Maximum Operating Range for RF Communication of Tactical VHF/UHF Networks

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Abstract – **For analysis of Maximum Operating Range of VHF/UHF Communication, the Hata-Okumura propagation model is used. In the latter, according to the military standards, different modulation techniques are researched, which are used for Tactical Communication. In this paper the mainly used modes, such as voice and data communication and synchronization, are presented. The values of receiver sensitivities of the radios are taken from MIL-STD Standards and the characteristics of the most popular tactical radios, which are used around the world. Conclusions and recommendations are made for the building of the Radio Cannels in Security Services Control and Management.**

Keywords – **Ultra wide band, pulse position modulation, time hopping, delay hopping**

I. Introducion

Nowadays the communication between different people (or groups of people) is a integral part of human life. For instance are used improved and newer systems especially for security service management after the world changes after the attacks against World Trade Center in New York in 2001.

These changes in the world have increased the security service requirements too. A support of reliable and secure performance for each operation is usually determined by stable communication with maximum operation range. This would be realized by means of interaction in very good quality between different participants and high coordination on operation stage. It sets a part radiocommunication as one of fast growing branches of high technology. This approach provides secure communication between mobile objects on huge distances with radio networks. VHF/UHF is used Band for security services managements, according to the ITU standards. The main radio links of Police and Army are established in these bands.

II. VHF/UHF Point-to-Point Communication

Single channel VHF/UHF radios are used for establishment of direct connection (point-to-point) between mobile users and command. They work in $100 \div 512$ MHz Frequency Band. In the most cases these radios are unique communication equipment of Special Forces, according to the requirements that they are communicated into the area of special operation. This demands high quality of tactical & technical parameters as the most important are [5]:

- Maximum protection against radio intelligence of the enemy (ECCM – electronic contra-contra measure);
- Communication service without searching and adjustment;
- Work in high jamming conditions (ECM – electronic contra measure);
- Minimum communication duration without stops and repeats;
- Information security transmission;
- Selected user calling or selected user groups.

All of these hard technical requirements can be met using of different operation modes. Incapability of old radios to satisfy high tactical & technical parameters, connected mainly with ECM independent of the enemy or crime and current technology development, has brought a qualitative leap to contemporary radio communication equipment development. DSP is implemented everywhere and every module uses computer management. Standards with high requirements against RF jamming (MIL-STDs) were created for improvement of ECCM and increase of battle possibility of RF communication in ECM conditions in NATO.

One of the fastest and secure ways for quick transport of special groups for a mission is used by Air Craft. Air Traffic Control and the linking between command point and special group is usually organized with VHF/UHF radios. For example many VHF/UHF Air Craft Radios are utilized in NATO Air Force and national polices. Harris radios are built in AH-64D Apache, Bell 206(406), Sikorsy and etc. Rohde & Schwarz is the basic contactor for Eurofighter-2000. Besides other world leaders of RF production present VHF/UHF radios on the market. The most popular radios, their modes, the used modulations and the basic technical parameters are presented in Table 1 [4, 6-11].

For hidden management of any mission it's quite important to know the maximum operation range where reliable and secure RF communication can be provided. It depends on the following:

- Carrier frequency;
- Conditions of radio wave propagation;
- Output power;
- Receiver's sensitivity;
- Operation modes;
- Modulation and etc.

The most important circumstance for establishment of any RF connection is to appear information signal with necessary power, according to the chosen mode, on the receiver's

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Table 1.

Radio Manufacturer (country)	**BASIC SPECIFICATIONS**						
	Frequency Range (MHz) Power Output (W)	**Channel Spacing (kHz)**	**Emission Modes (Functions)**	**Modulations**	**Data Interface**	**Sensitivity (dBm)**	**Data Rate**
RF-5800U-MP Harris (USA)	90 ÷ 420 MHz 20 W FM; 10 W AM	5, 6.25, 8.33, 12.5, 25 kHz	Analog Voice, 16 kbps CVSD Voice, 16 kbps Data	AM, FM, ASK/FSK	Synchro-nous or asynchro-nous 75 ÷ 115 kbps RS232/422	FM– 116 dBm; AM –110 dBm for 70% modul.; minimum for 10 dB SINAD	16 kbps. Options for 48 and 64 kbps
TRC 6020 Thales (UK/France)	30 ÷ 400 MHz 15 W FM; 10 W AM	8.33 and 25 kHz	Voice: clear / secure, Data: point-to-point, option (TDMA, L22)	AM, FM, MSK, FSK	ARINC 429 or RS 422	FM– 106 dBm; AM –103 dBm for 30% modul.; FFH –100 dBm	16 kbps
MRR Ericsson (Sweden)	30 ÷ 400 MHz 5 W, 50 W	45 kHz	CVSD Voice, 16 kbps Data	GMSK	RS-232 by EURO-COM D/1	- 116 dBm	16 kbps
M3TR Rohde&Schwarz (Germany)	1,5 ÷ 400 MHz 10 W; 15 W	5, 8.33, 12.5, 25 kHz	Analog Voice, 16 kbps CVSD Voice, 16 kbps Data		Internet/ Intranet access via IP-interface (UDP/TCP)	FM– 117 dBm; AM –110 dBm	Up to 64 kbps
Spectre Datron (USA)	30 ÷ 88 MHz, Option up to 512 MHz 10 W	12.5, 25 kHz	Voice: FF FM, sim-plex or half-duplex, Data: 16 kbps output, internal FEC	AM, FM, ASK/FSK	Interface: RS232, 100 bps to 56 kbps, asyn-chronous	- 106 dBm;	Up to 64 kbps
CNR - 9000 Tadiran (Israel)	30 ÷ 88 MHz, Option up to 512 MHz 10 W	25 kHz	Analog Voice, 16 kbps CVSD Voice, 19.2 kbps Data	AM, FM, FSK	Automatic data rate adaptation	-108 dBm	Up to 32 kbps

input. Therefore it's necessary to know the receiver's input signal intensity. Radio wave propagation is related to propagation loss in environment. This means that the receiver's power would be rather different from the transmitted power.

III. VHF/UHF Propagation Model

The increasing demand for mobile communication has led to the need of more efficient propagation prediction models as one of the essential parts of the radio network planning tools and operation range determination. The basic equation, which is used for an obtaining of input receiver's power P_r is the following [3]:

$$P_r = P_t\Big(\frac{G_r G_t \lambda^2}{16\pi^3 r^2}\Big), \tag{1}$$

where P_t is transmitted power in dB, G_r (G_t) indicates the rate of Antenna Directivity Gain of receiver (transmitter), r is the path and λ is wavelength.

More propagation models, which are suitable for some different radio waves and propagation conditions, are used into practise. The large-scale propagation models give results as path loss versus range. The characteristics of the basic point-to-point path loss prediction models widely used in generating signal coverage map, co-channel interference area map and handoff occurrence map follow below.

Log-distance path loss model, theoretical and experimental propagation models indicate that the average received signal power decreases logarithmically with distance and [1]:

$$PL(d) = \overline{PL}(d_0) + 10n \lg\left(\frac{d}{d_0}\right) + X_\sigma, \tag{2}$$

where path loss, PL, is in dB, n indicates the rate at which the path loss increases with distance d, d_0 is the reference distance, which is determined by measurements close to the transmitter, X_σ is a zero-mean Gaussian distributed random variable (in dB) with standard deviation σ. X_σ accounts for the variation in average received power due to the shadowing. The values of n and σ? are derived from measured data. A smaller value of σ means more accurate path loss prediction. Typical values for n are: $n = 2$ (free space), $n = 2.7$ to 3.5 (urban area), $n = 3$ to 5 (shadowed urban area). However this model requires a huge number of empirical data and it's used when it is not necessary to make any frequency planning.

When it is looked at the RF links usually the antennas are isotropic. The propagation loss is the difference between the radiated power and the receiver power. It can be obtained with the equation [1]:

$$L_p(\text{dB}) = P_t - P_r = P_t(\text{dBW}) - E(\text{dB}\mu\text{V/m}) - 10\log_{10}\left(\frac{\lambda^2}{4\pi}\right) + 145.8, \quad (4)$$

where $E(\text{dB}\mu\text{V/m})$ is received field strength of an isotropic antenna. The most popular signal prediction modelling is Hata-Okumura model [2]. It is based on extensive measurements in urban area over a quasi-smooth terrain using vertical omni-directional antennas at the base and mobile stations assuming $h_t = 1000$ m and h_r(mobile)= 1 m. This model is a proper model for an analysis of propagation loss when it is researched cellular networks and communication quality between ground-to-air. The median attenuation relative to free space $A(f,d)$ was presented by Okumura as a family of curves plotted as function of frequency (100 MHz $< f <$ 1920 MHz) and as function of distance from the base station (1 km $< d <$ 100 km). The model previews correction factor accounting for the terrain type, G_{area}, which is given in another set of curves, as well as different expressions for antennas height gain factors, $G(h_t)$, $G(h_r)$, and for values of h_t, h_r, others than the assumed in the curves (the antenna pattern is not taken into account). The median value of the path loss following the model can be expressed as [2]:

$$L = L_0 + A(f,d) - G(h_t) - G(h_r) - G_{area}, \quad (5)$$

where L_0 is the free space propagation loss. The formula for median path loss is given by (6), where f is in MHz, h_t is the effective base station height in meters (30 $< h_t <$ 200 m), h_r is the effective mobile antenna height (1 $< h_r <$ 10), the distance d is in km, $a(h_r)$ is a correction factor related to the mobile antenna height. The values of $a(h_r)$ for small to median sized cities can be found in [6]. The model is applicable for frequencies from 100 MHz to 1500 MHz and $1 < d < 100$ km.

$$L = \begin{cases} 69.55 + 26.16\log_{10} f - 13.821\log_{10} h_t - \\ \quad -a(h_r) + \log_{10} d(44.9 - 6.55\log_{10} h_t), \\ \qquad \text{for urban area} \\ L(\text{urban}) - 2\left[\log_{10}\left(\frac{f}{28}\right)\right]^2, \\ \qquad \text{for suburban area;} \\ L(\text{urban}) - 4.78(\log_{10} f)^2 - \\ \quad -18.33\log_{10} f - 40.98, \\ \qquad \text{for open rural area.} \end{cases} \quad (6)$$

The above-described model is among the best (and simplest) models, it has standard deviation between predicted and measured path loss value about 10 to 14 dB, [1], and is used in practically all cellular and land mobile radio systems planning tools. This model can be used for calculation of propagation loss of air-to-ground VHF/UHF communication. It's important when it is necessary to obtain the minimum distance for reliable, but hidden, operation management. This model allows determining where the staff must dispose the Air C4I point.

IV. Simulations and Conclussions

When the security and hidden management is organized, Air Command Point usually situated into helicopters is used. The manager staff officer must know the maximum operation range for reliable communication. It can be calculated by (6). The simulation results for propagation losses are presented on figure 1, figure 3 and figure 2. Onto all of the figures propagation losses in Open Area are presented with red curves, propagation losses in Sub-urban Area are presented with green curves and propagation losses in Urban Area are presented with blue curves. There is a research about three typical Helicopters Output Powers such as 5 W, 10 W and 15 W.

The propagation loss for carrier frequency 220 MHz is presented on fig. 1. This frequency is in the beginning of Security Air Traffic Control Frequency Band. A simulation of propagation loss for carrier frequency 300 MHz can be shown on fig. 2. This frequency is in the middle of the Band. The flight altitude for these cases is 100 m. A research of propagation loss for carrier frequency 400 MHz is presented on fig.3. This frequency is in the end of the Band and the

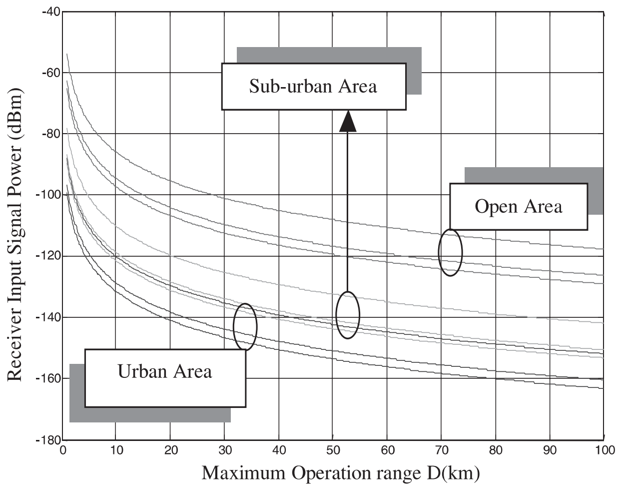

Fig. 1. Propagation Losses for Carrier Frequency 220 MHz

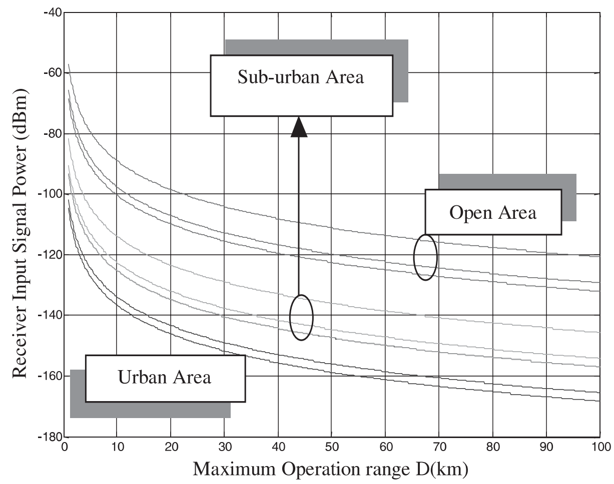

Fig. 2. Propagation Losses for Carrier Frequency 300 MHz

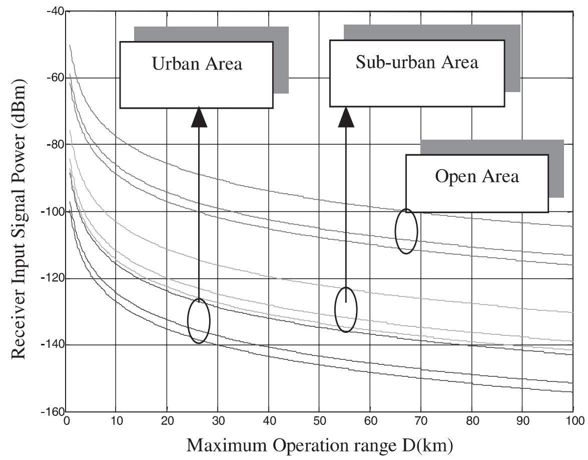

Fig. 3. Propagation Losses for Carrier Frequency 400 MHz

flight altitude is 500 m. The higher altitudes are not usually used for Helicopter Flight.

The researches lead to the following conclusions:

1. It's possible to organize hidden operation management by Air Command Point;

2. In open area the management with operation range for over 30 km can be organized independent of operation mode and carrier frequency;

3. For Urban and Sub-urban areas the maximum operation range is about 10 km. This is sufficient range for hidden management;

4. It is too important to make quality frequency panning due to escape used channels and to establish communication between command point and the mission with maximum covert to maximum operation range;

5. Reliable radio links for over 50 km can be established for low band frequencies. This can be used for military command;

6. The combination between hidden management and hidden Air Command Point is the best approach special service.

Present research shows the possibility for hidden C4I application. It is very important nowadays when the crimes can get special equipment via illegal market. The application of hidden command is a problem, which can be solved by tactical specialists and operation management staffs and officers.

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