坦克通訊與 MOS 指標

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俄烏戰爭中，坦克車大量被摧毀，其中原因包括重度依賴智慧型手機等「不安全通訊裝置」，容易成為攻擊目標。今日戰車指揮主要靠無線電通訊，須避免受到受到天候、地形等影響。軍方便宜行事，鼓勵車長自購民用無線電設備，通訊效果當然不佳。幾年前台灣 CM-11「勇虎」坦克墜入河道事故，是前方車長沒有收到後方車長的無線電警告。

自從邱吉爾 (Winston Churchill) 在第一次世界大戰發展出馬克坦克車後，在實戰下進行了一系列通訊設施的改良。馬克一號車內有四位成員，由於空間限制，彼此只能有極少的通訊互動。車長一般以敲打駕駛員左右肩膀的方式，指揮行進方向，對外界則靠手語及旗語。，必要時則跳下車去對方的坦克車說話。若要向總部報告，則由坦克車的視窗裂縫放出通信鴿。

1930~1950 年間，坦克車的通訊方式開始大幅度改進，終於有內部通話的對講機裝置，並且有無線電可對外和步兵連繫。坦克車不需有放鴿子的洞口要歸功於美國通訊部隊少校阿姆斯壯 (Edwin Armstrong)。1930 年代初期，阿姆斯壯研發出 FM(Frequency Modulated) 無線電技術，很有效地濾掉無線傳輸的噪音。阿姆斯壯將這項價值數十億美元技術的專利免費讓美國陸軍使用於第二次世界大戰。阿姆斯壯對美國政府很慷慨，但一直和美國無線電公司 (RCA) 打專利官司，最後跳樓自殺。

坦克車大致會配備二到三套無線通訊管道，為了提升通話品質，坦克車內的通話過程嚴格遵循「無線通話程序」。軍事行動通話，不是一般電話點對點的方式，而是許多人可以同時參與的對講機 (Push-to-Talk；PTT) 模式。PTT 通訊有協調通話的必要，因此無線通話程序有如下的規則：講話前先聽（不要搶話）、講話時要慢且清晰 (戰況火燒屁股時可能慢不下來) 、長話要短說，常出現以下無線電對話用詞：Over(我講完啦，等你回話)、Out(會談結束，你不必回話)、Roger(我聽懂你剛剛在講啥) 、Wilco(聽懂且遵命)、Read back(請複誦)、Radio Check(告訴我訊號清晰度，以 1 到 5 區分) 。

為了不誤認英文字母的發音，會以「字」代替「字母」，例如 Alfa 代表 A 、Bravo 代表 B 等。關於 PTT 通訊，可以採分散式的自動化協調。我曾做過相關研究，發表於國際期刊《IEEE Transactions on Intelligent Transport Systems》。

戰爭緊急狀況，通訊品質往往無法控制，必須再三確認對方聽得見。當對方要求 Radio Check 時，你會憑主觀感覺聲音清晰度，回覆說：「Receiving you strength 2」(表示通訊品質不佳) 。

其實，聯合國電信組織已訂定電話語音的品質的指標 Mean Opinion Score(MOS)，該指標考慮設備及損傷 (Impairment) 參數，能由人耳感知，主觀的量化語音傳輸的品質。MOS 的數值共有五級，1 代表最差 (unacceptably bad)、2 代表貧乏 (poor)、3 代表尚可 (fair)、4 代表極佳 (good)、5 代表優異 (excellent)。MOS 值可經由演算法來模擬人耳的聽覺，自動算出語音線路的通話品質。測試時，MOS 值要達到 3.5 才算合格 (其實就電信等級而言，這個標準並不高)。我也曾以 MOS 值量測並評估加密過後無線通訊的語音品質，發表於《IEEE Internet Computing》。

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Tank Communication and MOS

During the Russian-Ukrainian war, a large number of tanks were destroyed. One of the major causes is the heavy reliance on "insecure communication devices" such as smartphones, which makes tanks easily targeted by enemies. Nowadays tank command mainly relies on radio communication and therefore it is necessary to reduce interference by weather, terrain, etc. However, the military took a shortcut with encouraging the commanders to purchase civilian radio equipment. The quality of communication is obviously far below the expectation. Several years ago, a Taiwanese CM-11 "Yonghu" tank crashed into the river just because the front commander did not receive a radio warning from the rear commander.

Since Winston Churchill developed the Mark I during World War I, a series of improvements on communication facilities proceeded according to the battlefield. The Churchill Mark I had a crew of four. Due to space constraints, communication between crew members is limited. The commander generally instructs the driver the direction of movement by tapping his left or right shoulders, and uses sign language and semaphore to communicate with the outside world. Whenever necessary, the commander will jump out of the tank to speak to allies. To report to headquarters, carrier pigeons are launched from hatches on the tank's sponsons.

Between 1930 and 1950, the techniques of tank communication began to advance greatly. Finally, tanks are equipped with walkie-talkie devices for intercom, and radio stations to communicate with the infantry outside. Thanks to Major Edwin Armstrong of the United States Army Signal Corps, tanks don't need hatches for pigeons anymore. In the early 1930s, Armstrong developed FM (Frequency Modulated) radio technology, which effectively filtered out the noise of wireless transmission. Armstrong granted the US military free use of his multibillion-dollar technology patents during World War II. While Armstrong was very generous to the US government, he had filed lawsuits in the United States District Court against the Radio Corporation of America (RCA), and finally committed suicide by jumping from a building.

Tanks are generally equipped with two to three sets of wireless communication channels. In order to improve call quality, the call process in tanks strictly follows the "wireless call procedure". Instead of using a point-to-point connection as a regular telephone system, Military radio is a walkie-talkie (Push-to-Talk; PTT) mode in which many people can participate at the same time. Therefore, due to the necessity of coordinating calls in PTT communication, the following rules are regulated in the wireless calling procedure: Listen before speaking (don't rush to talk), speak slowly and clearly (you may not be able to slow down when the battle is getting fierce), and keep long stories short. The following radio conversation words often show up: Over (I'm done talking, waiting for you to talk back), Out (the conversation ends and you don't have to talk back), Roger (I understand what you just said), Wilco (understand and obey), Read back (please recite), Radio Check (request signal strength on a scale of 1 to 5).

In order to avoid any misunderstanding of pronunciation in English letters, a set of “words” are used to substitute “letters”, such as Alfa for A, Bravo for B, etc. With regard to PTT communication, decentralized automated coordination can be adopted. I have done related studies and published the result in the international journal "IEEE Transactions on Intelligent Transport Systems".

When the battle is getting fierce, the quality of communication is often out of control. It is necessary to double-check if the peer can hear the voice. When the peer asks for Radio Check, you can subjectively measure the clarity of the sound and reply: "Receiving you strength 2" (indicating poor communication quality).

In fact, the United Nations Telecommunications Organization has established the Mean Opinion Score (MOS), an indicator of the quality of telephone voice. Considering equipment and impairment parameters, MOS measures the quality of voice transmission that can be subjectively perceived by the human ear. MOS rates the quality of a voice transmission on a scale from 1 to 5. 1 is "bad," 2 is “poor,” 3 is “fair,” 4 is “good,” and 5 is “excellent.” The analytics algorithm can simulate human hearing, and automatically calculate the MOS score to reflect voice quality over phone calls. The MOS score around 3.5 is considered acceptable (in fact, in terms of telecom level, this standard is not high) during tests. I have also measured and evaluated the voice quality of encrypted wireless communication with MOS score, published in "IEEE Internet Computing".

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