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TECHNOLOGIES AND OPERATIONAL APPLICATIONS OF „TACTICAL" SATELLITE COMMUNICATION

A „HARCÁSZATI" MŰHOLDAS TÁVKÖZLÉS TECHNOLÓGIÁI ÉS MŰVELETI ALKALMAZÁSAI

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Abstract

This paper gives a new and universally applicable definition to "tactical" satellite communication, usually used as TACSAT, contrasts it with other military satellite communication applications, and describes various technologies and operational scenarios related to TACSAT.

Keywords: *TACSAT, satellite communications, command and control, propagation planning*

Absztrakt

Jelen közlemény egy új és általánosan alkalmazható definíciót mutat be a "harcászati" műholdas távközlés részére, amit általában TACSAT-ként említünk. Szembe állítja a műholdas távközlés más katonai alkalmazásaival és bemutat számos technológiát és műveleti forgatókönyvet a TACSAT-hoz kapcsolódóan.

Kulcsszavak: *TACSAT, műholdas távközlés, vezetés és irányítás, rádiós összeköttetés tervezés*

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INTRODUCTION

Beyond line-of-sight (BLOS) communications are especially important during military activities, when we step outside the command and control of combat within an infantry company. That small geographical area can usually be spanned by line-of-sight VHF or UHF combat net radios. But even at an armoured command post designated for the company commander (the PK-2 radio command post in the Hungarian Defence Forces) we find an HF radio, which is the archetypical tool for BLOS. As we move toward higher echelons, where the geographical distance gets greater and greater, the need to communicate far away increases.

A special case of combat C2 is the application of airborne command elements, typically used at brigade and above (Joint Force Command level in the Hungarian Defence Forces, as we can see in the Staff Operations Manual [1]). For such command posts to be effective, given their high organizational position in the command hierarchy and constantly changing physical position on the battlefield, BLOS is an absolute must.

Moving away from the vertical layering of unit hierarchy, different special applications are also dependent on BLOS. Special operation forces, long-range reconnaissance patrols, artillery and joint fires observers are typical examples during conventional ground combat. Urban and mountain operations are even more demanding, as the line-of-sight is broken up by ground clutter and terrain.

In the ground-air domain, close air support and medical/casualty evacuation operations benefit most from the possibility of early and location-independent communications.

As mentioned above, the classical means of BLOS is the HF radio. This is a robust tool, because as long as there is groundwave or ionospheric propagation, it will work. But it requires high power (therefore large, heavy and energy-consuming) power amplifiers and physically large antennas, all of which limit mobility. Moreover, while it is adequate for voice transmission, the data throughput is generally very limited – for higher data rate, even more power and even larger antennas must be used to support higher-order modulations, in addition to the spectrum management issues.

On the other hand, there exists a way to break out of this stalemate. It is possible to use very- or ultra-high frequencies for BLOS, we just need retranslation. This way, the radio propagation between transmitter and receiver is always line-of-sight, but the optimal positioning of the retranslating station(s) ensures that the information propagation can overcome the obstacles. These retranslating or repeating stations are crucial for the operation of the links and the network in the end, therefore they are prime targets and their protection is important above all. In addition to this, the higher they are placed geographically, the greater the radius of their coverage. Putting these two factors together, we can find that the best place to deploy the repeater is on-board a space satellite.

Satellite communication has been used to support military operations for decades, and the applications are numerous. The Hungarian Defence Forces also uses SATCOM, but it is still considered a niche and somewhat exotic application. One of the reasons behind this is the lack of satellite transponder capacity readily available and controlled by military signal specialists to be tailored for the actual needs to support the operations.

In this paper I will describe a part of military SATCOM most often called as "tactical satellite communication" or TACSAT, explain why this name is inadequate and offer corrections, and also describe new approaches to utilize existing military resources to enable higher-intensity SATCOM support for operations during a national defence scenario (or other Article V. operations) and non-Article V.-type military activities.

TERMINOLOGY

The traditional classification of military activities as "tactical", "operational" and "strategic" is nowadays a misnomer. Small units operating "tactically", such as SOF or long-range recon can have strategic importance [2], and while the term "strategic missile" is generally understood as an intercontinental delivery platform carrying a nuclear warhead, no one can dispute the strategic importance of an antitank guided missile, fired by a small infiltrating team, striking a long-range air surveillance radar. On the other hand, a high-flying surveillance platform can transmit the recorded signals (be it visual or electronic/signal intelligence) over "strategic" distances to a rear-echelon or home-based analysis centre, from where the mission-critical products will be transferred back to the battlefield for immediate use by the commanders and their staffs in near-real time "tactically".

Therefore, the term "tactical SATCOM" does not necessarily mean short-range. TACSAT links can connect ground stations hundreds or thousands of kilometres away, or they can span a distance less than 10 km – depending on the operation, the C2 structure and the terrain. They can be used for conveying tactical information, such as artillery fire control, or strategic C2 of SOF strikes [3]. The radios capable for transmitting and receiving voice and data traffic up to the "Top Secret" level [4]. Based on this, a new definition is necessary for the existing term. I propose the following:

TACSAT, as a word and not as an abbreviation, means satellite communication (equipment, services and procedures) used directly for command and control of military activities on the battlefield or operational area. TACSAT uses specialized military equipment in the ground stations, optimized for battlefield use by soldiers.

At the same time, we need another term to describe military SATCOM other than TACSAT. This "other" consists of *reachback from the operational area or battlefield to the home country or a higher command located far away from the frontline; high-rate transmission of raw intelligence or surveillance data and generally the SATCOM support of units and headquarters not engaged in direct combat. Technically this type of SATCOM is accomplished via systems resembling civilian VSAT networks*, and I, for lack of a better terminology, will call these systems military VSAT or MILVSAT in this paper. Readers are welcome to offer a better word.

TECHNOLOGY

UHF TACSAT

TACSAT is traditionally served in the UHF band, specifically, the 225,000 – 399,995 MHz range [3]. Prime examples of hardware for this range are the AN/PRC-117 or -152 radios manufactured by Harris. Some applications in the military Ka-band are coming up, with equipment like the AN/PSC-11 SCAMP Single-Channel Anti-Jam Man-Portable terminal by Rockwell Collins. The Hungarian Defence Forces uses Harris equipment mentioned above, and also the AN/ARC-210 airborne radio (also manufactured by Rockwell Collins) installed on-board transport helicopters.

UHF TACSAT can operate in dedicated single-channel mode, when a physical radio channel is used for the direct support of a selected mission. In this case, the assigned 5 or 25 kHz channel is for the exclusive use of the radio net it is dedicated to. The ground stations are configured (channel number or frequency, and encryption) before deployment and the net is operational in itself. As the radio spectrum is dedicated to the operation regardless of actual traffic, this mode should be used only when the channel is active continuously or when immediate and unconditional access to the channel is required.

The other operational mode of UHF TACSAT, the DAMA (Demand Assigned Multiple Access) is based on a special ground station, the DAMA controller, which assigns time slots to the terminals when they request it. This mode should be used when the traffic to be transmitted is intermittent but the number of ground terminals is large. Depending on the access control scheme and the actual traffic patterns, DAMA can increase the number of potential TACSAT users 4 to 20 times, compared to dedicated single-channel mode. The downside of DAMA is the requirement for the controller itself and for specific admin training to configure it.

A different kind of use case for dedicated single-channel TACSAT is the retranslation of a ground radio net via satellite to a remote operational area; this way practically integrating the two radio nets into one, which would otherwise be impossible because of the distance or other propagation obstacles.

TACSAT, in general, is well-suited for SATCOM-on-the-move or SATCOM-on-the-pause operation. However, in such cases the highly directional antennas used for stationary transmission need to be replaced with antennas with broader main lobe and the loss of gain need to be compensated with higher-power amplifiers.

L band extension of UHF TACSAT

Operational application of UHF TACSAT in practice is restricted by the lack of sufficient satellite capacity. As the antennas on the satellites generally cover the whole visible hemisphere of the Earth and the antennas on the ground can have quite broad beam width, frequency reuse is limited. Therefore, adding new satellites with similar capabilities would not help much. The civilian satellite service provider Inmarsat recognized this problem and, cooperating with British manufacturer Spectra, developed a solution to enable military forces to offload part of the UHF traffic to the civilian L band satellites of Inmarsat when operational security constraints permit it. This service is called L-TAC, and the equipment required for the use of L-TAC is called SlingShot [5].

The L-TAC service is provided via the I-4 satellites of Inmarsat, the same satellites that carry the commercial BGAN, SwiftBroadBand and FleetBroadBand services. These satellites are very capable, high-power space vehicles, but of course they lack the hardening of military satellites. On the other hand, these satellites generate spot beams, therefore they provide spatial isolation within the hemispherical coverage area, which offers some protection against ground-based jamming.

L-TAC, in contrast with the aforementioned commercial services, is not billed after use, but the assigned satellite capacity is actually leased by the user and is always available, just like the UHF service. It is the responsibility of the user to design and deploy the communication network based on the leased capacity, be it dedicated single-channel mode or DAMA (the DAMA controller is also the responsibility of the user).

The greatest difference between L-TAC and UHF TACSAT is the spot beam-based frequency reuse, which means that the leased bandwidth is available only within the spot beam (ground diameter of 1000 km approximately) or the regional beam (ground diameter of 3000 km approximately), as seen on Figure 1. Tailor-made coverage can be configured by Inmarsat based on user requirements, connecting neighbouring or faraway spot beams within the hemispherical coverage of the satellite. This way the coverage can be adapted to the operational area, while frequency reuse remains available outside.

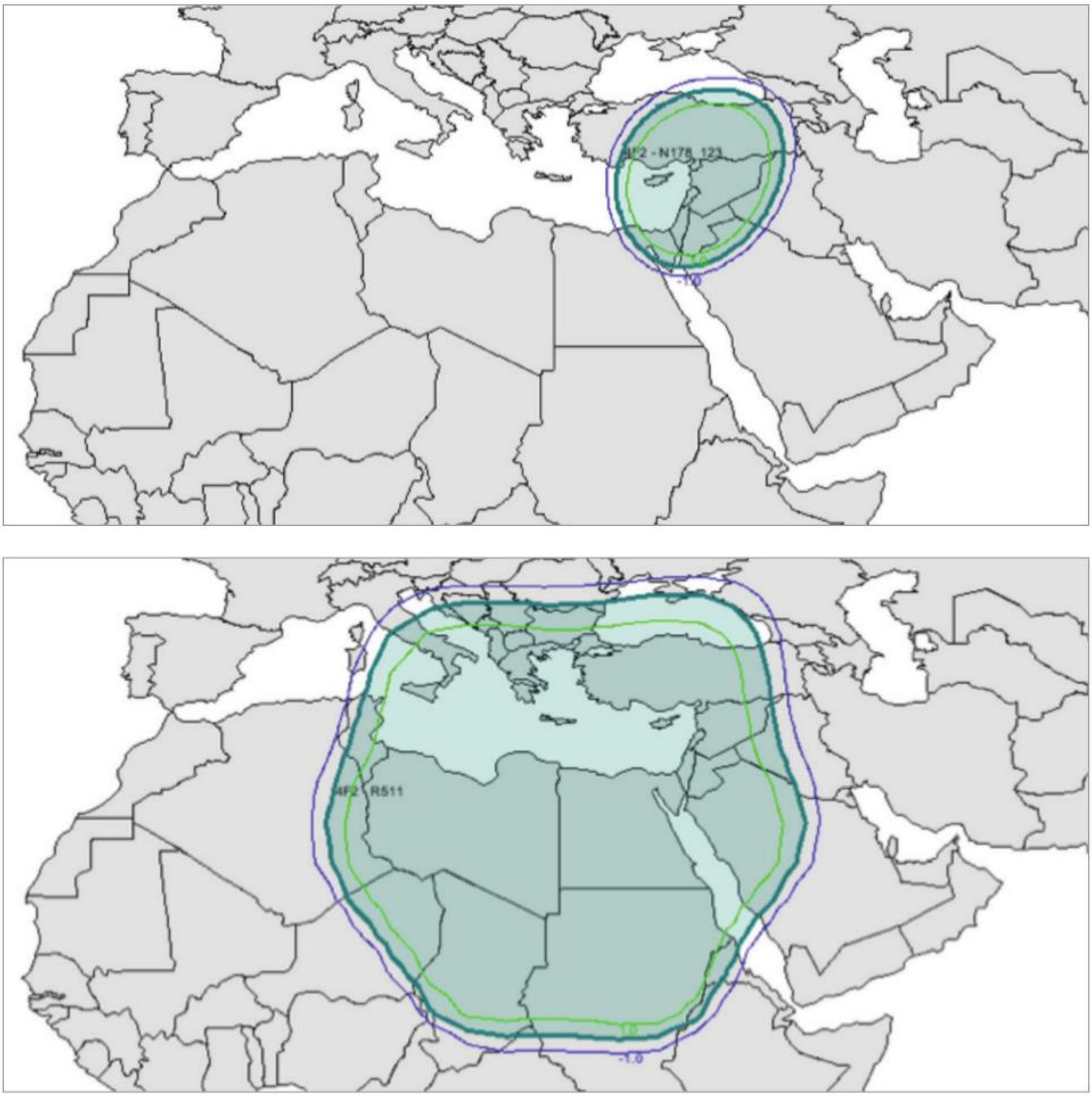


Figure 1: L-TAC beam examples (spot beam on top, regional beam below) [5]

L-TAC uses the existing UHF TACSAT radios as ground terminals, making training and deployment easier by reducing equipment diversity and logistical footprint. As these radios, by definition, operate in UHF and the satellites in L band, a converter and a matching antenna is needed to make the system work (Figure 2). The SlingShot unit transparently converts the UHF spectrum present on the antenna connector of the base radio and radiates it towards the satellite. On the receiving side the SlingShot downconverts the L band signal to UHF and the base radio can process it just like native UHF traffic. The SlingShot does not restrict the capabilities and services (such as voice or data transfer, or encryption) of the base radios.

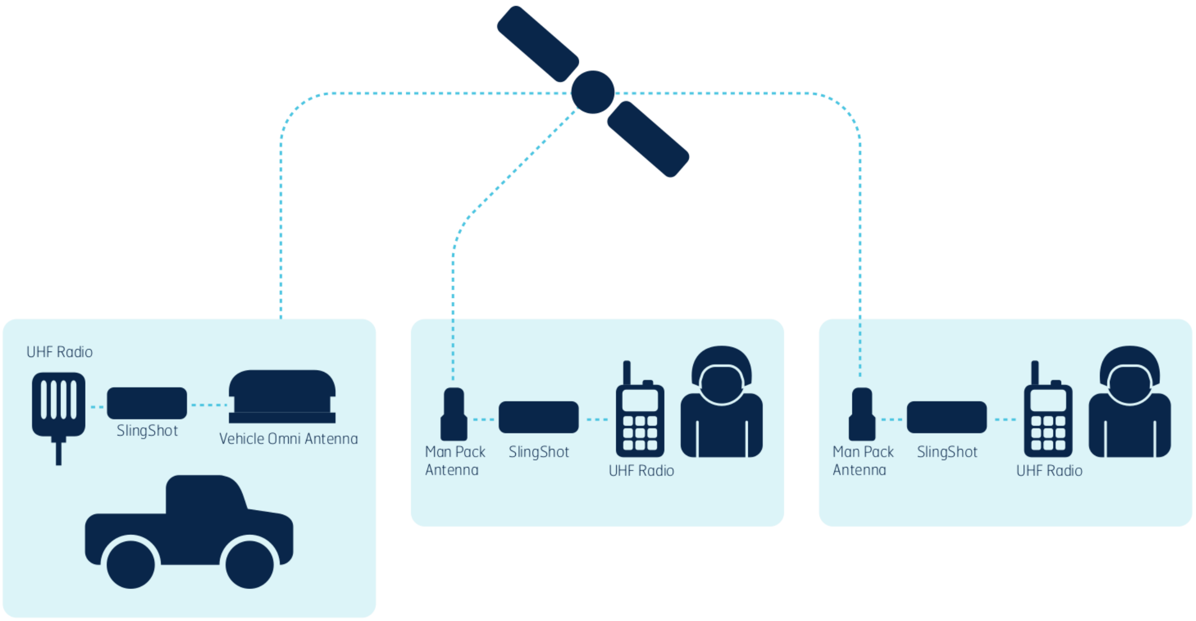


Figure 2: Connecting SlingShot to existing radios [5]

Based on the applicability of military radios approved to carry classified operational C2 traffic, two out of the three criteria of information security is met, that is, confidentiality and integrity. The remaining third, availability can suffer when the risk of deliberate attack (be it kinetic, electromagnetic or cyber) on the satellite and associated ground infrastructure is present. In such cases only the military UHF satellites provide adequate service. But every other time, for example during training or during military activities other than war, L-TAC and SlingShot is a useful tool for the soldiers. Another property of L-TAC to be considered is the significantly higher operational frequency, when man-made and natural obstacles provide much higher attenuation and masking than even in UHF. As the only concern is a free propagation path toward the satellite, the antenna can be installed in positions where the ground-level propagation toward the enemy is blocked, denying enemy electronic warfare receivers of input signals, guarding own units against detection, direction-finding and interception. This blocking is much easier to achieve in L band than in UHF.

The SlingShot is available in "manpack", vehicular, maritime and airborne configurations for military VHF (58-88 MHz), military UHF and civilian VHF frequencies, all of which is interoperable as long as the base radios have common interoperable waveforms.

All in all, L-TAC, SlingShot and the military TACSAT radios together meet the "GOVSATCOM" definition by the European Defence Agency, which describes a resilient and assured service, but not as hardened as military SATCOM [6].

SlingShot can be installed in the radio station permanently, or can be used as a temporary add-on.

Manpack version provided by Spectra is optimized for attachment to combat loadbearing vests. On the contrary, the vehicular version is prepared for permanent installation. The middle ground is the "Walk-On Fit", which is marketed for airborne systems, but as the internal contents are identical to the manpack, it is possible to use it on the ground.

Capacity management, as mentioned before, is the responsibility of the user party, as Inmarsat provides a transparent radio channel. The basic contracting unit is one spot beam, at 25 kHz bandwidth, for one month.

Capacity management in the spatial domain is concerned with matching the spot beams with the operational area. When one spot beam cannot cover the required area, Inmarsat can connect any required number of spot beams.

Capacity management in the frequency domain is concerned with assigning the 25 kHz bandwidth as a whole to the mission, or cutting up the bandwidth into 5 kHz segments to support several missions at the same time, based on the information transfer requirements, C2 structure and radio waveforms. For larger operations, one 25 kHz channel might not be enough, but a second or even third channel can be ordered from the service provider.

Capacity management in the temporal domain is concerned with assigning channels to actual activities within the mission, and reassigning them to different user groups when the operational tempo makes it necessary.

Military VSAT

MILVSAT is traditionally served in the X band, but often commercial VSAT services over C or Ku band are used also when the lack of threats to the SATCOM service infrastructure permits it. High-throughput Ka band services are coming up. As this paper focuses mainly on TACSAT, MILVSAT is only mentioned when it cooperates with the TACSAT services for extension and augmentation, and also to explain the different use cases.

Based on the limited channel bandwidth of UHF TACSAT, the practical data throughput of such systems is generally 64 kbps or less, even down to the less-than-one kbps range (used in maritime C2 systems). This make UHF TACSAT unsuitable for raw intelligence or surveillance data transfer or to transfer large amount of background information which the commanders could use during the formulation of their plans. MILVSAT, on the other hand, is well suited for such applications, as the multimegahertz-bandwidth channels, backed by high-power amplifiers and relatively large aperture antennas can support the transfer of data in the 10+ Mbps range. This means that MILVSAT is better applied to connect deployed headquarters and intelligence/surveillance data aggregation nodes.

SATCOM-on-the-move application of MILVSAT is possible, but this is very wasteful of satellite bandwidth (because of the inferior radio properties of the small antennas), so it should be used only when it is absolutely necessary (such as airborne command posts or mobile intelligence platforms).

However, as the satellite capacity (even with added civilian capacity, if permitted) is a scarce and expensive resource, consideration must always be given to use terrestrial communication technologies, such as HF radios (even in ground-wave or near-vertical incident sky wave mode) for the replacement of TACSAT, and troposcatter relays as a replacement of MILVSAT, thereby relieving the satellite-based systems and enabling the communication planner to use those to support the missions really in need of them.

OPERATIONAL SCENARIOS FOR TACSAT

In this section I will present several operational scenarios for standalone TACSAT use and also the integration of TACSAT and other telecommunication services.

Air-ground integration – Close Air Support or Medical/Casualty Evacuation

Ground-air communication is traditionally done in the UHF band via line-of-sight connections. The geographical and operational environment can severely restrict this line-of-sight in practice, especially in urban or mountainous terrain and when the aircraft (typically helicopters) must perform low-altitude (nap of Earth) flying.

TACSAT extends communication distance out to the airbase or forward operation base where the supporting aircraft is departing from, so the aircrew can be directly connected to the

JTAC, JFO or terminal guidance operator any time, when any party requires it, and both of them can perform their duties as efficiently as possible. Most of all, the ground operators can provide as much information to the aircrew as they have, without time restrictions, because they can start briefing earlier; and the aircrew can fly the aircraft using maximum terrain masking as a cover against detection and enemy fire, while receiving and even relaying tactical intelligence from the rear (Figure 3).

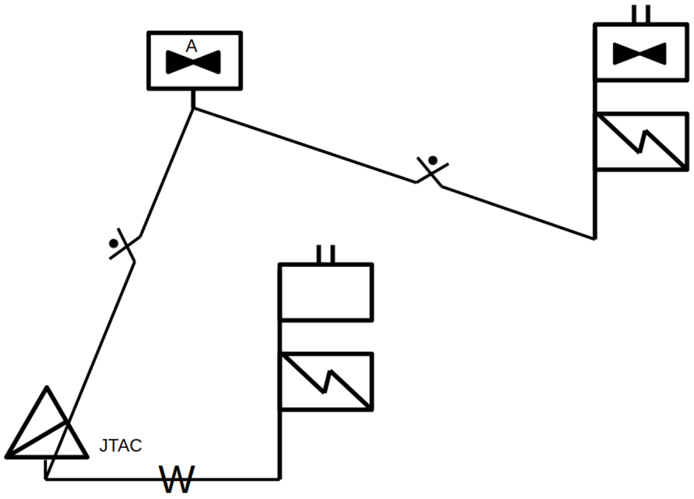


Figure 3: TACSAT connection of attack helicopter with JTAC and helicopter base
(image created by the author)

The same is true for the MEDEVAC/CASEVAC scenario, when the status of the casualties can continuously be reported to the approaching aircraft and when they are being airlifted, to the receiving medical facility.

Ground-ground integration – Extension of short-range tactical nets

Tactical C2 of ground units is traditionally done in the VHF band via line-of-sight connections, and HF via groundwave propagation. Again, environmental factors can be problematic for VHF, although this band is somewhat more resilient. Link geometry and terrain obstacles, however, can only be overcome by raising the antenna higher, but this is practically impossible when the radios are carried by soldiers or are mounted on moving vehicles. During conventional combined-arms operations, when squads, platoons, companies are organized hierarchically and deployed accordingly, the distances are within VHF range. The case is different during peace support operations, when the operational areas are significantly greater; or when the unit is deployed outside the geographical boundaries of its superior unit as a forward-deployed screening or security force. In such cases the distances might be too great for VHF (the Combat Manual of the Hungarian Defence Forces specifies the distance of the battalion-level forward-deployed screening force during marches as 30-40 km from the main body [7]), but at the same time, the information to be transmitted might be too much for HF to convey (Figure 4).

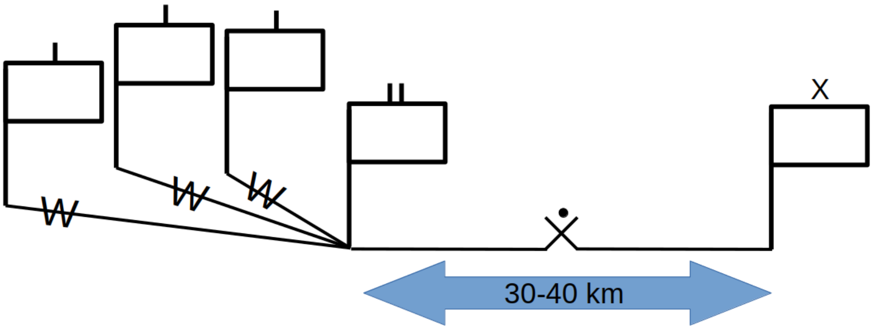


Figure 4: Extension of forward-deployed radio net toward the rear (image created by the author)

In this scenario, the internal radio network of the unit is based on ground VHF or UHF, with as low radiated power as possible to make the task of enemy direction finding units harder. The connection of the unit commander and the higher-echelon command is provided, at the same time, via TACSAT. Terrain masking and the use of directional antennas (when possible) minimise the probability of detection.

TACSAT-MILVSAT integration – Reachback toward operational or strategic command

When the operational area is far away from the higher-echelon C2 elements, they might not be in the same satellite footprint. This is very much possible when using L-TAC spot beams (as they are approximately 800-1000 km in diameter), but can even happen with UHF, when units are deployed overseas. Military operations of strategic importance sometimes require near-real time oversight and (military or even political) decision-making from a C2 element stationed in home territory. In this case SATCOM is the only viable solution to establish connections between the fighting force, the in-theatre command element and the home territory. Retranslation is required between the various SATCOM network to span the (sometimes intercontinental) distances (Figure 5).

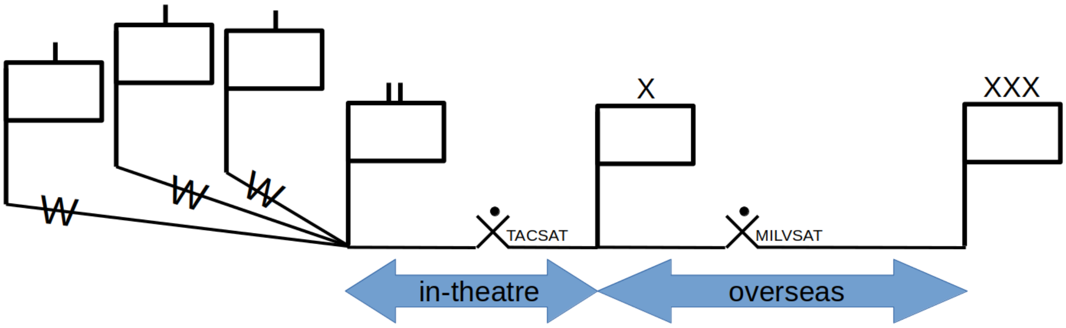


Figure 5: Extension of in-theater radio and TACSAT net toward home territory (image created by the author)

As pricing of L-TAC is based on the number of spot beams, economical factors (in addition to operational and coverage-dependent constraints) also favour reachback connection via MILVSAT instead of via shaped L-TAC beams.

Airborne command post operation

As mentioned earlier, the Staff Operations Manual of the Hungarian Defence Forces defines the Airborne Command Post as a C2 element of the Joint Force Command, specifically, as a subsection of the Main Command Post. In addition to this, the Forward Command Post of the JFC can also operate a Mobile Command Element, which can be deployed onboard a helicopter (Figure 6). We can see examples of airborne command posts installed onboard helicopters operated by brigade-level commands, the prime example is the Army Airborne Command and Control System used by the U.S. Army.

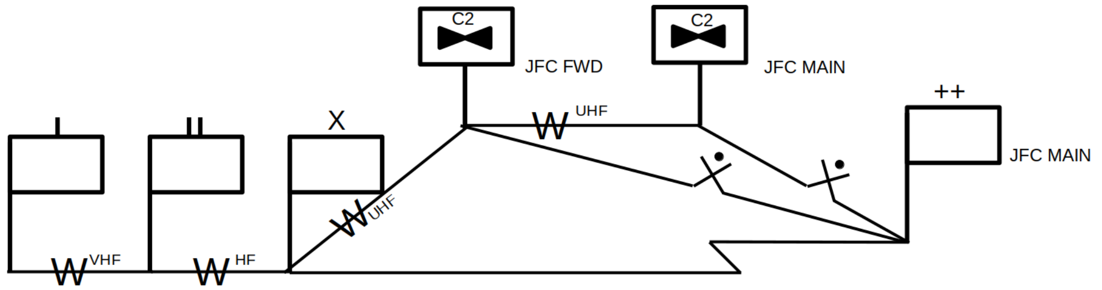


Figure 6: Various terrestrial, air-to-air and satellite networks of a deployment with airborne command posts (image created by the author)

There is no active airborne command element used by the Hungarian Defence Forces right now, but the A2C2S can be seen as a good, operationally proven example, and there we surely can find satellite communication systems for high-speed data transfer to connect the onboard C2 network to the ground networks. As the A2C2S was designed to support Operational Iraqi Freedom, a civilian service, specifically, the Inmarsat BGAN was selected for this purpose [8]. Military Ka band high-throughput links can replace BGAN, or TACSAT also can be used (via UHF or L-TAC) with high-performance waveforms, which can provide up to 64 kbps datarate, and that is equal or faster than the terrestrial VHF combat net radios.

MODELLING OF VHF AND UHF PROPAGATION

In this section I will illustrate Beyond Line-Of-Sight in practice to emphasise the importance of TACSAT, as the horizon on the battlefield is much closer than some might think. Selected “operational” areas within the boundaries of Hungary will be examined using the radio propagation modelling software SPLAT! for area coverage [9].

SPLAT! stands for Signal Propagation, Loss And Terrain analysis, which is a very powerful free software created by John Magliacane, KD2BD, and distributed under the GNU General Public License Version2. The digital terrain model used by SPLAT! is created from the Shuttle Radar Topography Mission flown on-board Space Shuttle Endeavour during STS-99 in 2000. The elevation data was generated by a C and X band combined synthetic aperture radar. SRTM data is released in two versions, the 3-arcsecond version provides approximately 90 meter, while the 1-arcsecond version provides 30-meter resolution. SPLAT! has two operational modes accordingly, splat and splat-hd. This paper shows imagery generated by splat, as these lower-resolution images serve just as well for our case, and the time taken for area coverage map generation by splat is significantly shorter than splat-hd.

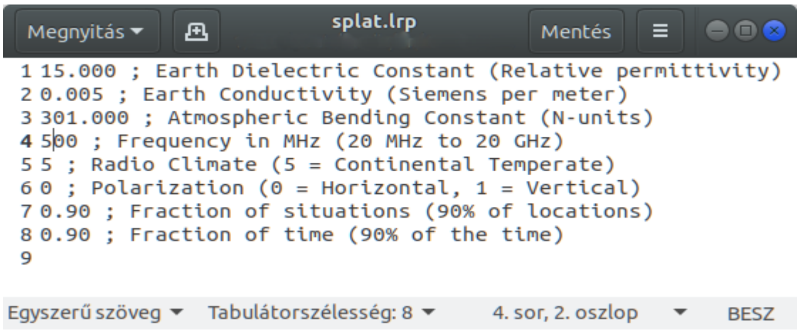
The current version of SPLAT! uses the Irregular Terrain With Obstacles Model (ITWOM) for propagation calculations. Earlier versions used the standard Longley-Rice (Irregular Terrain) model, and the next version will return to this again.

SPLAT! creates text reports, terrain profiles with various parameters via gnu plot in .png format, and area maps in Portable Pixmap (.ppm) and Google Earth Keyhole Markup Language (.kml) formats. With .kml, it is possible to overlay the generated coverage area map onto Google Earth maps or satellite imagery for better visual interpretation. The grayscale .ppm maps are better suited for the analysis of the effects of the terrain itself (however, as .ppm is a very inefficient file format, the pictures should be converted first).

SPLAT! is a Linux command line software which uses parameter files and command line operators as inputs to model the radio wave propagation. Selected parameter files and commands will be shown which I used during propagation modelling. SPLAT! can be operated via batch processing, when all the parameter files and commands are prepared beforehand, the parameter files saved in their respective directories while the commands entered into a text file saved as a batch script. Calling the batch script instructs SPLAT! to start modelling and the computer can be left alone (large combined coverage map calculations with several emitters and multiple emitter parameters can easily take a night). On the other hand, a point-to-point analysis gives back a comprehensive text report within seconds.

SPLAT! in its original form is a very versatile tool which can support the radio link engineer in every step of link design and evaluation. It is used (among several others) by utility companies to design SCADA networks, wireless internet service and broadcast service providers to generate radio license applications, and scientific projects to model radio propagation on the Moon and Mars, using appropriate radio climate data and terrain elevation databases. Moreover, as a free software, the source code is available and can be modified to customize its operation.

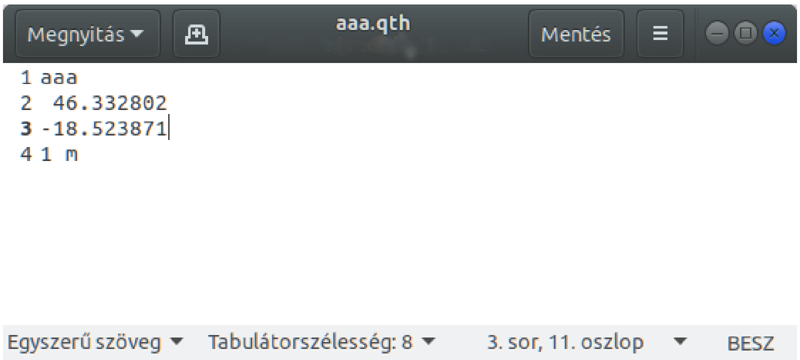
Example of the Longley-Rice parameter file used for the calculations can be seen on Figure 7, while an example of the radio station parameter file is shown on Figure 8.



```
15.000 ; Earth Dielectric Constant (Relative permittivity)
0.005 ; Earth Conductivity (Siemens per meter)
301.000 ; Atmospheric Bending Constant (N-units)
500 ; Frequency in MHz (20 MHz to 20 GHz)
5 ; Radio Climate (5 = Continental Temperate)
0 ; Polarization (0 = Horizontal, 1 = Vertical)
0.90 ; Fraction of situations (90% of locations)
0.90 ; Fraction of time (90% of the time)

```

Figure 7: Longley-Rice parameters typical for Central European farmlands and forests (image created by the author)



```
aaa
 46.332802
-18.523871
1 m
```

Figure 8: Station data file with station name “aaa”, located west of Szekszárd, antenna 1 meter above ground (image created by the author)

Coverage maps and terrain profiles are generated regarding the 4/3 Earth radius rule of atmospheric radio propagation. The model examines masking by the natural terrain only, the effects of structures and the attenuation by vegetation is not calculated.

SPLAT! propagation analysis over flat terrain

This analysis shows theoretical area coverage over Kiskunság region of Hungary (transmitting station located at 47 degrees North, 19,4 degrees east), with the transmitting antenna 3 meters above ground, receiving antenna 2 meters above ground. These antenna heights represent vehicular radio stations.

The .kml file generated during the analysis was imported into Google Earth Pro, and its transparency was set to approximately 50% (unfortunately, Google Earth does not allow transparency level to be entered in numeric form). This makes it possible to see the surrounding terrain.

As we find, even with this relatively flat terrain, the line-of-sight rarely reaches the yellow circle with 10 km radius (Figure 9).

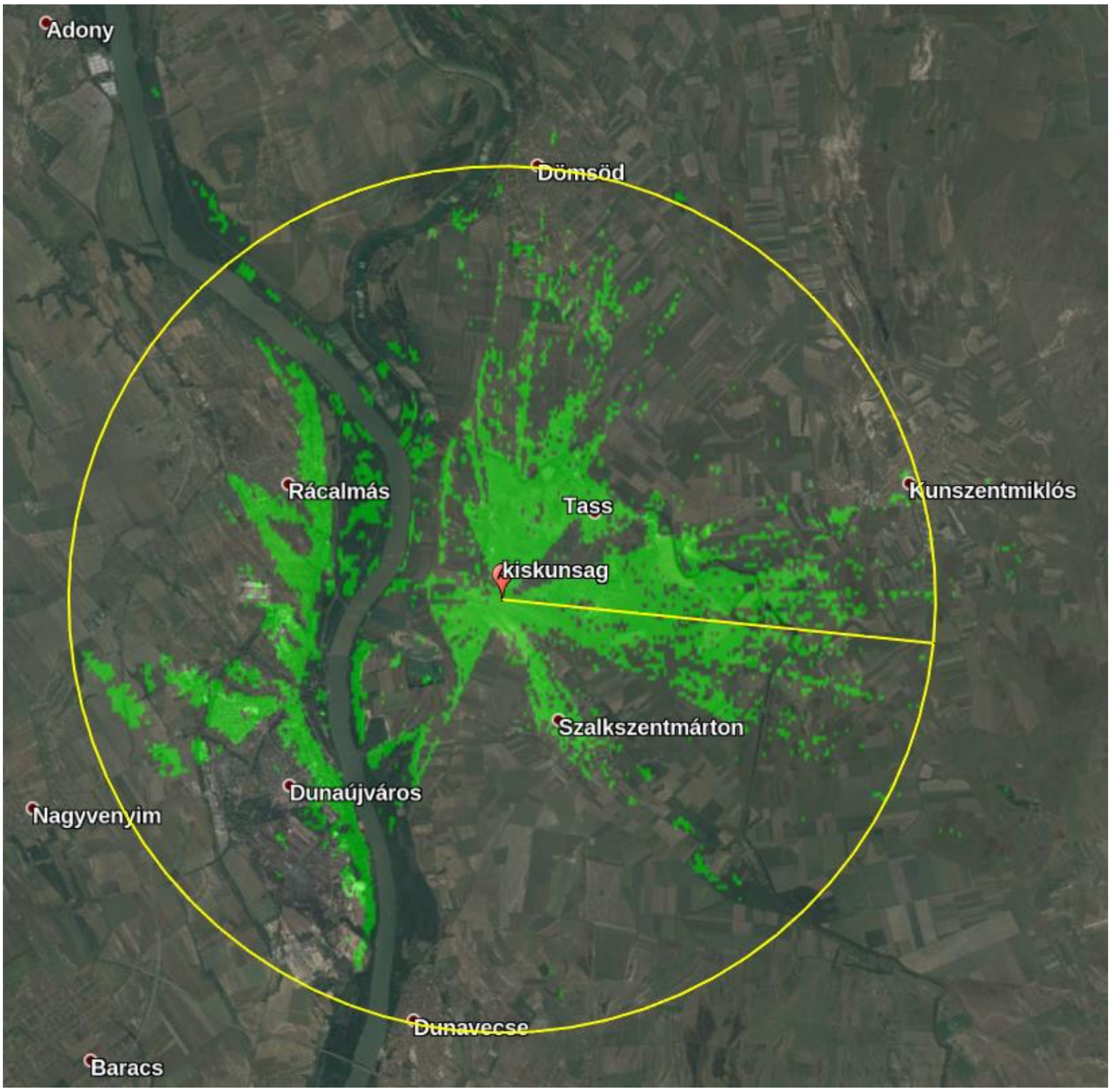


Figure 9: Ground-ground, flat terrain coverage area map overlaid on Google Earth satellite imagery (image created by the author)

In an air-to-ground scenario, with the helicopter flying at 100 meters above ground level, the coverage extends to 18 to 50 km (worst case to the west and best case to the east, respectively, Figure 10), which is about 3,7 to 10.2 minutes of flying time for an Mi-24 helicopter at cruise speed [10].

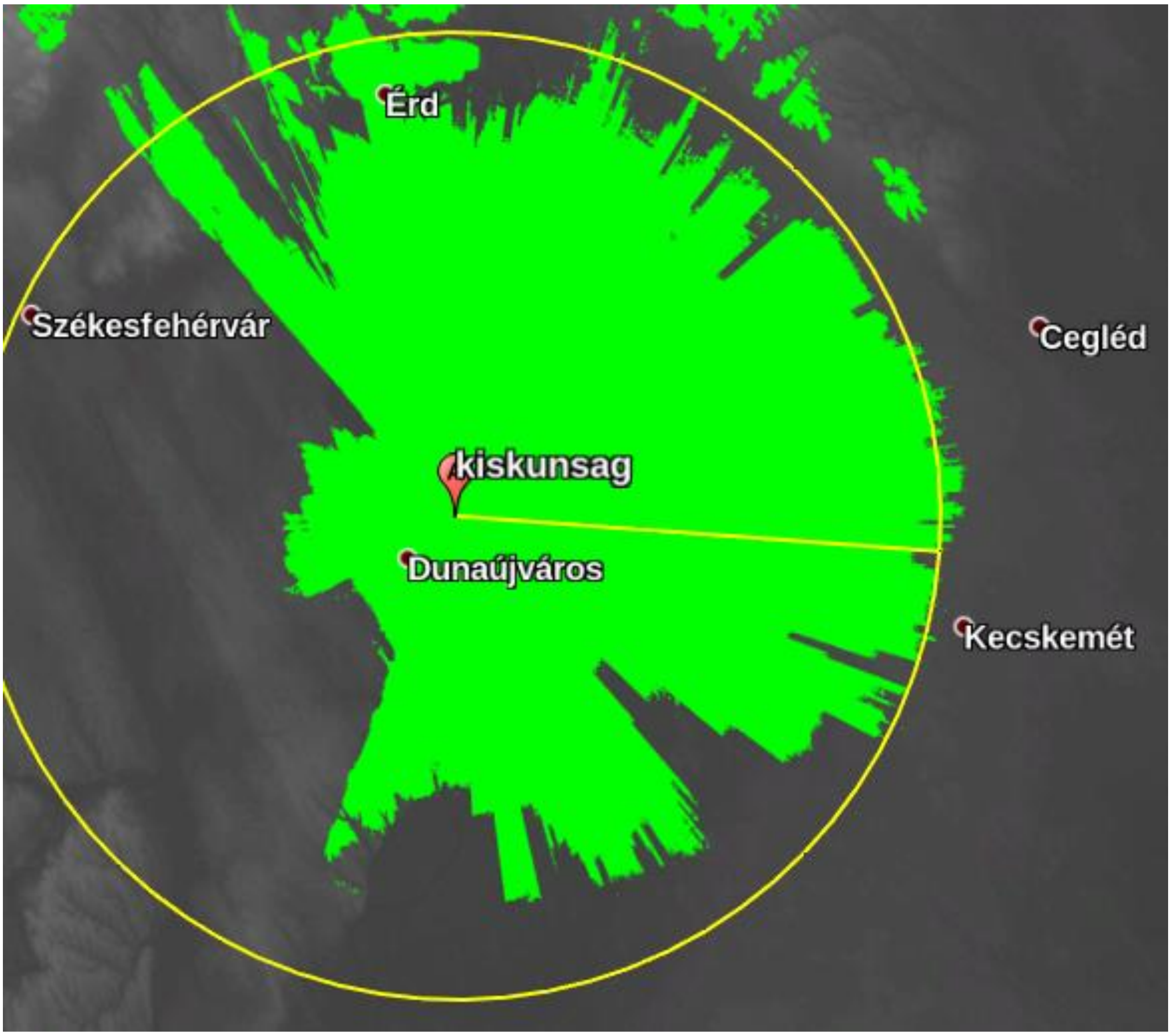


Figure 10: Ground-air, flat terrain coverage area map (image created by the author)

SPLAT! propagation analysis over rolling terrain

This analysis shows theoretical area coverage over Zselic region of Hungary (transmitting station located at 46,25 degrees North, 18,11 degrees east, just outside the town of Sásd), with similar antenna heights. The generated .kml file was also processed the same way as described above.

The command line used for this analysis was:

```
splat -metric -m 1.33 -t zselic.qth -c 2 -o zselic.ppm -kml zselic.kml
```

where the `-metric` switch instructs SPLAT! to calculate with heights in meters (instead of feet, which is default), the `-m 1.33` switch defines the 4/3 Earth radius multiplier, the `-c 2` switch defines the height of the receiving station antenna above ground (the transmitting station antenna height is given in the station .qth file), and the rest defines the various input and output files.

The rolling terrain makes the job of the radio planner very hard, as the terrain breaks up the line-of-sight. The yellow circle in this case has 2,5 km radius only (Figure 11)!

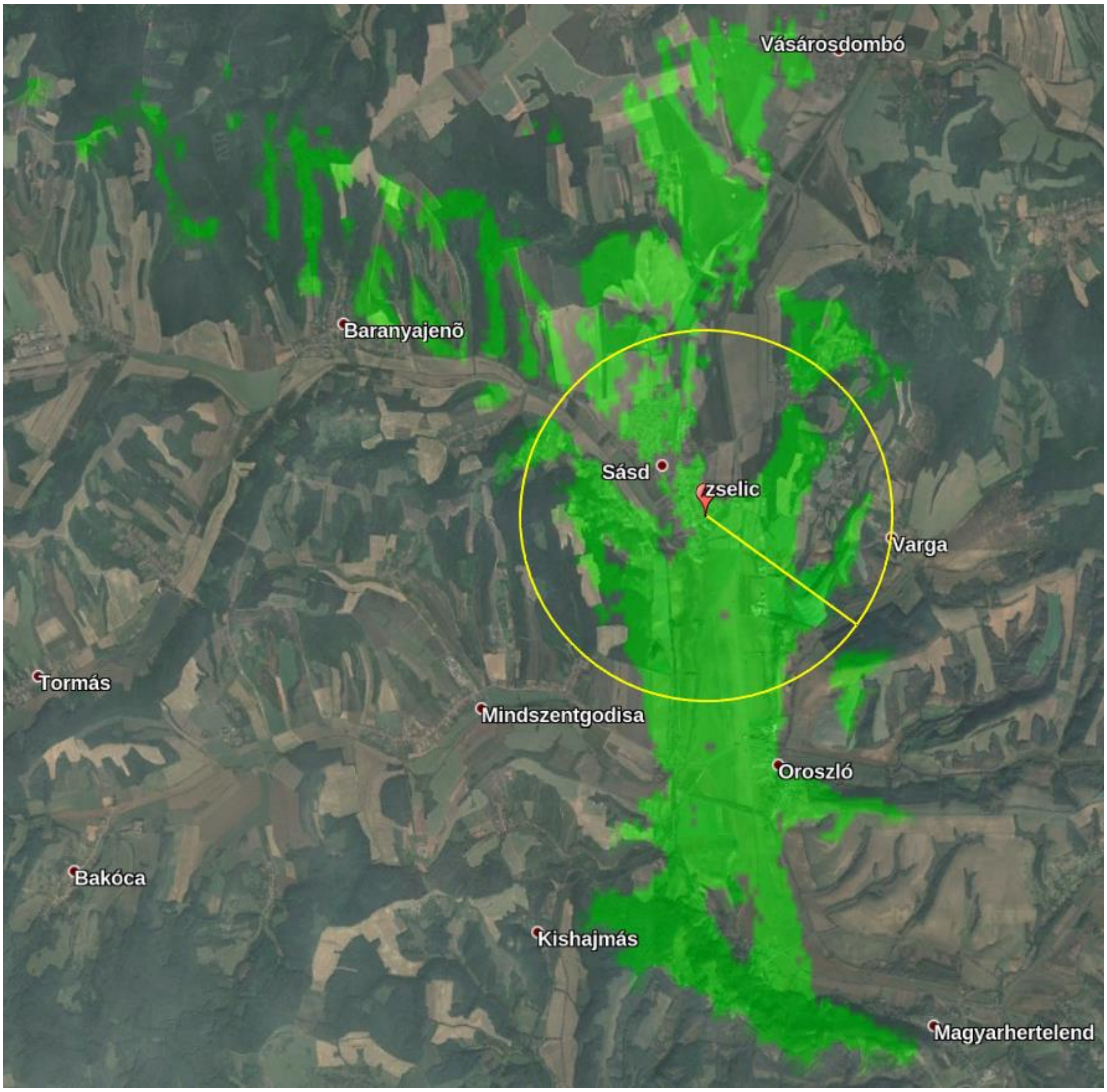


Figure 11: Ground-ground, rolling terrain coverage area map (image created by the author)

For the ground-air operation, again with an aircraft flying 100 meters above ground level, we get an unequivocal picture. To the east and west the line-of-sight is only 3 km, it goes up to 12 km to the northwest, 18 km to the south, but extends out to 35 km towards Dombóvár and beyond (as shown by the yellow line and circle), as in this direction the hill country changes into flatland (Figure 12). These distances correspond to 0,6, 2,4, 3,7 and 7,1 minutes of flying time for the Mi-24, respectively.

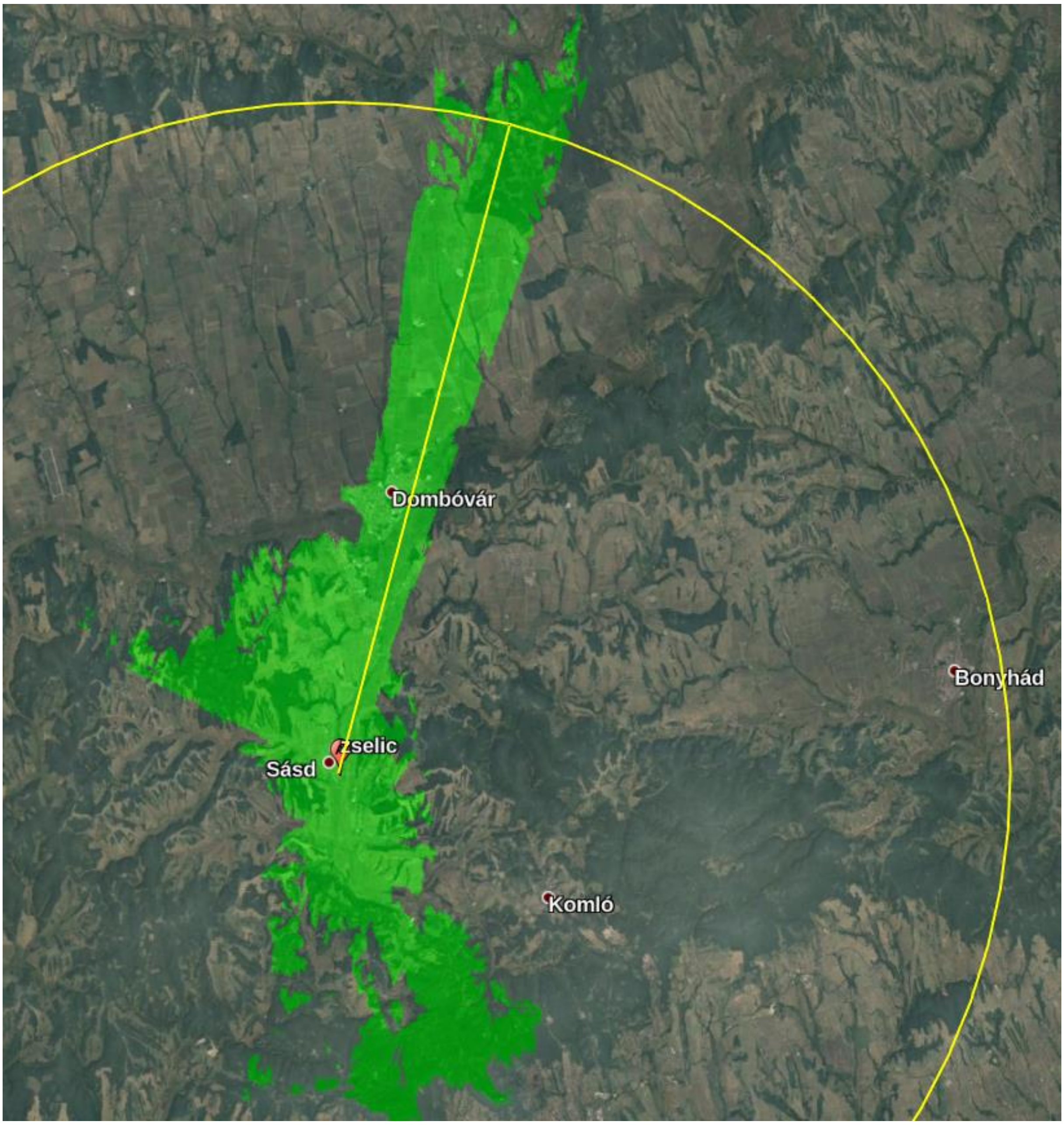


Figure 12: Ground-air, rolling terrain coverage area map (image created by the author)

CONCLUSIONS

In this paper I described and defined tactical satellite communications as used by military forces for the operational command and control of deployed units. TACSAT is known by Hungarian signal personnel, but is rarely used, for the lack of readily available satellite capacity. This is a waste of expensive equipment, and might cause problems because of insufficient training of combat and combat support forces. In my personal experience, based on discussions with military personnel serving in the forces of spacefaring nations who operate their own military communication satellites, this shortage cannot be overcome by money only. The demand for TACSAT is so huge that simply there is no bandwidth to sell.

However, the L-TAC service developed by Inmarsat is just the answer from the business side: Inmarsat has satellite capacity, and selling this capacity is their job. With the addition of the SlingShot equipment package to the existing AN/PRC-117, -152 or AN/ARC-210 radios, our radio terminal operators could be trained intensively in the technological details of

TACSAT, and the operators supported by this type of communication could get realistic operational training.

We have seen how broad is the range of operational scenarios when BLOS communication is necessary and TACSAT is by far superior to HF regarding bandwidth and resilience to enemy electromagnetic warfare.

In the final section of this paper I have shown how close the horizon is, beyond which the deployed soldiers often need to broadcast, when seen from the ground. In the case of dismounted soldiers, it is even closer. In addition to this, the operational areas assigned to units are likely to get greater, which also forces us to realize that over-the-horizon radio communication is not the exception, it is pretty much the rule.

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