demonstrated the feasibility of optical wave propagation. Waves of OAM character are considered helical that can be configured with different modes and forms of energy density on the plane perpendicular to the direction of propagation. Higher-order modes of these waves are mostly attenuated according to distance, this technology is one of the most useful. At present, the scope for which it has been tested is insufficient. Still, this technology has the potential to better develop its coverage, as well as enjoying the possibility of a high rate of data transmission, so with a bit of development, it could become an alternative that leads in the future of aviation.

Orthogonal Time Frequency Space Modulation (OTFS)

It is a new two-dimensional modulation technique proposed by Chere Technologies that works from a Doppler effect with a coordinate system instead of the conventional time-frequency domain system. The system above has successfully operated in multiple access communications schemes (OFDM (A)), multiple access code division (CDMA), MA time division (TDMA) and MA frequency division (FDMA)) according to [O2[, in addition, it has been effective for the implementation and 5G technologies.

The transmission is carried out in the form of pulses as if it were a radar with intervals of repetition of a burst of pulses. According to the increase in the burst of pulses, a better resolution of the Doppler effect is achieved. This technique is improved by using equalization techniques to improve its performance; in addition to this, nonlinear equalization techniques are used to perform multiple frequency diversity, not only in the delay domain (as known as TDMA and CDMA) but also in the Doppler domain.

Machine Learning for Aviation Communications of the Future (ML).

The application of Machine Learning as a tool for the use of Artificial Intelligence has been studied and proposed for applications in aeronautical communications systems The potential achieved by the application of ML in communication lies in the creation of solid cognitive radio networks (CRN). Which is an adaptive network that self-regulates to automatically detect the multiple channels available in wireless network spectrums, enabling a greater number of simultaneous users. It is achieved through this technology to better employ the available resources effectively and reliably. There is strong evidence of the application of CRN in terrestrial communications and WRAN wireless regional area networks and most IEEE 802.22 standards for UHF/VHF and its TV bands between 54 and 862 MHz [45].

III. METHODOLOGY

The systematic review carried out in this document contemplated in a first search 226 articles of the IEEE Xplore (168) and SCOPUS (58) scientific bases, using a search of the keywords: Military communications, Communication protocols, Information transmission, Technologies. 50 documents that were repeated in the two bases were eliminated, later of the 176 documents, 125 screened were eliminated according to the title and abstract. Of the 51 articles considered, 14 were excluded, thus obtaining 15 articles that strictly addressed the appropriate topic to carry out this research work, the procedure can be seen in Figure 6.

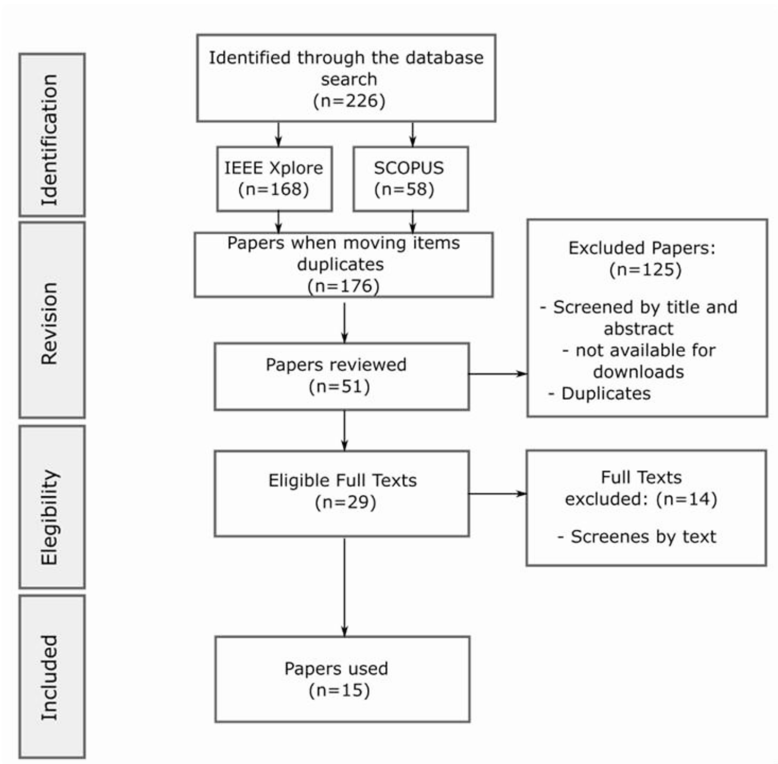

Fig 6. Workflow schema in reviewing reference documents

IV. RESULTS

Multiple technologies were found based on developments or improvements of existing and previously used technologies and new ones with the implementation of artificial intelligence and Machine Learning. In most of the communication technologies addressed, the communication frequencies that are most used correspond to HF for long distances and VHF for short distances with respect to fixed stations for both the aeronautical and maritime areas. There are methods that use technologies very different from those used in previous generations and that instead consist of quantum and extrasensory advances based on brain perceptions.

These technologies are still under development; however, they allow very high capacities compared to conventional technologies in data transfer capacity and brain signals by non-standardized but experimentally successful methods.

Electromagnetic effects, the emission of radar waves and sound, are being replaced by technologies of an optical nature due to their transmission speed and range. In addition, technologies have been proposed that take advantage of the dispersion of the ionosphere and allow the rebound of waves achieving short ranges but with high fidelity of communication.

CONCLUSIONS

Tactical communications on the battlefield have multiple alternatives in terms of communication protocols, equipment and technologies under development, and since the results take into account the participation of a swarm of satellites, they allow an improvement in accessibility for the military, which optimise communications options through the use of satellites. Cognitive radios, synthetic telepathy and quantum communications are now the buzzwords. India brings great developments.

Technological advances in the aeronautical field are highlighted by the use of electromagnetic waves, light and radio waves; these technologies employ frequencies commonly used in previous technologies. The capabilities in transmitting images, video and voice of the users have been significantly improved.

Many of the technologies used in the military-strategic field and its operations on land work to date in multiple countries. Given the variety of equipment, origins, and variable frequencies, the equipment has been developed that provides the flexibility to communicate with a multitude of bands and the same equipment.

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