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# ULTRA WIDEBAND DATA CHANNELS FOR SPECIAL OPERATIONS FORCES

***Abstract***

*Hungarian and coalition special operations forces – striving to satisfy the growing need for information – conduct information and communications support for their operations using almost the entire throughput capacity available to them. Innovative methods, such as extremely high frequencies and alternative modulation modes, offer so far unprecedented ways in frequency bandwidth development. Transmission technology, miniaturization, and the development of optimization processes facilitate the use of innovative applications in providing increased bandwidth and channel capacity with smaller form factor and less power consumption. This scientific essay presents a usable solution to achieve increased bandwidth for supporting the full spectrum of the voice and data communications activity of special operations forces.*

*A nemzeti és koalíciós különleges műveleti erők - a megnövekedett információigény kielégítése céljából - a rendelkezésükre álló rádiófrekvenciás spektrum lehető leghatékonyabb kihasználásával igyekeznek megvalósítani műveleteik infokommunikációs támogatását. Innovatív megoldásokkal (magasabb frekvenciasávok használata, magasabb rendű modulációs módok alkalmazása) újabb lehetőségek nyílnak meg a jelenleg rendelkezésre álló sávok kiterjesztésére. Az átviteltechnika, - technológia, és miniatürizáció, valamint az optimalizálási eljárások fejlődése olyan új megoldások alkalmazását teszi lehetővé, amelyek a csatorna-sávszélesség hatékony felhasználása és a támogató rendszerek méret és energiafelvétel csökkentése területén jelentős előrelépést jelenthetnek. A közleményben egy ilyen lehetséges megoldás, illetve annak háttere kerül bemutatásra a különleges műveletek teljes spektrumában végrehajtott műveletek híradó és informatikai támogatása területén.*

***Keywords:*** *bandwidth, special operations forces, communications ~ sávszélesség, különleges műveleti erők (KME), híradó biztosítás*

## INTRODUCTION

Numerous scientific essays have been published in military literature about the operations carried out by conventional and special operations forces, manoeuvres in the open field, on different types of terrain and in built-up areas and about planning and executing combat activities. The tasks of small units include support to own force and the enhancement of combat effectiveness. If we look at 21st century military operations and the political and economic processes of our asymmetric and multi-polar globe, it can be seen that the war on international terrorism requires special methods, techniques and procedures that meet the new challenges [1].

The training and preparation for battle of international special operations forces require a special emphasis on information and communications support. The 21st century witnesses revolutionary developments in the microelectronics industry, both in civilian and military applications. These developments enable the special operations forces to reach a higher level of operational effectiveness and facilitate a higher level of situational awareness[1] [2].

In military jargon we can often come across the phrase "digital soldier", i.e. a soldier equipped with target-oriented optical and communications and information devices, integrated weapons and communications systems which provide secured communications with command and control [3]. His equipment consists of modern software defined radios[2] for voice and data communications systems to visualize the movements of own forces for better situational awareness[3], systems against improvised explosive devices[4] and systems to process, analyze and transmit aerial reconnaissance data [4].

The requirement of near real time data transmissions and situational awareness visualization necessitate the use of satellite communications to maintain battlefield initiative and superiority and consequently achieve success. As operational communications require higher and higher bandwidths to transmit the increased amount of information, a lot of attention must be paid to how data transmission channels are designed in the interest of the optimal utilization of the frequency spectrum. Its practical realization requires great familiarity with the command and control systems and, if necessary, their reinforcement and further development with modern software defined(SD) radios.

This essay tries to provide an overview of a wide bandwidth radio communications system that can broaden the possibility of special operations applications worldwide.

## SPECIALTIES OF SOF[5] OPERATIONS

In order to provide signal and IT support as well as information security for SOF commanders, planners must know the full spectrum of SOF operations. In peacetime and in the battle preparation phase, it may be the basis of the development of an operable and efficient system, which in the theatre of war – even with considerable changes if required – is capable of supporting command and control. The AJP-3.5[6] defines more than precisely the SOF operations in the NATO/ISAF joint operational area. These are special reconnaissance and surveillance (SR&S), direct action (DA) and military assistance (MA). SR&S complements national and allied theatre intelligence collection assets and systems by obtaining specific, well-defined, and possibly time-sensitive information of strategic or

[1] Situational Awareness SA
[2] Software Defined Radio SDR
[3] Blue Force Tracking System BFTS
[4] Improvised Explosive Device IED
[5] SOF - Special Operations Forces
[6] AJP-3.5 – Allied Joint Doctrine for Special Operations

operational significance. It may complement other collection methods where constraints are imposed by weather, terrain-masking, hostile countermeasures or other systems availability. SOF may conduct these tasks separately, supported by, in conjunction with, or in support of other component commands [5]. DA missions are precise operations that are normally limited in scope and duration. Forces usually incorporate a planned withdrawal from the immediate objective area. DA is focused on specific, well-defined targets of strategic and operational significance, or on the conduct of decisive tactical operations. SOF may conduct these tasks independently, with support from conventional forces, or in support of conventional forces [6]. MA is a broad spectrum of measures in support of friendly forces throughout the spectrum of conflict. MA can be conducted by, with, or through friendly forces that are trained, equipped, supported, or employed in varying degrees by SOF. The range of MA is thus considerable, and may vary from providing low-level military training or material assistance to the active employment of indigenous forces in the conduct of major operations [7].

The security requirements of SOF demand that special care is taken to ensure that SOF C2[7] is closely integrated with the C2 of the joint force through appropriate liaison and communications and information systems interfaces. NATO and the nations are responsible for the extension of secure CIS connectivity to the highest level of national or multinational tactical and operational command in theatre. For special operations this equates to the joint force command providing connectivity to the combined joint forces special operations component command (CJFSOCC) for C2 during the operations and exercises. The nation appointed is generally responsible for providing CIS connectivity to the highest level of command of all assigned, attached and supporting elements. The CJFSOCC is also responsible to ensure that CIS connectivity is provided to all liaison teams. Nations are responsible for providing their own internal CIS connectivity. Secure CIS connectivity for protection of sensitive information should be provided to the maximum extent possible. When secure CIS is provided within a national unit, secure (cryptoized) connectivity should be provided down to national levels for interface purposes. Secure CIS should include provisions for primary voice, data, and fax capability. Nations should consider tactical satellite communications as an invaluable means of establishing the secure connectivity. SOF requires a C2IS[8] network that allows timely C2 and implements the required security measures. All of these must be taken into consideration by the planners when the CIS planning process commences [8].

## RULES AND REGULATIONS FOR ENABLING SOF CIS

With regard to SOF connectivity to host nations and the allied partners, no Hungarian CIS regulations are to be found, however NATO standardization agreements (STANAGs) are applicable for this purpose. The CIS planner in allied operations has to consider STANAG 5048 and STANAG 4637. STANAG 5048 provides the minimum scale of connectivity for communications and information systems for NATO land forces. It states that fully capable CIS connectivity is required to exchange C2 information and coordinating instructions on the battlefield between superior and subordinate headquarters at all levels, between the headquarters of a unit being supported and the supporting unit, and between adjacent formations on the battlefield. The responsibility for providing the required connectivity is governed by the general principles of higher formation to lower formation, supporting formation to supported formation, and left formation to right formation [9]. STANAG 4637 is

[7] C2 – Command and Control
[8] C2IS – Command , Control and Information System

a tactical communications regulation, which governs the tactical level means and procedures with regard to enabling CIS connectivity from tactical units to higher units. It defines the interoperability requirements for a federated network consisting of interconnected national elements, in such a way that it appears to the users as one network, fulfilling all defined requirements for user services and their defined Quality of Service (QoS), capacity, robustness, security, etc. In the long term, the concept aims to provide advanced interoperability capabilities (including e.g., mobility) for network-centric operations, but, due mainly to the capabilities of the present national tactical communication systems and the limited availability of advanced security solutions, an evolutionary approach will be used. The STANAG 4637 concept is service based, supports an extensive set of end-to-end user service, defines network services, permits an independent implementation of network elements (NE) by nations, where NE is an interconnection of communication assets, forming, e.g., any combination of a local area, wide area, or mobile networks, under the control of one nation, standardizes the IOP to provide connectivity between NEs. Interconnected NEs form STANAG 4637 Federated Network (TFN), allows multinational performance guarantees through Service Level Specifications (SLSs) and with corresponding instantiated Service Level Agreements (SLAs), and standardizes External Network Access Points (ENAPs) to provide connectivity between a NE and a civilian or non-tactical military network [10].

The only Hungarian joint regulation for CIS connectivity is the Joint Operational Doctrine of the Hungarian Defence Forces[9]. Under 4.2.4.3 are the requirements a CIS planner needs to consider when the planning process starts. This is the practical approach to the tactical and operational level CIS planning process, including the full spectrum of connectivity detailed in the above mentioned STANAGS [11].

## TACTICAL LEVEL COMMUNICATIONS AND INFORMATION SERVICES

The smallest unit of SOF applications is the special operations task unit (SOTU). In the area of CIS connectivity, the following criteria need to be fulfilled. The CIS of SOTU is to be capable of supporting minimum one special operations forces command post, controlling 15 radio terminals in a common radio network and providing secure (classified) and unclassified services. The internal communications radio terminals of a SOTU need to be software defined radios that can provide Internet Protocol (IP) –based services and activate secure radio communications channels up to the level of NATO SECRET. They must provide wide bandwidth voice and data connection, keying and rekeying the radio terminals over the air (OTAR), and they have special waveforms, such as Soldier Radio Waveform (SRW) and secure wideband mode (ANW2) GPS[10] receivers. The terminals must be able to send and receive local positioning data and to operate both in open and secure channels using TYPE-I CCI[11] crypto keys. The radio terminals need to be compatible with high speed data networks and capable of sending and receiving imageries (jpeg, gif files) and video (mpeg4) signals in near real time. The radio devices must meet the requirements for high bandwidths and low weight so that they can be carried in soldiers' rucksacks.

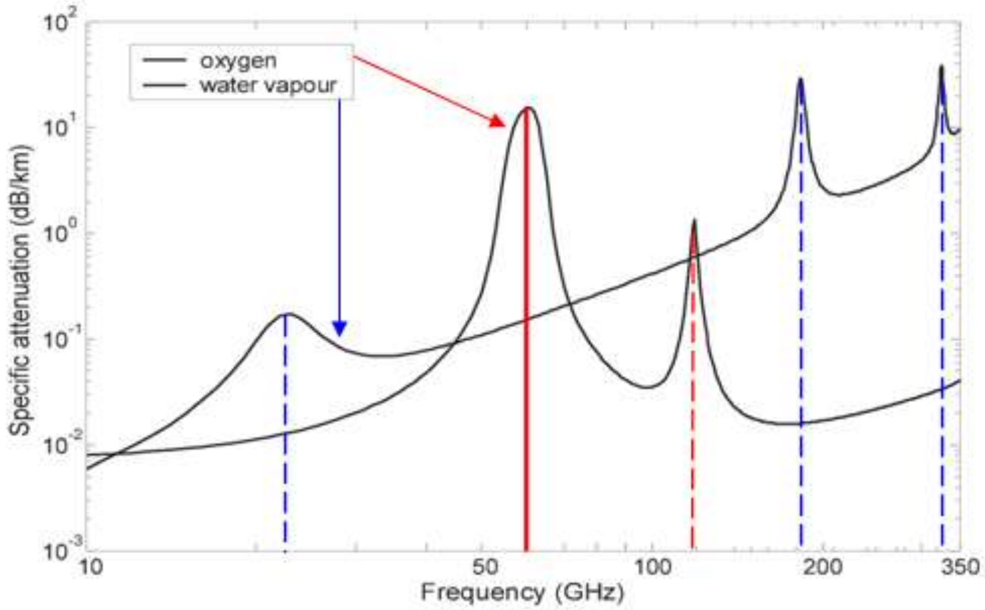
## PROPERTIES OF THE RADIO CHANNELS

When planning radio frequency systems, one of the most important tasks is to examine those physical factors which affect the propagation of the radio waves and the possible services in that given frequency range. In the frequency range of millimetre waves – 60 GHz – the

[9] MH Összhaderőnemi Műveleti Doktrína v 1.0 ZMNE
[10] GPS – Global Positioning System
[11] CCI – Crypto Controlled Items

physical factors of radio propagation are considerably different than in lower frequency channels. The frequency band of 60 GHz is an umbrella-term for the frequency range from 54-67 GHz [12]. For civilian users, a part of the 60 GHz band is free for using (unlicensed) while other parts of the band are licensed. The narrowest band of the unlicensed part is in Australia (59.4 – 62.9 GHz). In Europe the average bandwidth is 9 GHz (57 - 66 GHz) [13].

In microwave channels the most significant difference between the specialties of frequencies originates from the attenuation by atmospheric gases (oxygen, water vapour and nitrogen). Since the nitrogen component's effect on the transmission is only significant in the 300 GHz frequency range and above, table 01 only shows the oxygen and the water vapour attenuations in that band.




**1. figure.** [14]

It can be seen that the peaks of attenuation are formed where the resonance of the polarized molecules is the highest. In the case of water vapour, the first maximum is at 23 GHz with 0,2 dB extra attenuation, the second and the third absorption line is at 183 GHz and 324 GHz with an attenuation of 30/40 dB/km. The resonance of oxygen molecules is 1,5 dB/km in the frequency of 119 GHz, however, it is 15 dB/km in the frequency of 60 GHz which is the maximum of the resonance level [15]. At the edges of the 60 GHz band attenuation can reach 10dB/km. In addition to this, it is necessary to take into consideration the normal open-air power loss (128dB/km) [16]. More attenuation can be caused by vapour (rain) in the air and terrain features, such as mountains, valleys and hills in the way of radiofrequency propagation.

As a result of the above mentioned factors, the 60 GHz frequency bandwidth is mostly used in indoor applications by civilian users. In order to use the frequency range in outdoor military applications, it is necessary to install, operate and maintain (IOM) high-gain beacons such as high directivity antennas and to use line of sight connections between the data transmitter and the receiver. These services often meet the military requirements because they help to accomplish the operational requirements of radio electronic counter-surveillance and the prevention of problems caused by frequency jamming or spoofing. Examining the adaptive antenna systems that may be used, one can find several stationary antennas, whose performance, however, is not suitable for military applications, since the tactical and operational use in the ever-changing battlefield is far from stationary. Military planners and designers should try to find mobile military applications to meet the dual requirement.

Another difficulty for communications planners arises from the fact that the wide bandwidth results in frequency-dependent attenuations, in other words the various parts of the propagated frequency spectrum can be attenuated in different manners. Most channel-models do not take this rule into consideration [17].

For planning and designing a civilian application, several channel models have been developed and are described in scientific essays and articles [18][19][20]. These developments are modelling the civilian office environment, taking into consideration the effect of reflexions and multipath. Special operations forces often fight in built-up areas so these civilian models are also applicable to these special situations. In outdoor operations the probability of line of sight communications is higher but the effects of the environment, such as terrain, vegetation, vehicles, mobility and fading cannot be ignored.

The international frequency allocation defines both the frequency channels and the maximum radiated antenna power. The following wide bandwidth systems are currently under research and development. In the 60 GHz-frequency-range the maximum output power level (EIRP[12]) is allowed due to the fact that attenuation is also the highest in this frequency range. The EIRP for IEEE 802.11n[13] systems is 25 dBmW, and when using UWB only 10 dBmW is approved. However in 60 GHz-channels, it is possible to achieve 57 dBmW [21].

We need to consider other channel attenuations in particular frequency bands. In the case of a radio connection of 1 kilometre, which is actually unreal but easy to visualize even for amateur readers, using maximum EIRP, the UWB system's receiving antenna can measure - 122 dBmW signal level. In the case of 802.11n and 60 GHz, the signal level is - 81 dBmW. Because of the higher attenuation at 60 GHz, the increased EIRP compensates, thus the same received level. In order to choose between the 2 feasible solutions we need to examine further aspects. At 60 GHz a smaller amount of interference can be measured and the signal to noise ratio (SNR) is more favourable than when using Wi-Fi devices. This is primarily due to the increased channel attenuation, which enhances channel separation. However, it is more expensive than Wi-Fi technology (802.11n – 2.4 GHz – 5 GHz) [22].

To measure the data speed of frequency channels, the bit rate in radio communications systems is quantified using the bit per second (bit/s) unit, which corresponds to the radio spectrum bandwidth in Hertz (Hz). Using the expression ultra wide band can be deceptive because the bandwidth depends on the modulation techniques engineers use to design the frequency channels. The order of modulation determines how many information bits can be transported in the given bandwidth, in other words, what is the specific data speed in the channels. The higher modulation process we use the more data symbols can be transported in the frequency channel [23]. The more symbols are used the higher bandwidth efficiency can be achieved. Challenges can emerge when increasing the number of symbols, as the symbols' distinctness is reduced. This effect spoils the efficiency of power-consumption because at a given noise-level, the signal-level measured at the receiving antenna site needs to be increased. It will reduce signal range for a given quality of service. This effect is increased by section attenuations, and consequently the bit losses are also increased, which is a communications challenge (danger) for both conventional and SOF units.

Summarizing the facts, designers have quite a wide bandwidth at 60 GHz. At the same time, higher-order modulations are more complicated to produce and their implementation often requires complicated technologies and is not really cost-effective so they are not the best

[12] EIRP – Effective/Equivalent Isotropic Radiated Power. EIRP is the amount of power that a theoretical isotropic antenna would emit to produce the peak power density observed in the direction of maximum antenna gain.

[13] IEEE 802.11n (2009) is an amendment to the IEEE 802.11-2007 wireless networking standard to improve network throughput over the two previous standards - 802.11a and 802.11g - with a significant increase in the maximum net data rate from 54 Mb/s to 600 Mb/s.

solution for communications planners taking into the consideration the financial cuts in electrical and informatics engineering [24]. If the goal is to design/install a system with 1 Gbit/sec data speed at 40MHz, which is the available bandwidth for 802.11n, 25bit/sec/Hz channel efficiency should be achieved, which is very difficult to realize. However, using the 60 GHz-channels, where 1 communications channel can be broader than 1 gigahertz (in the case of well-constructed radio hardware), the most simple modulation schemes may be suitable. Despite all this, it is worth devoting time and energy to developing higher modulation schemes in the 60 GHz-channels in order to find optimal solutions enabling forward error correction (via redundant bits), robust systems and advanced information security.

The physical dimensions of hardware in 60 GHz are smaller than lower frequency channels, which are favourable for SOF applications. For this reason communications planners have a wide range of possibilities to design physical and electromagnetic defence capabilities that meet the new requirements of electronic counter-countermeasures (ECCM[14]).

From SOF point of view, it is obvious to use this frequency range for SOF wireless communications systems when the distance between the members of the radio network is not more that 100 meters because the ECCM-capability is much better than in the case of other Wi-Fi systems. It is possible, through compromises, to optimize systems for specific applications, which can be used effectively in military (both conventional and SOF) operations.

## ANTENNA SYSTEMS

While the antenna systems are actually, part of the radio channel, because of their importance, they are discussed separately. In 60 GHz-systems the most significant challenge is to produce the received signal level for special radios operated in this frequency range. This challenge can be met by planning a special antenna system to compensate for the radio transmitter system's weaker capability and the increased attenuation. Using special high-gain antennas, the lower level of output power can be counterbalanced. The special antennas radically decrease the electromagnetic radiation, thus reducing the possibility of signal jamming or spoofing, which is a basic requirement in SOF operations.

Using guided (vectored) antennas requires further compromises and can also increase the complexity-level of the hardware. The end-points of civilian systems are stationary [25] but the end-points of military systems (soldiers, vehicles) are always in motion. It requires some kind of radio network topology, where the radios and the antennas need to cover a special polar pattern of electromagnetic signals [26]. In order to satisfy the needs, it is necessary to use adaptive antennas in the soldier's uniform, called body-worn antennas. The solution is to disperse the adaptive antenna sets in the uniform. A more practical solution is to divide the antenna system into subsystems (micro strip antennas), and thus the hardware's mathematical apparatus is responsible for establishing electromagnetic lobes by switching between the subsystems**.** This is the MIMO[15] adaptive antenna system in which the input/output (I/O) channels are phase-controlled antennas. There are 2 levels of channel vector management. On the one hand the system needs to specify the end-points of the I/O channels, and on the other hand it has to manage the electromagnetic radiation of the active antennas attached to the I/O channels. The electromagnetic field is depicted mathematically by vectors and antenna control

[14] ECCM - Electronic counter-countermeasures is a part of electronic warfare which includes a variety of practices which attempt to reduce or eliminate the effect of electronic countermeasures (ECM) on electronic sensors aboard vehicles, ships and aircraft and weapons such as missiles. ECCM is also known as electronic protective measures (EPM), chiefly in Europe. In practice, EPM often means resistance to jamming.

[15] MIMO – Multiple Input / Multiple Output

is based on phase-information, so the system needs to use electromagnetic vectors. To put it more simply, the manageable number of vectors determines the number of end-points and the complexity of control.

The end-point control tasks can be reduced by network interaction. If an end-point is in the centre of the radio network, it is likely to have to connect several end-points. If the storage of channel-vectors is full, a new end-point cannot connect to it. In that case a “third party”, a new end-point is necessary, and a redesign in the adaptive communications network map. The “third party” is extremely important in SOF applications when – in case of operations – the line of sight connection between the SOF operators does not always exist. In that case active repeaters are important. The end-point can operate as a repeater or node centre, which is its intelligent function. This function reduces the possibility of connection fails (channel dropping, bit-loss).

The directional control of the antennas can be done in two different ways. The more simple but disadvantageous way is when the controller chooses the direction of propagation from an internal list and the resolution of the internal list determines the antenna’s gain and loss level. In the case of real adaptive functioning (adaptive antennas) the polar-pattern of body-worn antennas is the result of special individual tuning. This is a time-consuming but more precise method, in which the covered range of antennas and the SNR can be maximized [27].

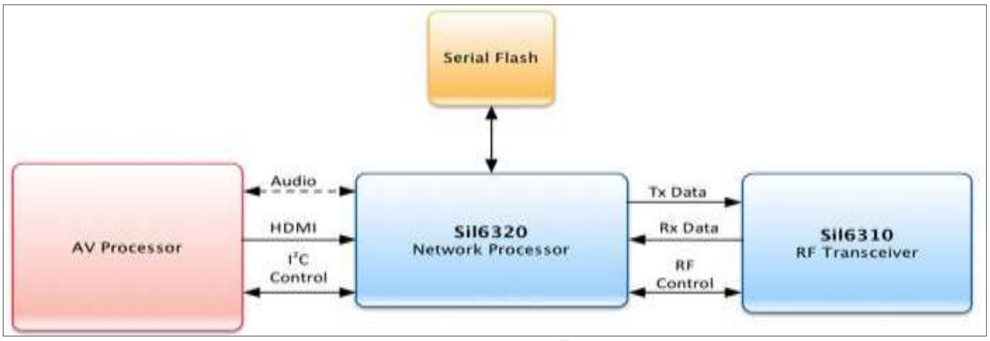
This assumes a special body-worn adaptive antenna system weaved into the uniform. This effort was published in the digital soldier model by the US Army [28].

## CIVILIAN STANDARDS AND DEVELOPMENTS

The commercial exploitation of the 60GHz band is proceeding in two directions. Both the WirelessHD consortium and the Wireless Gigabit Alliance (WiGiG) are developing standards for high-definition (HD) video transmission for personal computers and home entertainment[29] [30]. Both companies are developing version 1.1 of their respective documents. The WiGiG published its brand-new innovation in June 2010 but the full system description is only available to the subscribers of the company. It is entirely based on the IEEE 802.11n standard (for media access control). The goals of the two 60-GHz standards are almost the same: 7 Gb/s data speed for uncompressed HD video transmission, minimum 10 meters transmission range with adaptive directed antennas and the possibility of securing the channels.

Based on these standards, implementation is possible even on a single chip because the dimension factors of 60 GHz circuits are much smaller than the circuits in 2.4 GHz. The WirelessHD is in advantage since its *Silicon Image Sil6300* chips are already on the market. The chipset consists of 2 chips, the *Sil6320* is the network processor which transforms the digital (HDMI[16]) signals for the 60 GHz transmission, while the *SIL6310* is the transmitter-receiver [31].

[16] HDMI – High Density Multimedia Interface




**2. figure.** [17]

Panasonic produces a new chipset by WiGiG standards. The *AR900TB* circuit by Qualcomm is a 3-band-chip, which consists of both the IEEE 802.11n and WiGiG standards. The WiGiG is more suitable for average radio applications, as it was even the basic development philosophy, while the WirelessHD integrates several application elements which are specifically for multimedia services [32].


**3. figure.** [18]

Taking into consideration the application of both standards, they are not directly applicable for military users in military radio devices because they ignore the special needs of military services. The best solution for developers is to use GaAS[19] or CMOS[20]' based radio communications' chipsets and ICs[21]. These parts of integrated circuits would be cheaper and simpler to use and develop in military devices. The controlling algorithms and other basic-level signal processing units can be implemented within an FPGA[22] and attached to the 60 GHz radio communications devices to meet military (especially SOF) requirements.

In the course of development and manufacturing it is worth relying on national and international intellectual capital and practical experience represented by Hungarian manufacturers, engineers, enterprises and companies [33].

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[17] http://www.totaltel.hu/content/03products/031_products.htm
[18] http://www.mwjournal.com/Article/Qualcomm_Acquire_Atheros/AR_10104/
[19] GaAs – Gallium-Arsenide
[20] CMOS – Complementary Metal Oxide Semiconductor
[21] IC – Integrated Circuit
[22] FPGA – Field-Programmable Gate Array

## SUMMARY AND DEDUCTIONS

The special operations forces are specially trained and equipped to accomplish their tasks in the full spectrum of war and crisis response operations. They work mostly independently, in small units. They can be involved in indirect military action in crisis response operations or in providing military assistance and they can also be used in direct action. [34].

All levels of SOF need rapid, ready, reliable and interoperable communications and information systems (CIS) that provide interconnections to another CIS, improve the survivability of CCS and also provide the appropriate bandwidth for high speed communications and information transmission for reconnaissance and intelligence gathering purposes**.** Providing wider bandwidth with smaller devices is a manageable method for military applications especially in SOF applications. These types of devices primarily contribute to the extension of the communications range between SOF units by line of sight using ultra wide band channels to operate HD or HDMI special cameras and other high bandwidth data systems. The body-worn communications and information systems (adaptive directed antennas) increase the operational adaptation of the SOF operator (soldier) and provide a better chance to reach the common goal.

As a result of the development in the area of communications and information systems, the model of a digital soldier is appearing in the military services. The international SOF community will enjoy the benefits of this new development, which will make the SOF capable of adopting higher channel speed (bit speed) by using higher bandwidth, enhance IFF[23] capability and reduce the possibility of frequency jamming and spoofing.

The models described in this article are capable of providing communications and information support for SOF small units in built-up areas using high data speed wireless system applications for transporting voice, data, video signals by HD or HDMI resolutions applying line of sight (direct) communications channels. The aim is to use the systems described above for the transmission of HD video signals both in SOF and conventional operations. This method could be effectively used by explosive ordnance disposal (EOD) personnel. 60GHz is the most suitable frequency range for this purpose.

The current developments are aimed at the better utilization of the benefits of higher frequencies using high resolution video and extreme data speed provided by 60GHz digital channels [35]. National developers need to monitor the changes of the civilian electronic sector and adapt the innovations to military (conventional and special operations) applications.

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