VE6HQ 70 cm Solid State Amplifier

I rejoined the active amateur radio community after nearly a 50 years absence. In the late 1970's operating as VE6RI, I had conducted a series of exciting 432 mHz experiments using over the horizon tropospheric scatter propagation between Edmonton and Calgary. I wanted to renew this excitement, however soon realized technology has changed from the 4CX250B vacuum tube coaxial resonate cavity that I had constructed in the 1970's.

I embarked on a process to build a modern solid-state amplifier for 70 cm amplifier using the available LDMOS technology. The amplifier requirements included:

- 200 watt RF power output continuous operation
- Linear amplification with IMD products -30 dBc or better
- Harmonic suppression – 60 dBc or better
- Over temperature protection
- Sequencer / delay switching via PTT operation

The amplifier was to be driven by a SDR transceiver and appropriate intermediate linear amplification stages.

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A photograph of completed 70 cm amplifier is shown as Figure 1. For reference the cooling fans are 120 mm (4.7 inch) in diameter. Power (32 volts DC) and PTT connections are illustrated in the top left-hand side of this photograph.

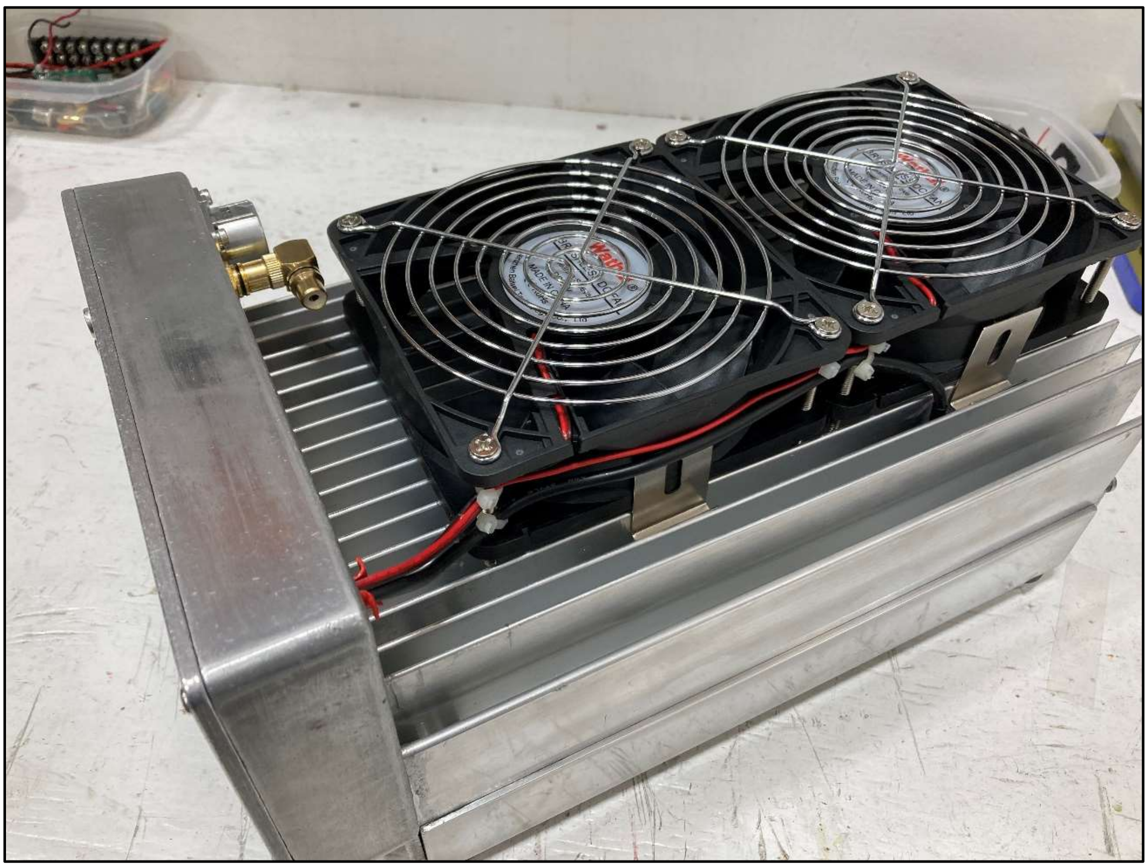

Figure 1 VE6HQ 70 cm 200 watt amplifier

The 70 cm amplifier project was based upon assembly of available subassembly components. This method provided a time and cost-effective approach to the project.

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A source for the RF pallet was available from Giulio Scaroni IK2DED.

Figure 2 shows a photograph and Figure 3 illustrates a schematic diagram of RF amplifier.

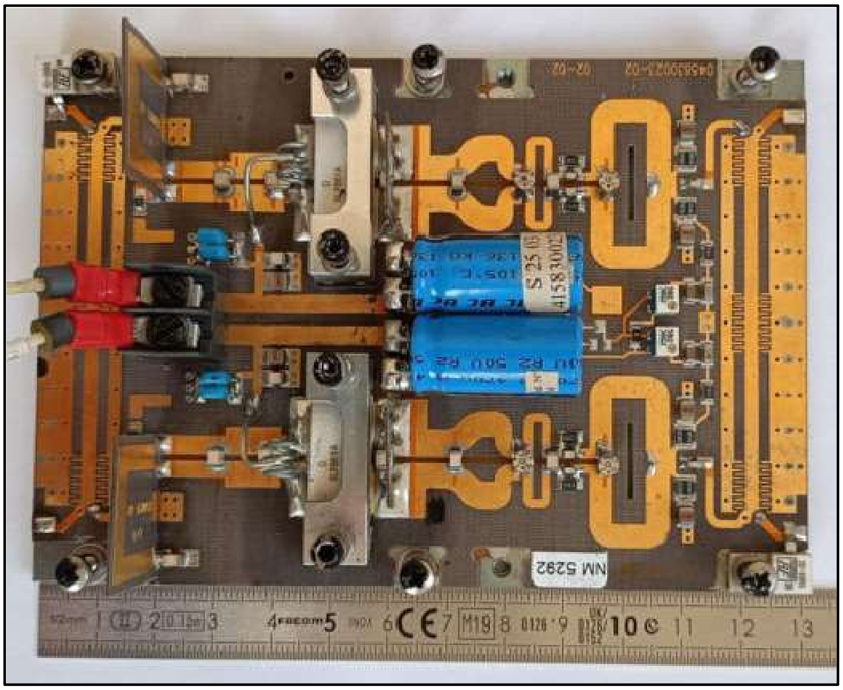

Figure 2 70 cm RF Amplifier

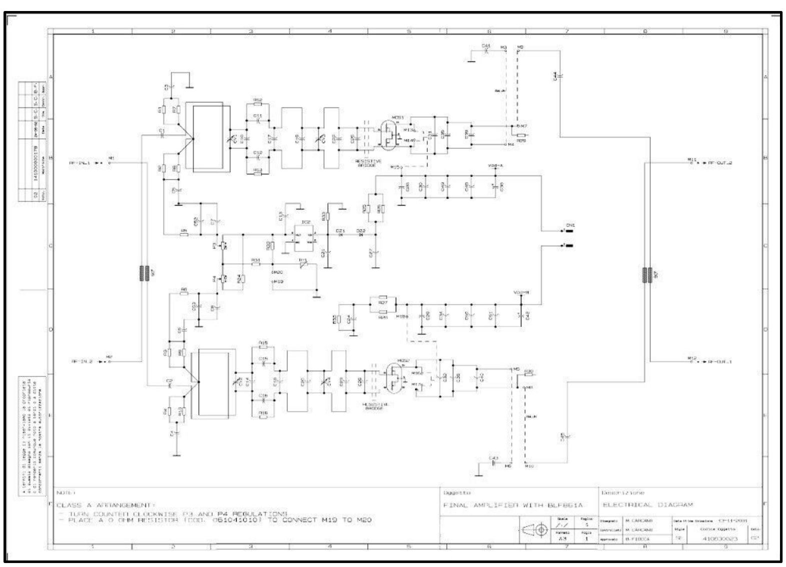

Figure 3 70 cm RF Amplifier Schematic

Suppression of harmonic signals is an important requirement for all RF amplifier design. I sourced a high quality 432 mHz low pass filter that also included an SWR sensor for forward and reverse power measurements.

The specifications for this low pass filter include:

- Insertion loss less than 0.15 dB
- 2nd order harmonic suppression 35 dB
- 3rd order harmonic suppression 55 dB
- Input and output impedance 50 ohm

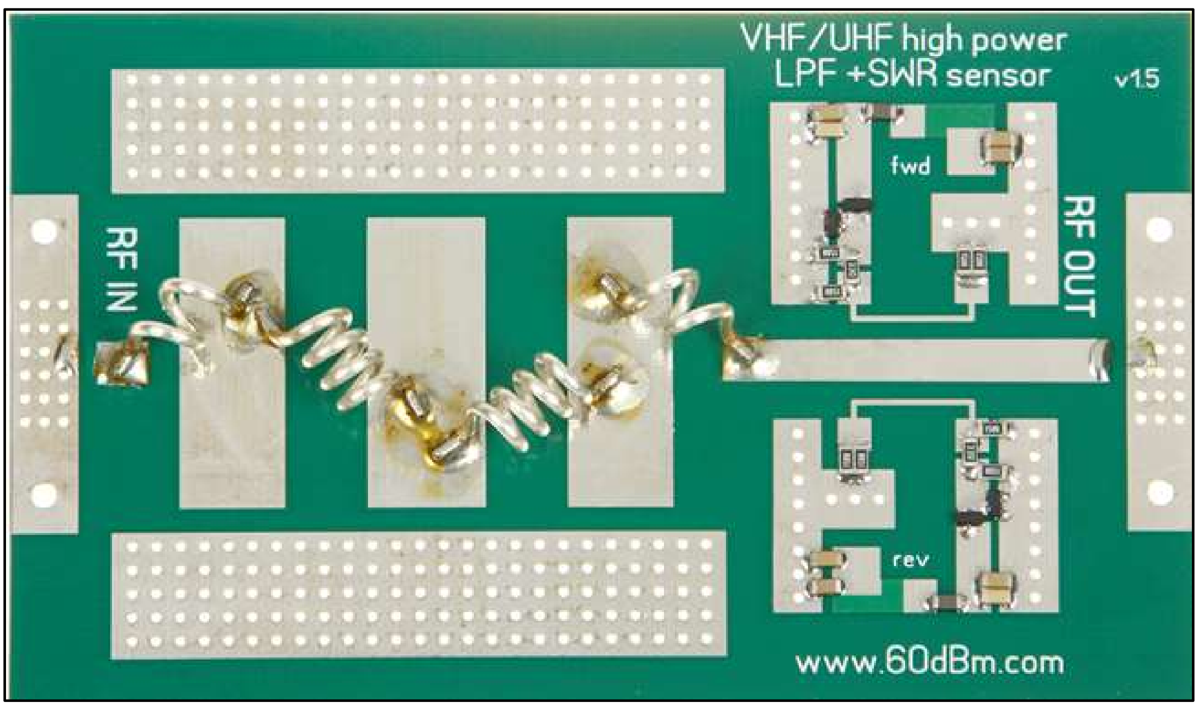

Figure 4 70 cm Low Pass Filter

A solid-state control board was an important component within the 70 cm amplifier design.

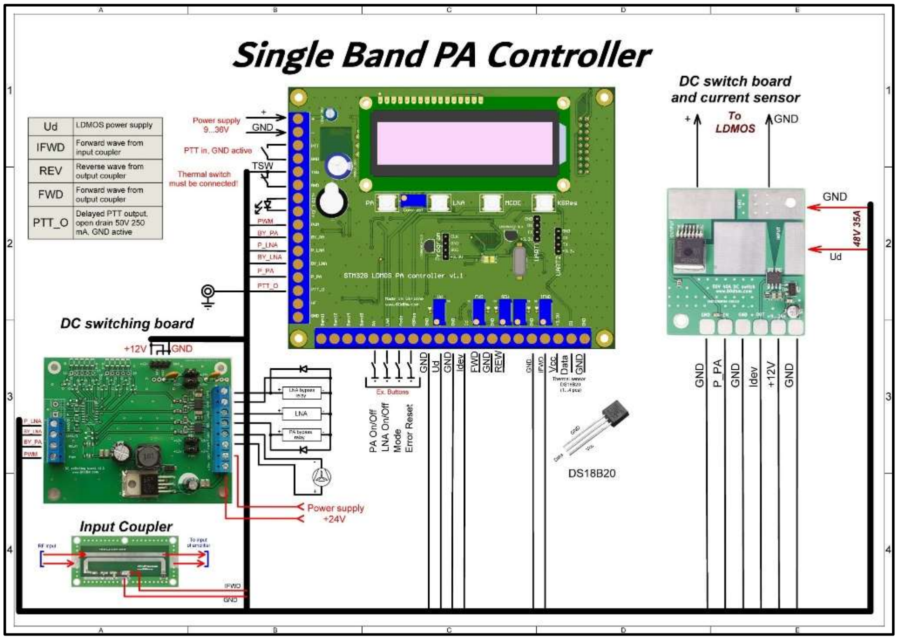

Figure 5 Control Board

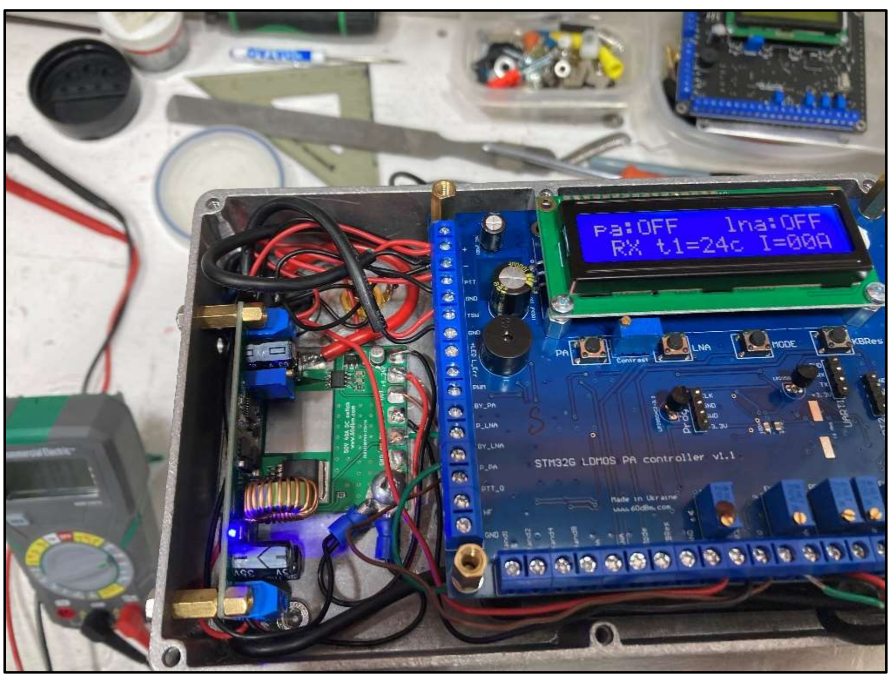

Figure 6 Control Board Installation

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The control board is based upon the STM32G070 CPU and a 16X2 LCD panel. Specifications for the control board include:

Temperature, up to 4 DS18B20 MAXIM digital thermometers

1 mechanical temperature sensor (normally closed contact)

Power supply voltage, 70v max

Power supply current, ALLEGRO ACS series IC as current sensor, 50A max

SWR and Output RF power from external sensor, 2000 watts max.

Input RF power from external sensor, 99 watts max.

Temperature protection, 2 levels, soft level can be set via software settings menu

Overvoltage protection, value can be set via software settings menu

Overcurrent protection, value can be set via software settings menu

Excess of output RF power protection, value can be set via software settings menu

Excess of input RF power protection, value can be set via software settings menu

This control board component was sourced from 60dBm.com.

Bench testing of the completed 70 cm amplifier was completed. Figure 7 shows a photograph of equipment used during testing. During all tests, RF power was terminated in a 350 watt RF dummy load. An SDR transceiver (Pluto Plus SDR) was used as an RF signal source with GPSDO oscillator frequency stability control. A separate SDR receiver (RSPDuo) was used to inspect all signals using spectrum analysis software. Not shown within Figure 7 are additional DC voltage and current monitors and DC power supplies.

Figure 7 Benchmark Testing 70 cm Amplifier

Figure 8 illustrates two tone intermodulation distortion (IMD) test results conducted as part of validation of this amplifier. In this case, two tones (700 Hz and 1900 Hz) were used to modulate the USB carrier. It was observed that the 3rd order IMD product was -34 dBc.

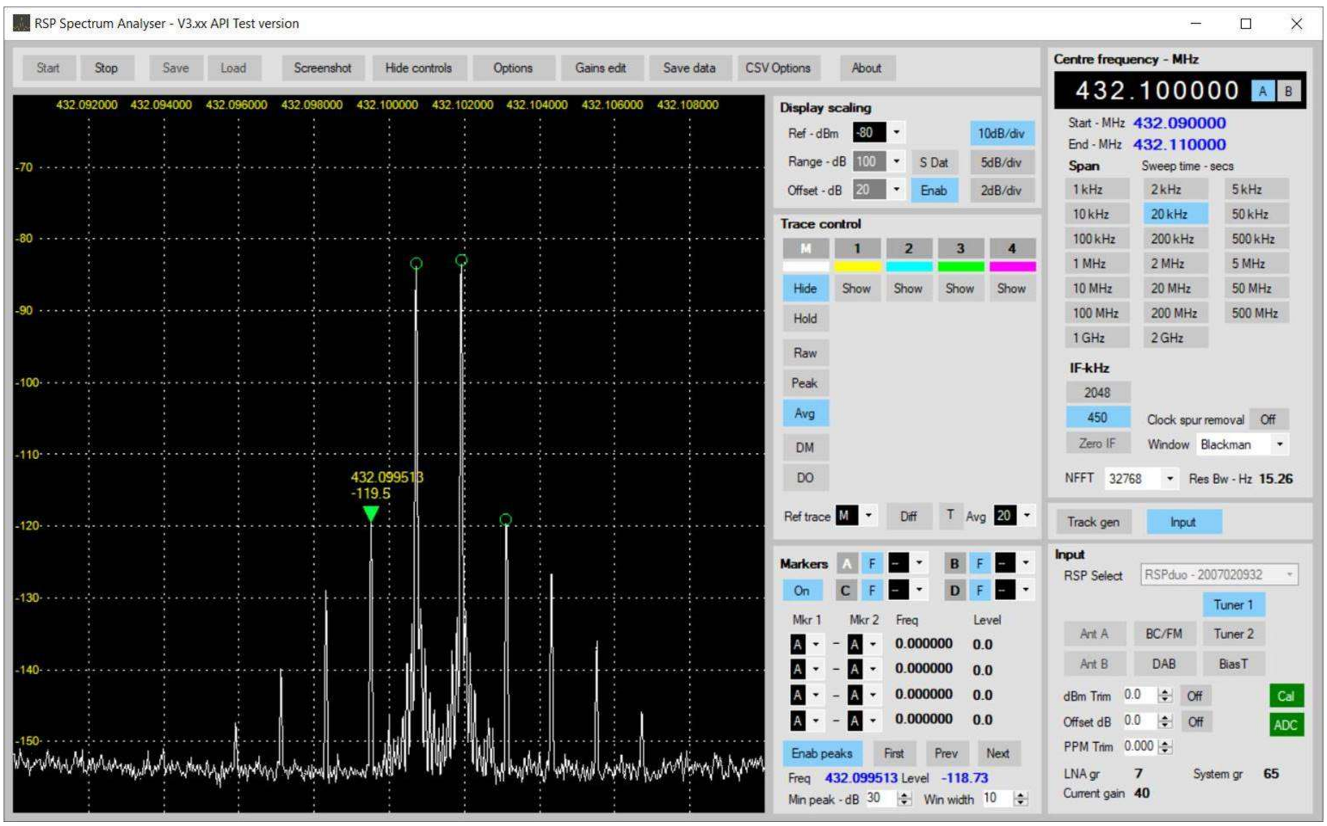

Figure 8 IMD Test Results 70 cm Amplifier

The SDR receiver combined with the RSP Spectrum Analyzer software was an effective test equipment solution for enhanced signal analysis including IMD and harmonic level measurements. Particular care through the use of RF couplers and attenuators was mandatory to prevent signal overload.

Importantly input drive level testing was conducted to gain knowledge for entire RF system operation. In this case, RF power level from SDR transceiver was step wise increased from 70 % to 100 % with amplifier IMD measurement at each power level. As indicated by Figure 9, increasing power from 75% to 100 % (**1.25 dB power increase**) results in over **13 dB increase** in distortion products. It was noted that drive levels from SDR at 70 to 75 % resulted in 70 cm amplifier output power of 250 watts. Once again, we observe that over driving a linear amplifier provides little RF power advantage and significant distortion and resultant signal interference on our shared frequency bands.

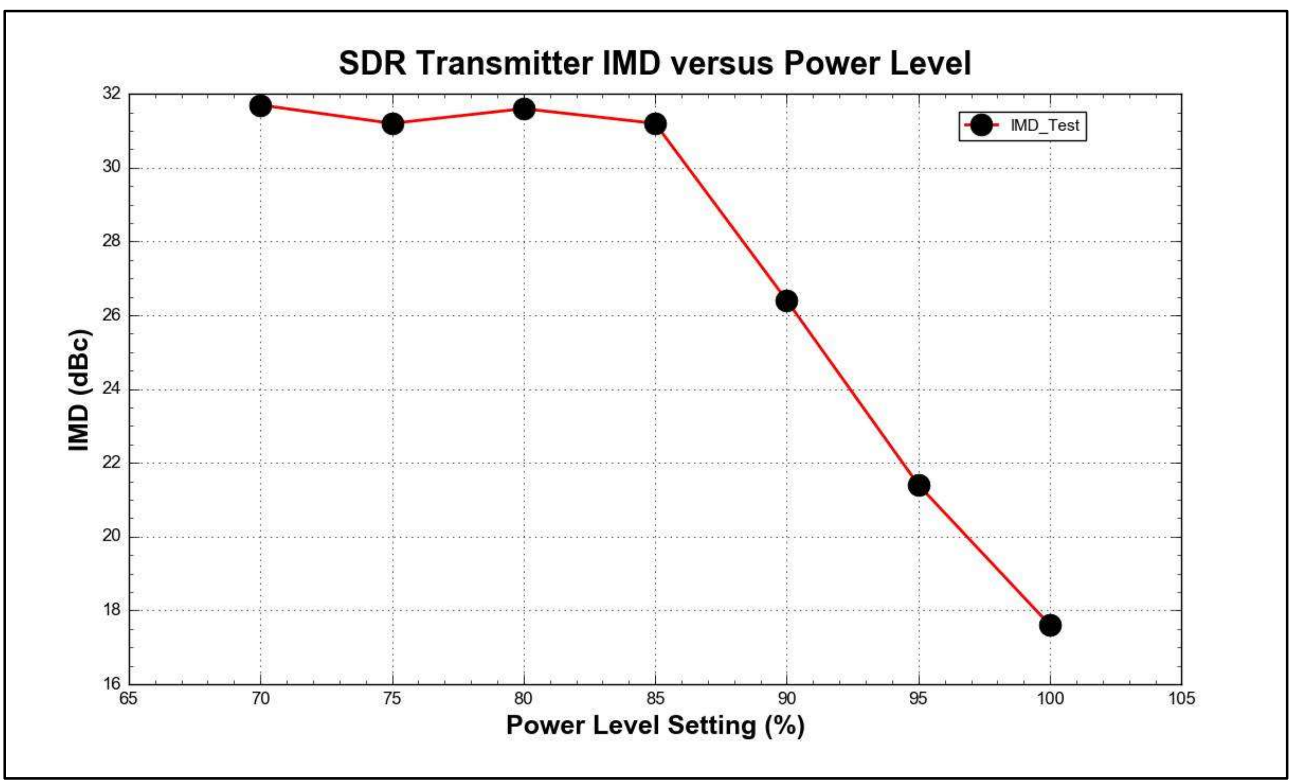

Figure 9 IMD Test Results versus SDR Drive Level

About the Author

Don has pursued a lifelong interest in science and engineering beginning as a youth in western Canada. He received his first amateur radio license at the age of 15 while attending high school in Edmonton, Alberta, Canada.

Don continued this interest and graduated from the University of Alberta receiving a Bachelor Science in Electrical Engineering. During the last 41 years he has worked in the Energy Exploration industry in Canada, the United States, Europe, South America, the Middle East and the Far East.

His technical area of interest lead to publications of nuclear magnetic resonance applied to reservoir characterization. He was granted numerous US patents for developments of wireline pressure core technology. Don Westacott strongly considers training and technology transfer as an important part of his role within the E&P industry. Don accepted a role as guest lecturer at the Colorado School of Mines providing instruction to a new generation of petroleum engineering students. Don was honored to be the Distinguish Speaker at the Harvard University Energy Panel Arab Conference. During 2020, Don received the prestigious Hart Energy Innovators Award.

I was first amateur radio license was in 1967 as VE6ANW, a year later achieved the advanced certification as VE6RI. I initially pursued 20-meter DX working using the Drake R4B / T4XB / L4B equipment and a 3 element Yagi/Uda antenna at 70 feet. Soon after, I became interested in weak signal UHF propagation. Constructing of a "home brew" 70 cm radio system complete with 4CX250 linear amplifier based upon a novel resonant coaxial cavity design was completed. Three hundred (300) kilometer daily communications using over the horizon tropospheric scatter was achieved between his Edmonton QTH and VE6JX located in Calgary, Alberta.

After more than 50 years have passed, I have rejoined the amateur radio ranks and currently active on 20 meters and VHF / UHF bands. I was granted the KI5KGX call as an extra class USA amateur operator. Subsequently, we moved to Canada and I reinstated by Canadian amateur radio certificate and requested my current call VE6HQ.

Don and his wife Marilyn enjoy the success of their sons Matthew and Andrew.

During 2021, I presented a webinar on Time and Frequency, which may be found at :

[VOD Player (qsotodayhamexpo.com)]