Programming Protel 7000: test of various consumer-grade modems

07/07/2023, rev. 1,   by peter(at)mabanana.com   *http://telesfor.org/payphones*

Foreword: Protel payphone controller boards need to be programmed with the correct options and rates to operate properly. This task is not always straightforward. Furthermore, the Protel 7000 utilizes a non-standard modem with 1200 bps FSK modulation, supported by a dedicated Protel modem. The common standard is DPSK, requiring the use of an option board. **Fortunately, a 300 bps FSK modulation (Bell 103A) is still available**. However, successful connections appear to be inconsistent. While it may work initially, there is a chance of failure later. Due to this uncertainty, I have decided to conduct this test in a systematic and reproducible manner.

1. Scope of the test: We will be examining the performance of popular modems made by US Robotics (internal 33k6 and external 56k) when used with ExpressNet software and a DOS running computer to connect to the Protel 7000 control board. Additionally, we will briefly test the following:
    - VirtualBox DOS emulation environment
    - Use of VoIP ATA as a phone switch (Grandstream and Cisco/Linksys)

2. Out of scope (these aspects will be covered in other documents)
    - Setup of the programming station
    - Setup of the phone switch (PBX)

3. Choice of modems:
    a. **US Robotics USR 5686E** – a popular US-market modem, readily available, often in new condition, at a reasonable price. Note there are different variants and USR 5686G might perform slightly different.

    b. **US Robotics USR5630G** – a popular EU-market modem. Availability is now limited, but it has been known to perform well with various modulations and handle poor line conditions in diverse European environments.

    c. **US Robotics 28k8/33k6 ISA card**
        (FCC model: 0374). It was popular during the 90s and still available as a second hand option.

    d. Bonus: **CompUSA 56k USB modem**. This inexpensive soft-modem was acquired by mistake but I decided to test it (virtual machine only). The driver is compatible with Windows 10, and the modem appears as a standard COM port that can be passed to VirtualBox.

4. Testing station:
    - 486DX2-66 PC with DOS 5.0
    - Analog PBX / line emulator

5. Test results

Without a dedicated extension board on a payphone side or a Protel FSK modem on the PC side, the **connection can only be established at 300 bps**. In some cases this requires forcing the modem to operate at this speed using AT commands. Fortunately, the ExpressNet program allows the modification of the modem setup string.

Successful connection is just the first step. Whole transmission takes a few minutes and often times it breaks before it's completed. During experiments it's been discovered it depends on at least two factors:

- Connection direction: to / from the Payphone. Reason is unknown, but modulation frequencies are different for the initiating and answering sides, also the negotiation depends on the origin. Unfortunately, calls to payphone are generally less successful. Calls from a payphone were always working.
- New init or a subsequent programming. In some cases the first call to a newly initialized controller is not successful.
- Previously broken communication makes the following calls more likely to fail

In total, 21 calls have been performed for the basic test (actually more). Timings were noted for one specific setup, it will vary if for example the rate file is larger.

Table 1: Test results in DOS environment.

Modem	Direction	Init state	Repeat	Result	Time	Comments
USR 5686E	To PC	New	1	OK	2:30 ±5s	• **Must force 300bps on the modem** (`AT&N1`) otherwise connects at 1200 and fails
			2	OK		
		Redo	1	OK		
			2	OK		
	To payphone	Redo	1	NOK		• Connects, receives OK (on the PC), transmit seems not OK. Tried different flow control (`AT&H`n) – H/W, S/W, none – no result
			2	NOK		
		New	1	NOK		
USR 0374 (ISA)	To PC	New	1	OK	2:15 ±3s	• Calls to the PC a bit faster than USR5686E, but modem negotiation very close to timeout
			2	OK		
		Redo	1	OK		
			2	OK		
	To payphone	Redo	1	OK	2:10 (always)	• Calls to PP link instantly at 300bps even w/ default settings • Must NOT enable Quick Connect • **Won't work anymore after a broken call**
			2	OK		
		New	1	NOK		• **Newly initialized phone won't take it**! First call must be made from payphone.
USR 5630G	To PC	New	1	OK	2:25 ±5s	• Modem negotiation instant like with USR5686E
			2	OK		
		Redo	1	OK		
			2	OK		
	To payphone	Redo	1	OK	2:35 ±5s	Works perfect even with "Quick connect" = On.
			2	OK		
		New	1	OK		

5.1. **VirtualBox** environment has been briefly tested. It appears to be more challenging than a "real" setup. It works, but the choice of modems is limited. Out of three tested, only one worked while another "almost" worked.

Table 2: Test results in VirtualBox environment.

Modem	Direction	Init state	Repeat	Result	Time	Comments
USR 5686E	Any	Any		NOK		• Connects but received data is completely wrong, fails
USR 5630G	To PC	Any		OK	2:07	• Works perfect, but must add `AT&N1` to init string
	To payphone	Any		OK	2:20	• Working even with a previously broken call
Comp USA soft-modem	To PC	New	1	NOK		• ExpressNet **does not detect RING** so can't answer. Very unfortunate, because there is potential otherwise
	To payphone	New	1	NOK		• Calls going to PP link at 300bps but break after correctly transmitting a few blocks.

5.2. **Use of a VoIP ATA** as a switching system (PBX).

It is generally believed the ATA should be set up in the following way:

- Disable the local / line echo canceller
- Disable the adaptive jitter buffer and set it to a fixed medium / high level depending on the network conditions.

However, actual experiments conducted with the **Grandstream HT502 ATA** revealed that disabling the line echo canceller (LEC) resulted in a failure shortly after establishing a connection. Enabling the LEC seemed to make the connection more robust, allowing the **programming to proceed through several blocks before eventually failing** (although taking significantly more time, indicating the occurrence of multiple transmission errors).

Cisco/Linksys SPA112 offers more options to try, which appears promising. The following options were tested:

- Default voice options: connects but fails soon after
- Modem Line = yes: call to payphone connects and transfers several blocks, to eventually fail and it takes longer than usual. Call from the payphone either fails to handshake in time or fails after several blocks.

Additionally, the following options were tried, but the connection would fail shortly after being established: (1) Modem Line = yes & Echo canc. enable = no, (2) Modem Line = no & Echo canc. enable = no, (3) Modem Line = yes & Echo canc. enable = no and fax (T38) = yes & fax mode = NSE / reinvite, (4) Modem Line = yes & jitter buffer adj. = no

SPA112 has a useful feature that allows enabling **Modem Line on demand** by dialing *99 before the number. This enables the use of the line for both modem and voice calls.

Above experiments demonstrate that both ATAs fail to connect modem calls at 300 bps, even with a simple setup where the SIP server is within the local network. In real-life scenarios, where the SIP server is on the internet, there is even more delay, jitter and packet loss. Interestingly, a connection between two external modems can be established over VoIP (using the two worst-performing modems from the experiment, rates varied from 4800 to even 33600), so it is unknown why a low speed like 300 cannot work. Possibly, the Protel board is more sensitive to transmission errors (similar symptoms were observed with the Elcotel board tested previously: the connection was established but broke soon after).

6. Test summary

Calls initiated by the payphone (*#3 in service mode) generally work flawlessly, but it is advisable to add `&N1` to the modem init string. In ExpressNet 1.55 this can be done by navigating to screen 5-4-1, selecting *Change/test modem*, then highligh *Other* and press F7. Append &N1 to the init string.

Calls originating from the PC are generally more challenging and only worked fully with European US Robotics modem USR6530G. The internal modem (ISA board, US Robotics OEM) only worked if the payphone has previously been successfully programmed. A very popular USR 5686E didn't work at all. Failure mode is not known, the data reception by the PC seems to function (in most cases it receives the station number), but the data is not recognized by the payphone and breaks after one or more blocks. Possibly, it's intentionally made difficult to prevent easy programming by hackers (it's also the reason why a non-standard 1200 bps FSK modem was introduced).

Using the **VirtualBox environment is also an option**. There were concerns about the serial communication going out of sync. **It worked with a serial modem** but seemed **very picky**: only the USR 5630G worked, while the USR 5686E connected but received completely incorrect data, causing it to hang up shortly after. Side note: it also didn't work for me with Elcotel software - modem would not reply over serial cable at all.

Softmodem (also known as winmodem) did not work properly calling the payphone. It linked and correctly transferred a few blocks, but would hang up shortly after. I suspect it would work when calls originate from the payphone, but for an unknown reason, **ExpressNet doesn't receive the "RING" message** over the serial link. The message is visible in emulated DOS (can be observed using the "`type COM1`" command), indicating a compatibility issue, possibly related to a hardware interrupt (IRQ) issue.

VoIP connections using ATA on a local network **were unsuccessful**, despite attempting various configuration options.