Introduction to Exail RF drivers and amplifiers for optical modulators

exail

Introduction

Exail designs, produces, and commercializes optical modulators intended for a variety of applications including optical telecommunications, quantum optics, pulsed lasers, fiber sensors, RF over fiber …

Each application involves a specific modulation format:

- Optical telecommunications most often require digital modulation. As an example, non-return-to-zero (NRZ) format results in long sequences of 0 and 1 symbols distributed randomly with time.

- Pulsed laser requires periodical pulses generation, showing short rectangular shape or arbitrary waveform, and applied with a long duty cycle.

- RF over fiber (RoF) & radar signal processing require analog modulation. The signal shows random amplitude variations, generally around a microwave carrier.

All the above modulation signals are delivered by specific electrical generators. The optical modulator then converts as faithfully as possible these electrical signals into optical signals.

Optical modulators are declined under three main families:

- Amplitude modulator of Mach-Zehnder type,
- Phase modulators,
- I&Q modulators (Dual Parallel Mach-Zehnder modulators nested in a larger combiner circuit)

These modulators are all characterized by their **half-wave voltage V_π**

- For amplitude modulators, it corresponds to the voltage required to switch from the On-state to the Off-state
- For phase modulators, the V_π is the necessary voltage to obtain a π phase modulation

The V_π parameter indicates generally the voltage required range to get the best dynamic modulation. It is typically in the range of 4 to 6 V.

Most of the test equipments and generators are designed to deliver voltage much below this value. Typically, a PRBS (Pseudo Random Bit Sequence) generator or an AWG (Arbitrary Waveform Generator) delivers a peak-to-peak voltage ranging from 400 mV to 1000 mV. If directly applied to the modulator, such a low-level signal would result into a poor modulation efficiency, showing a low dynamic range and a reduced signal-to-noise ratio.

Therefore, it is generally mandatory to amplify the electrical signal to reach optimum amplitude before applying it to the modulator electrodes. This is the function of the **RF modulator driver**.

Modulator driver presentation

The modulator driver is a high bandwidth amplifier built with a cascade of MMIC's (Monolithic Microwave Integrated Circuit) based on the Gallium Arsenide (GaAs) technology and on a distributed amplifier topology, designed to drive an optical modulator in the best suited conditions.

All Exail drivers, except the DR-VE serie, are AC-coupled meaning they don't transmit nor amplify any continuous signal or very low frequencies of the signal. A DC-block internally set at the output of the modules avoids the driver to deliver a permanent bias voltage that would be then converted into a DC-current in the modulator.

Exail designs these amplifiers, the passive microwave PCB, all the biasing electronic for cold-start operation and the package. Exail takes a particular attention to the packaging. The latter is optimized to manage the heat dissipation and to avoid internal cavity resonant frequencies. Mechanical design allows these modules to be easily connected to the Exail modulators. For ease of use and safety, a single +12 V DC voltage is necessary to operate the driver. An additional voltage V_{amp} can be applied for fine adjustment of the gain.

A heat sink is highly recommended for heat dissipation, the driver's performance being degraded at higher temperature.

The RF connector type depends on the aimed data rates or bandwidth (BW). Our drivers, comes with:

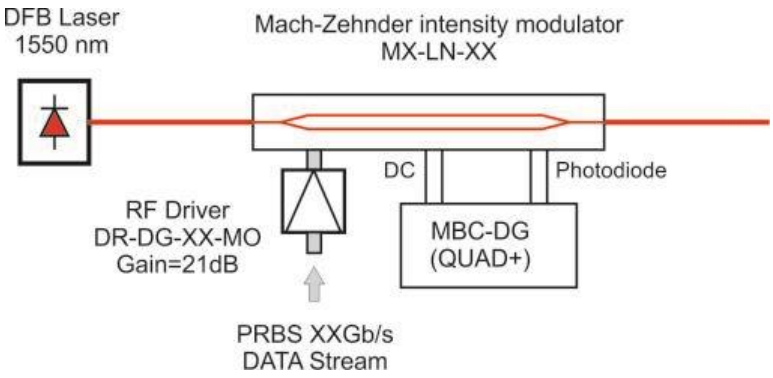
- SMA connectors for BW ≤ 12.5 GHz
- 2.92 mm / K connectors for BW from 12.5 GHz up to 30 GHz
- 1.85 mm / 2.4 mm / V connectors for frequencies above 40 GHz and for 40 Gb/s and above data transmission.

DR-PL-20-MO 20 GHz pulsed modulator driver

Next paragraphs give more information about the four main types of modulator drivers offered by Exail. They also give explanations about the differences of design between them.

The DR-DG-XX serie

DR-DG serie modules are drivers optimized for digital signals. Their main application is optical fiber digital communications for which the On-Off Keying (OOK) format based on non-return to zero (NRZ) is the most common modulation format.



Typical set up for digital modulation

DR-DG-XX-MO

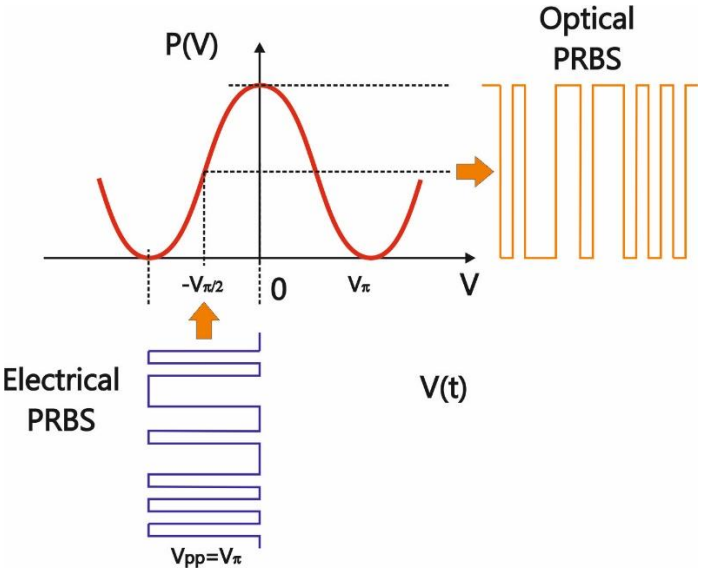
> Gain

The **DR-DG-XX-MO** serie drivers allow amplifying an incoming data stream with a 0.5 V peak-to-peak voltage up to 6 V_{pp}. Such a voltage is suitable to drive the modulator at its half wave voltage V_π . The voltage gain expressed in dB is 10.5 dB and the power gain of the driver is **21 dB**. The gain is tunable via an additional voltage.

> Bandwidth

XX is the bandwidth expressed in GHz for the targeted operation data rate: 10, 20 or 44 Gb/s.
The DR-DG-XX-MO has a high frequency cut-off equivalent to the aimed data rate (10 GHz for 10 Gb/s). The high frequency cut-off is not smaller than 0.8 x data rate. The low frequency cut-off is kept as low as possible, typically 50 kHz, to transmit the low frequencies of the signal (long series of 0 or 1).

Typically, the average output level is always set at zero. For a voltage of 6 V_{pp}, when the data stream is balanced between 0's and 1's, then the maximum voltage is +3 V and the minimum voltage is -3 V.



Electrical 10 Gb/s data stream with V_π peak-to-peak voltage applied to an intensity modulator to generate a high SNR 10 Gb/s OOK optical data stream

> Saturation

"MO" stands for Medium Output voltage. The driver is designed so that the saturation of the amplification corresponds to the aimed operating peak-to-peak voltage (approximately equal to the V_π of the modulator). When combined with the sinusoidal shape of the modulation transfer function of the modulator (figure above), it allows a full dynamic range output modulated signal with much reduced overshoots, showing a high Q-factor and high **SNR** (Signal to Noise Ratio) factor.

> Other parameters

For the DR-DG serie, the other characteristic parameters are the rise time and the fall time, SNR, peak-to-peak jitter and RMS jitter.

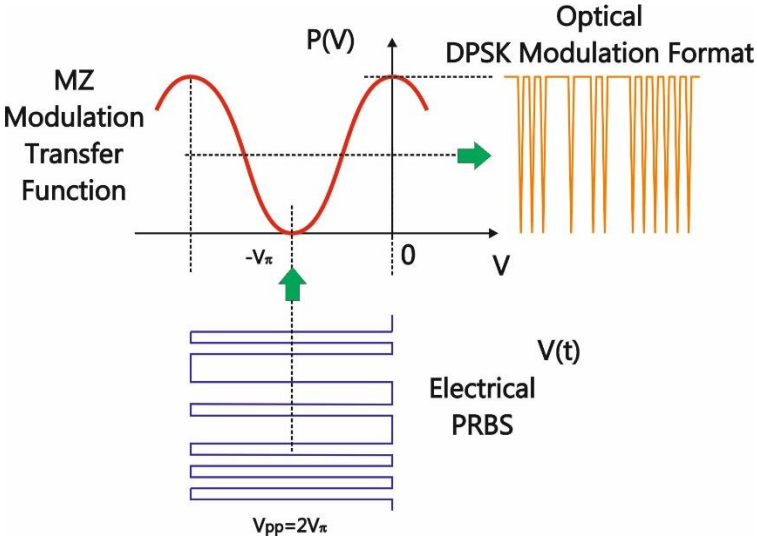
The Exail drivers' datasheets, available on our website, provide detailed technical information about the electrical bandwidth, return loss and output voltage versus the V_{amp}. Examples of eye diagrams can also be found there.

DR-DG-XX-HO serie

The DR-DG-XX-HO drivers differ from the MO serie by the higher peak-to-peak voltage that can be delivered. The HO letter stands for High Output voltage.

Actual high data rate fiber optics communications modulation formats (DPSK, DQPSK & QPSK) require modulating with a peak-to-peak voltage of twice the V_π of the modulator. If the V_π of the modulator is 6 V then, the peak-to-peak output voltage of the driver should reach 12 V. To make this possible, the driver should integrate a high output power final stage.

> Performances



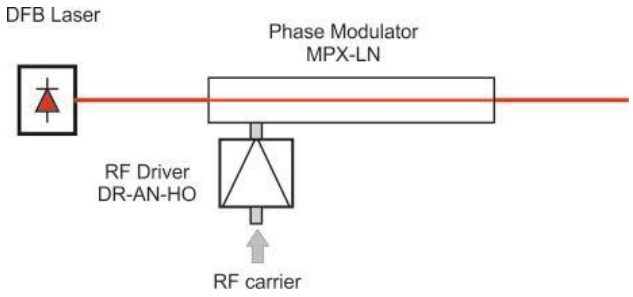
Electrical 20 Gb/s data stream with 2 x V_π peak-to-peak voltage applied to an intensity modulator to generate a high SNR 20 Gb/s DPSK optical data stream

Compared to the DR-DG-XX-MO, the linear gain in amplitude is twice, i.e. an extra 6 dB in power. The gain of the driver is thus typically **29 dB**, and the saturated power typically **+26 dBm**.

The heat management and dissipation become even more critical with HO series and the use of a heat sink is therefore mandatory.

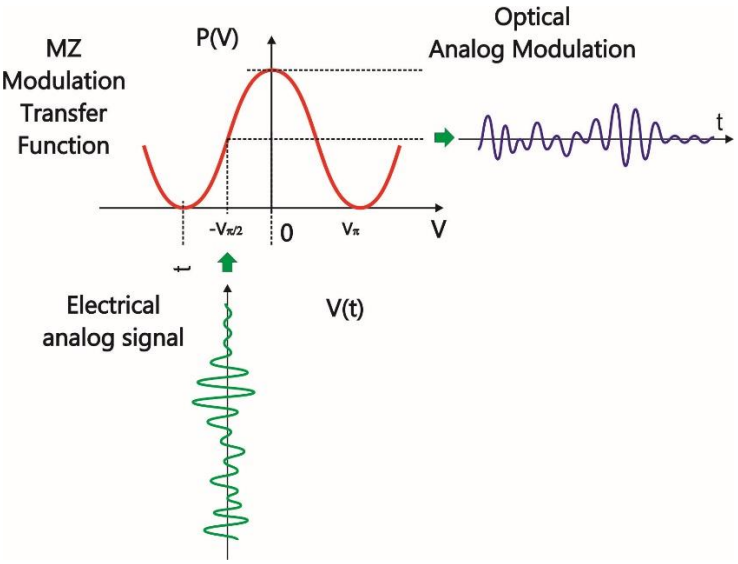
The DR-AN serie

The DR-AN series drivers address analog applications. In such applications, the incoming signal is a random signal in amplitude and frequency around a microwave carrier. The combination of driver and modulator should convert this signal without distortion and without excess additional noise. To do so, the amplifier must have a high saturation level.



Typical set-up for analog modulation applied to phase modulator

The DR-AN serie must perfectly reproduce the incoming signal with an amplitude level nearly equal to the linear part of the modulator sinusoidal transfer function, thus avoiding distortion from the modulator.



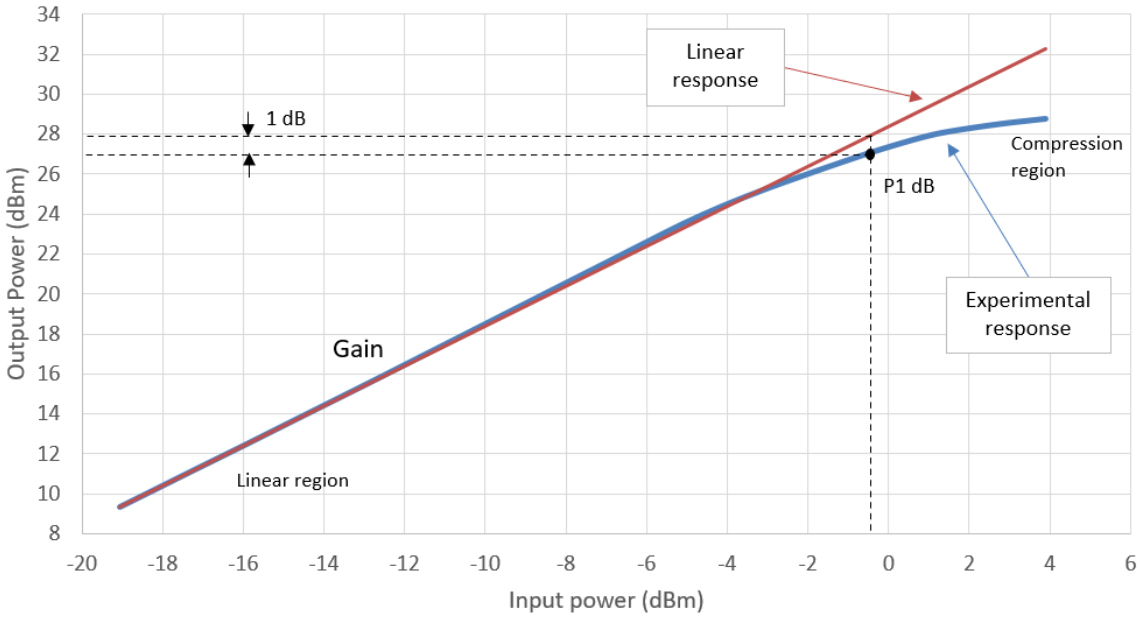
Analog electrical signal with < V_π peak-to-peak voltage applied to an intensity modulator to generate a faithful optical reproduction

DR-AN-XX-MO

The optimization of the DR-AN-XX-MO serie modules is focused on the linearity and the 1dB compression point (P_{1dB}), whereas the optimization of the DR-DG series is focused on output signal parameters such as cross point, SNR and jitter.

The 1 dB compression point is the output power level at which the difference between the linear response and the experimental one of our drivers is 1 dB (see figure below). Once a driver reaches this point it goes into compression. It is now a non-linear device which implies distortion, harmonics and intermodulation. That's why our drivers should always be operated below the compression point.

For the DR-AN-XX-MO serie, P_{1dB} is around +23 dBm, which is higher than the power level required for the modulator's full modulation (V_π). This guarantees a large dynamic range with improved linearity. The modulator nonlinearity will then be the only limitation factor.

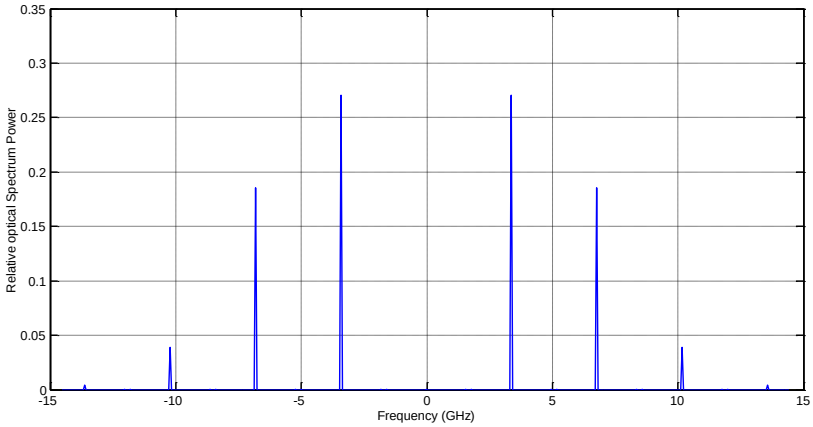


Measurement of the output power versus the input power response of the DR-AN to determine the compression point

The level of the electrical signals that must be amplified, for instance signals coming from antennas, can be very low. Thus, the analog amplifier must exhibit a high gain, typically 30 dB**,** that is significantly higher than the gain of the DR-DG series.

DR-AN-XX-HO

The DR-AN-XX-HO serie addresses specific applications in which sinusoidal signals with high amplitude levels are required, typically in SSB, CS-DSB or CS-SSB applications. In such configuration, a phase modulator is driven with a DR-AN-XX-HO driver so as to generate controlled optical sidebands around the optical carrier.

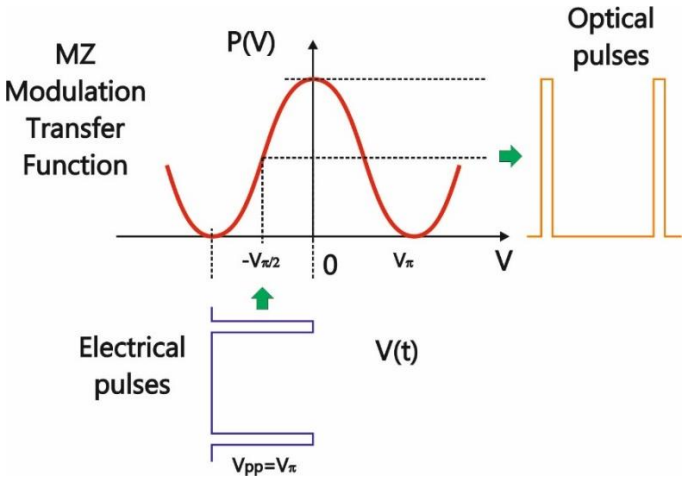


Relative optical power spectrum of a CS-DSB generation set up

The DR-AN-XX-HO drivers have a typical output power of +28 dBm in saturation mode.

The DR-PL-20-MO

Pulsed modulation requires specific drivers. The DR-PL-20-MO is designed for these applications working at 20 GHz.



Pulse electrical signal with V_π peak-to-peak voltage applied to an intensity modulator to generate optical pulses with high extinction

The DR-PL-20 driver is designed to amplify low-level electrical pulses to a peak value of typically the V_π of the modulator. The typical set up usually intends to generate high extinction ratio optical pulses. The requirement for the DR-PL drivers is to maintain the rectangular shape of the input electrical pulses and to be transparent to both the pulse duration and the duty cycle, the latter being potentially very low, or guarantee the temporal waveform of the incoming pulse in case of Arbitrary Waveform applications. This is obtained by a specific configuration of the MMIC chips that allows to obtain a sufficient gain without ripple and overshoots and reaching the saturation level at the same time.

The low frequency cut-off can be optimized on requirements to reach very low pulses repetition rate. This can be useful in specific application such as amplification of pulse burst. The rise and fall time of the DR-PL-20 drivers are typically 20 ps, which allows us to produce short duration pulses of 60 ps. The operating pulse width can be extended to 10 ns.

To have wider operating pulse width and for applications under 20 GHz, the DR-VE-XX-MO serie is the solution.

The DR-VE-XX-MO serie

Our new « VE » serie stands for Versatile. It allows the user to use the same driver to address all applications listed above:

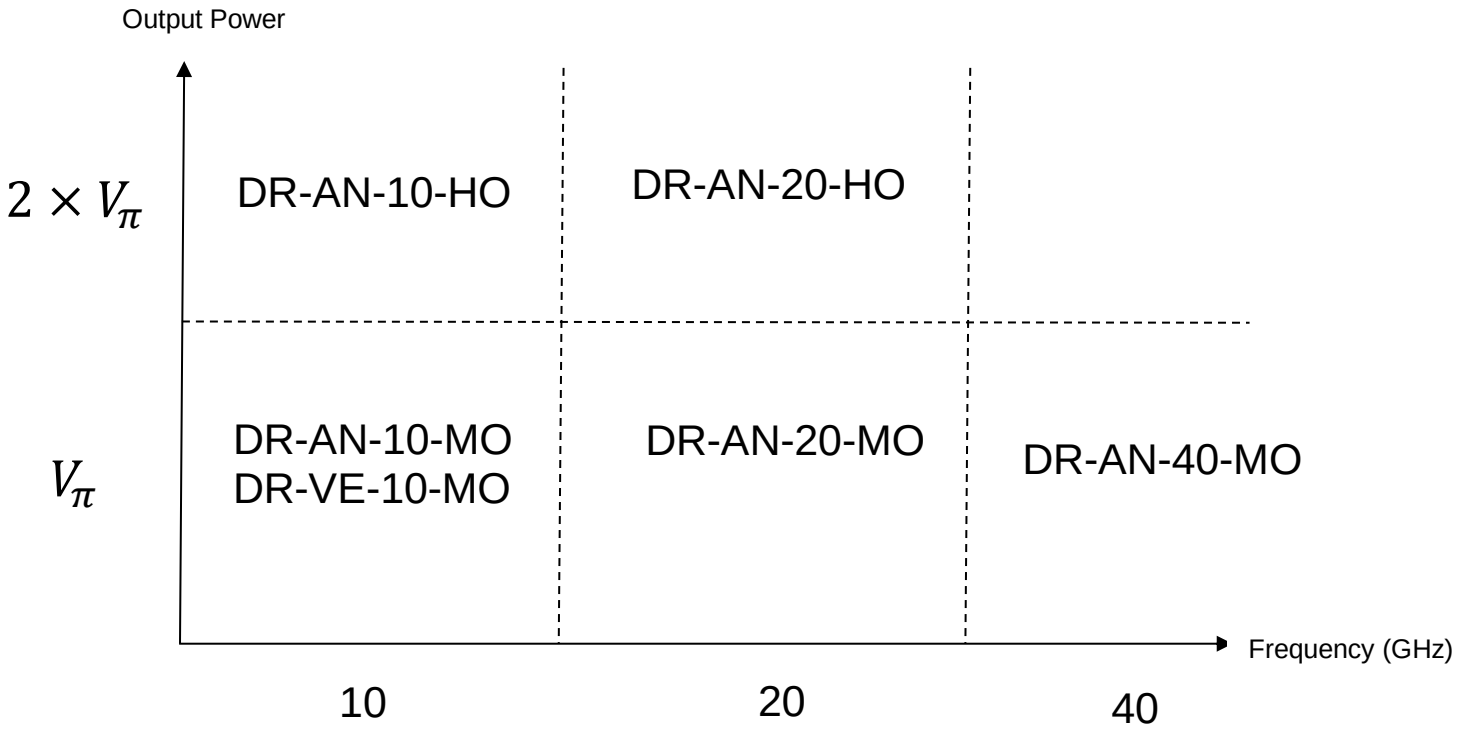
- The DR-VE-0.1-MO and DR-VE-0.5-MO address the low frequency market in which a DC coupling of the amplifier is required - an example would be the phase optimization of optical beams.
- The DR-VE-10-MO is a smart driver which integrates an embedded controller preset with optimized parameters for AN, DG, or PL applications. This allows the user to generate pre-optimized signals depending on the required application.

Picture of the DR-VE-10-MO

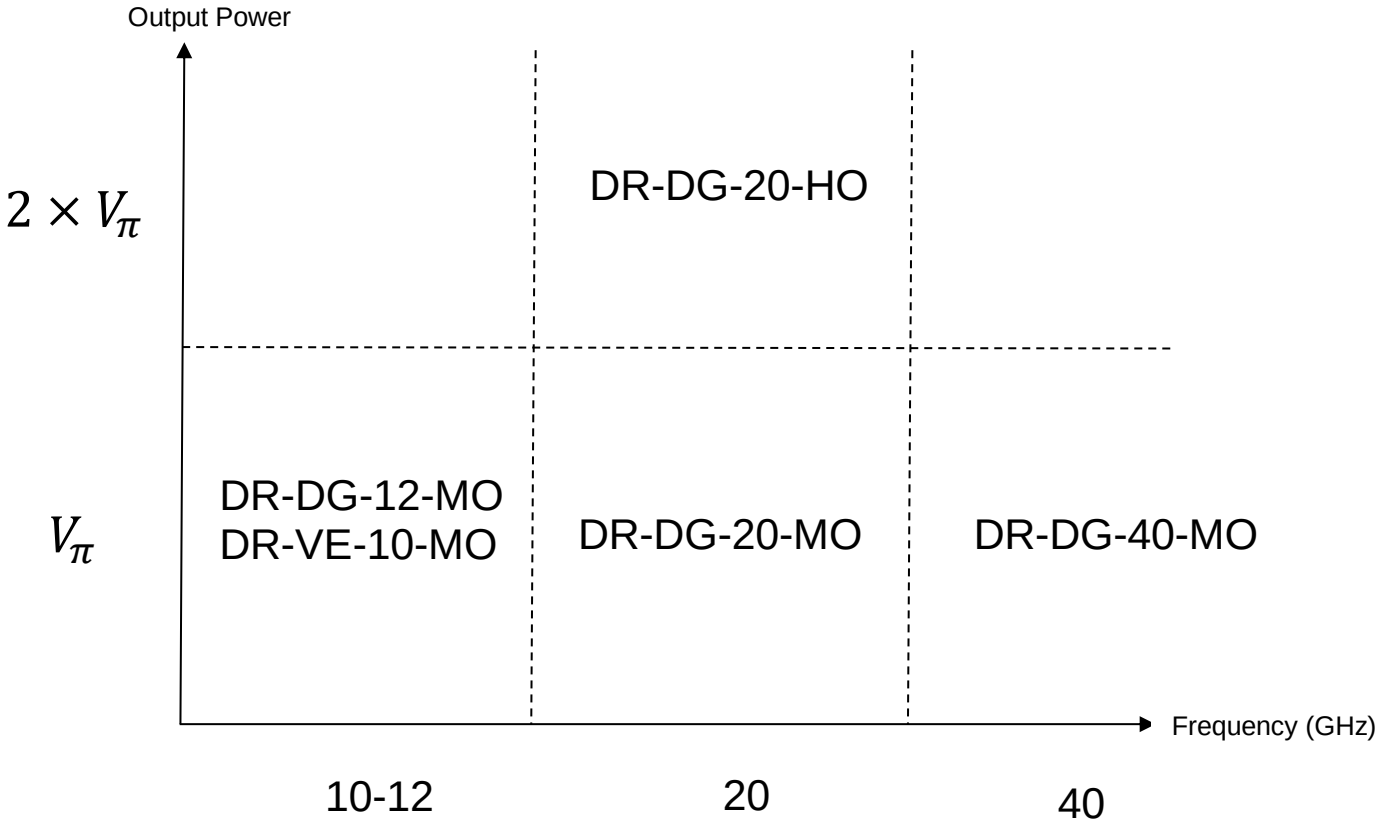
Conclusion

Exail provides a wide variety of drivers addressing all the applications. The charts below will help you to find the best solution depending on your modulation scheme and the frequency used.

Analogic Market



Digital Market



Pulsed Market