

# Abrupt Carrier Phase Reversal Keying

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ACPRK and ACPSK modulate the RF carrier directly without going through the IF modulation and up conversion stages. This has many advantages with short pulse abrupt phase changes, since for many applications, no transmitter filtering is needed. All narrow band filtering is done in the receiver to obtain the narrow noise bandwidth.

The phase change for ACPRK is 180 degrees, but an abrupt phase shift network keyed with varactor diodes can yield almost any desired phase shift. ACPSK uses 90 degrees.

## Advantages:

RF transmission frequencies up to 60 GHz can be accommodated, whereas the previous methods were limited to about 150 MHz in the IF stage.

The absence of filtering in the transmitter lowers the cost of the transmitter and reduces the tuning steps in production. Since no IF stage is used, the expense of the IF frequency oscillator and bandpass filters is spared. This can be a distinct cost advantage with telemetry units, such as the iMeter.

An IF amplifier with narrow band filtering is required in the receiver, but the absence of a transmitter IF section removes any cross talk in transceivers between transmitter and receiver. This has been a serious problem in full duplex units previously built. For simplex operation, the transmit VCO must be disabled.

The receiver IF frequency is not specified. It can be any frequency that will have enough IF cycles for clean detection.

## Disadvantages:

Compared to 3PRK or WPRK (RZ), the maximum data rate is only 1/2 as high for a given IF frequency.

This disadvantage is due to the loss of carrier synchronization with data, which limits the data rate for a given receiver IF frequency. The carrier and data are not synchronized as it is with the discrete IF frequency methods.

No filtering at RF means the method must be restricted to uses where the spread  $\sin x/x$  pulses are at or below regulatory maximums.

**ACPRK is a 'Minimum Sideband' method ( MSB ).**

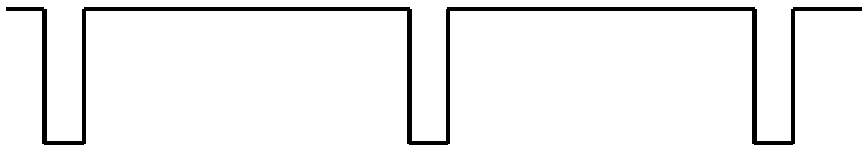
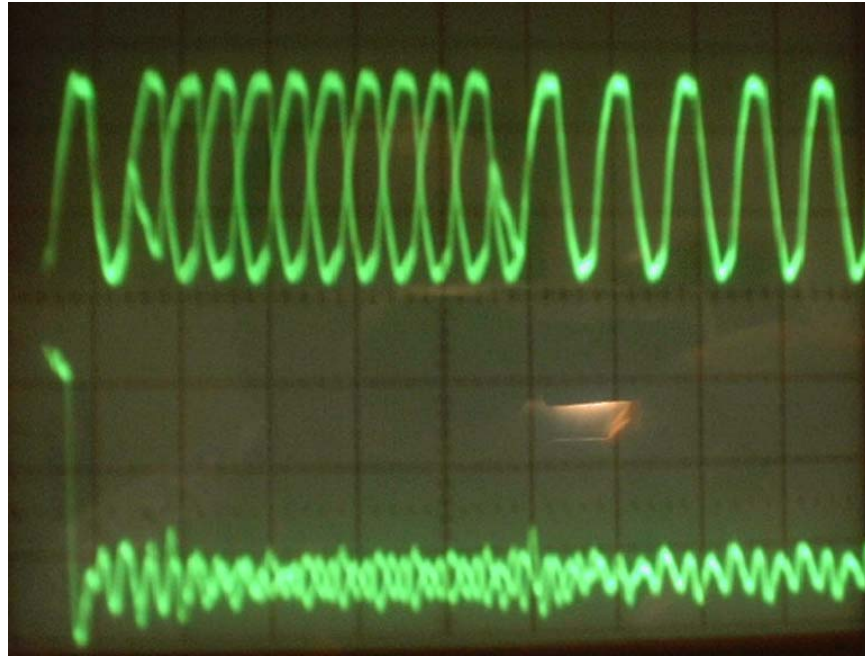


Fig. 1. The Ultra Wide Pulse used as a baseband input for ACPRK and ACPSK.

**The pulse is on for a long time, off for a short time.**

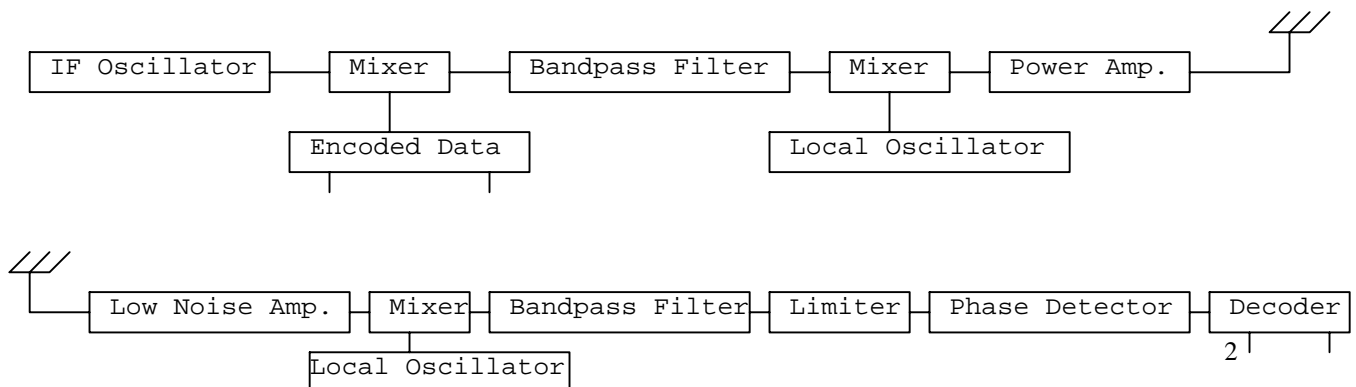


**Figure 2. The Phase Reversing Waveform. ( ACPRK ).**

Figure 2 shows the result of the baseband signal from Figure 1 after being applied to a phase reversing modulator. In this case, an XOR gate was used. XOR gates are limited to frequencies below approximately 150 MHz. Phase reversals can also take place in diode ring mixers ( balanced mixers ) that can operate well into the microwave frequency range.

If the operating frequency of the system is 400 MHz and up, the XOR gate cannot be used directly, but must be used to modulate an Intermediate Frequency ( IF ), which is then up-converted to the desired transmission frequency ( RF ). This is then down-converted in the receiver to restore the IF frequency, which is detected and the information decoded.

Figure 3 is a block diagram of the standard Superheterodyne transmitter and receiver.



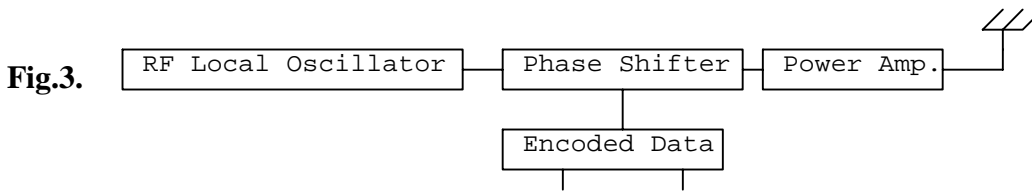


Figure 4. ACPRK Transmitter.

The much simpler ACPRK transmitter is shown in Figure 4. This method can be used well into the GHz region in preference to the more complex up-conversion method. The superheterodyne receiver is still required. Some form of automatic frequency control in the receiver is required due to the very narrow bandwidth of the receiver filters.

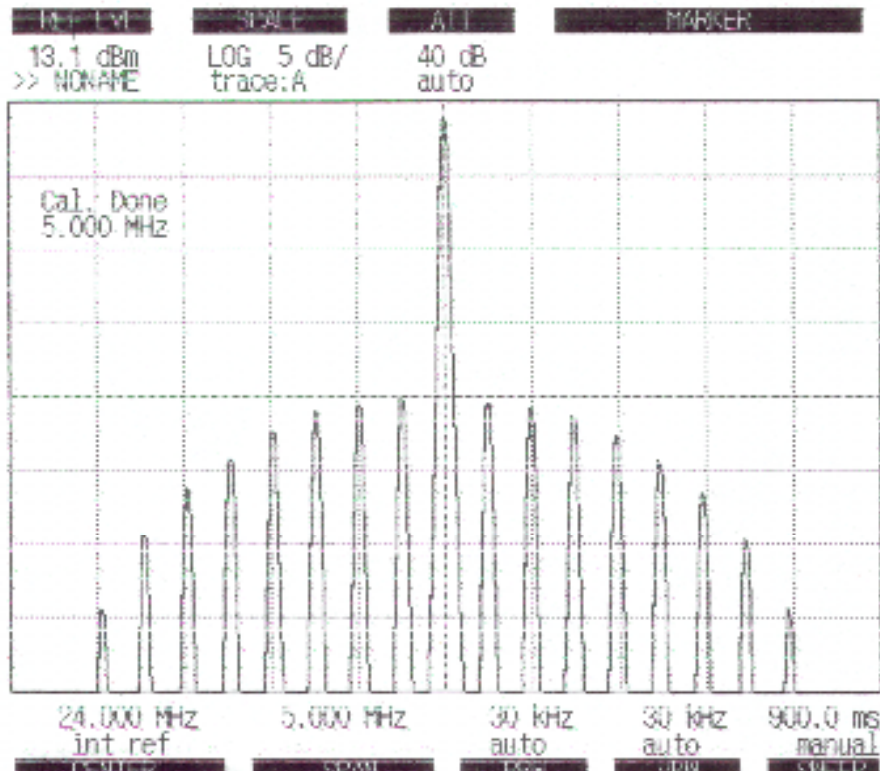


Figure 5. The Spectrum for ACPRK Modulation.

Figure 5 shows the spectrum transmitted using ACPRK when the on time is 90% and the off time 10%. Actually this is phase 1 time 90% and reverse phase time 10%. The useful modulation is in the single frequency line at the center. The lower spikes are filtered off in the up conversion method, but must be accepted using ACPRK, since there is no ultra narrow band filter. In this example, the lower spikes, which are Fourier amplitude spikes, are 20 dB below the peak level of the desired spike. They can be lowered by using a different timing ratio.

The peak level is  $-20 \log_{10} (T/t)$ . The RMS level, which is what the FCC uses for regulatory purposes, is  $-40 \log_{10} (T/t)$ . In the above example, the RMS level is 40 dB

below the peak level. The method uses phase shifts for ones only, which occur 50% of the time, so the actual RMS level is 6 dB lower, or -46 dB, which barely meets the FCC requirements for a 1 Watt Cellular unit ( Fig. 5 ).

Cellular Tower phone use could require a lower level. Suppose the desired level is -60 dB. The peak level must be -30 dB, which requires a timing ratio of 30/1.

The data rate available is a compromise between the timing and the IF frequency in the receiver. A minimum of 3 cycles of the IF waveform are required for reliable detection of the pulse 'off time' to obtain the 46 dB RMS level above with 10/1 timing, the IF frequency must have 27 cycles on and 3 cycle reversed, or 30 cycles per bit period. Assuming a 24 MHz IF, the maximum data rate is  $24,000,000/30 = 800,000$  bits/second. Using a 45 MHz IF, the maximum rate is rate is 1.5 Mb/s. With a 90 MHz IF, it is 3 Mb/s. To obtain the -60 dB RMS level for the  $\text{sinc}/x$  Fourier pulses, it is 1/3 the above rates.

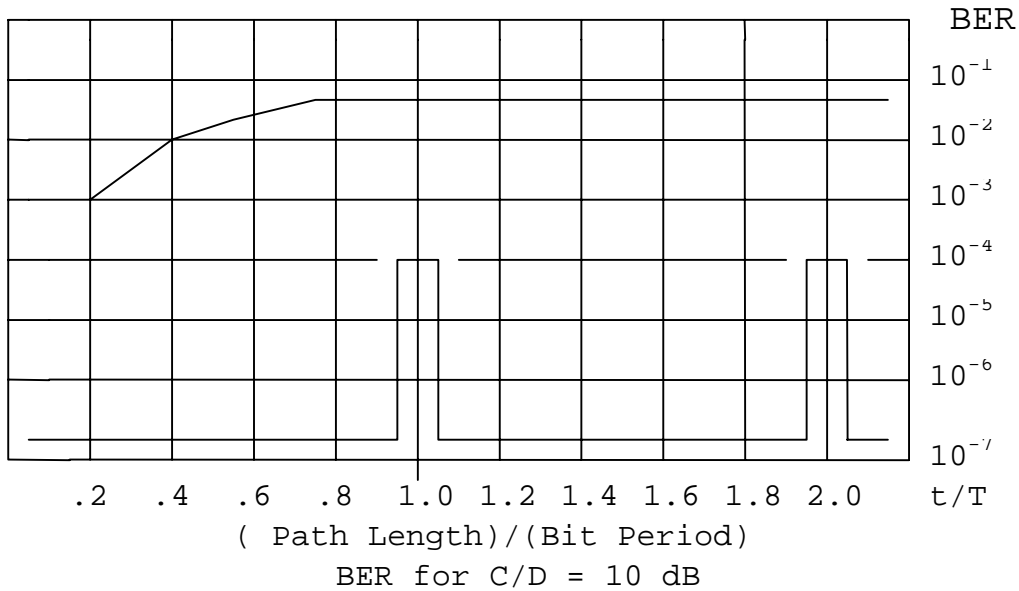


Figure 6.

This method has excellent multi-path characteristics, and an excellent SNR. Other MSB methods can achieve much higher data rates, but they do so by sacrificing multipath performance and some SNR. The multi-path performance of ACPRK is far better than any other method and the SNR is better than that for BPSK modulation, or for GSM or ordinary FM. Interference occurs only when the echo path length RF travel time equals the pulse separation time. That is, when the pulses from the two paths overlay. At all other distances, the interference can reach nearly 0 dB. No other modulation method can approach this performance. The curve at the top of Fig.6. is for all other methods.

Figure 7 shows the schematic of the ACPRK/PSK modulator. If the variable capacitor at the top is omitted, the phase shift is 180 degrees. (PRK ). **If it is added, the shift can be**

adjusted to 90 degrees. ( PSK ). It has been observed this improves the overall operation slightly.

A 90 degree shift can also be accomplished with a 90 degree combiner / splitter device.

The mixer is a standard RF mixer such as those from MiniCircuits (TUF5) or Hittite. Those with a high frequency IF spec. are preferred, as this reduces the amount of pulse edge carry over to the RF. The two NAND gates ( 74AC00 ) are used to create a controlled pulse of variable width. The series RC creates a 50% Vcc bias and limits the current to the mixer IF input. It matters little whether the signal comes in on the RF and out LO pins, or vice versa.

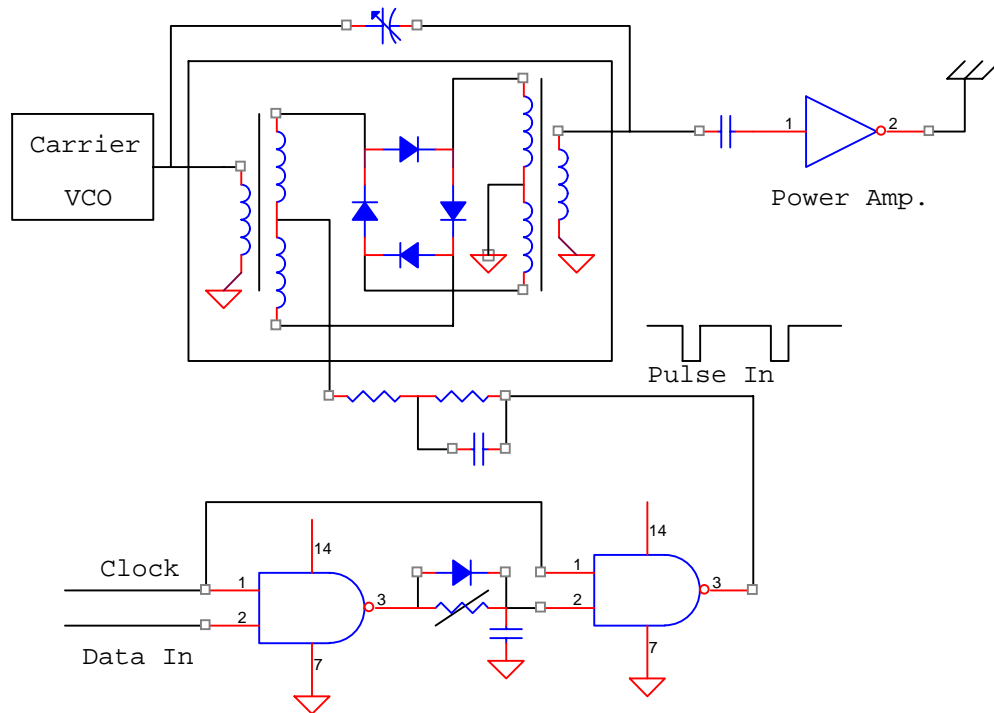


Figure 7.

The pulse width is varied by the variable resistor. This in turn regulates the level of the spread  $\sin x/x$  pulses seen in Fig. 5. The trimmer across the mixer can cause a phase shift to 90 degrees.

Applications include Telemetry, Satellite links, Microwave links, or any other method where the carrier is above 150 MHz.

MSB modulation is an abrupt phase change phase modulation method that does not produce Bessel sideband products. Note Fig. 5. There are no Bessel  $J_n$  products, even though the phase angle change is  $\pm 90$  degrees. If there were Bessel products present, the  $J_1$  products alone would be at -5dB below the carrier. Obviously they are not there. Yet the detector detects the phase change as  $\pm 90$  degrees, or  $\pm 45$  degrees.

Use 74F00, 74ACT00, or 74AC74 one shot. 74HC and AC00 have sloppy recovery on the pulse backside. Drive to the mixer should be 10 ma. The LO level can be -5 to +15 dBm. Loss is only 2-3 dB.

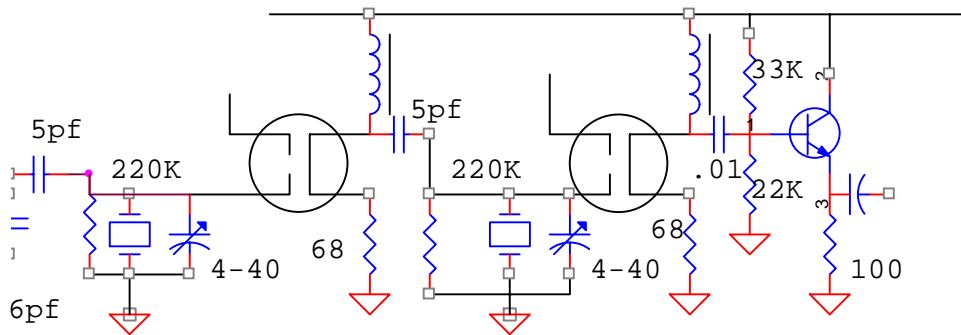


Figure 8. Sample IF filter for MSB/VMSK. A pre filter is used ( not shown ). The Walker Shunt crystal filters that follow have a 2-3 kHz bandwidth. The pre-filter has a 3dB noise bandwidth of about 500kHz. With a 10 pf coupling cap and crystal as shown, the upper operating frequency is about 12 MHz unless the drive circuit has no complex impedance. Properly coupled, these circuits have been used to 90 MHz.

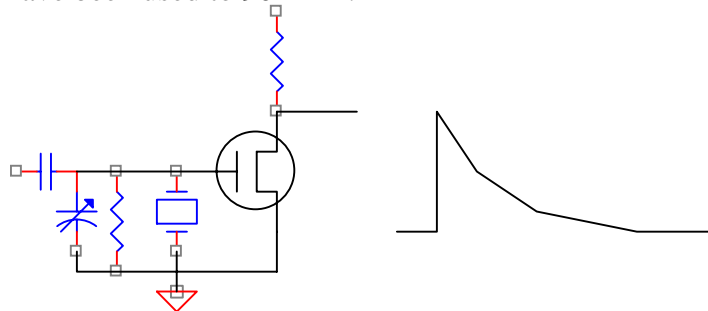
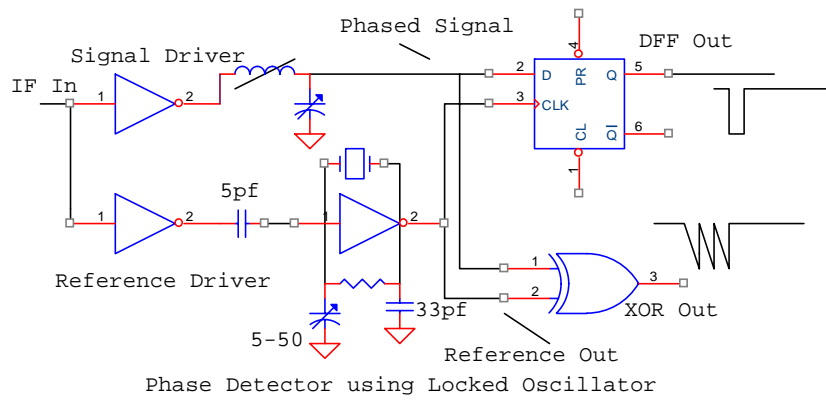


Figure 9. Basic zero group delay filter circuit is a differentiator at parallel xtal resonance. The IF frequency at the receiver is not predetermined. It can vary with the local oscillator offset. As a practical matter, most limiters available do not function well above 32 MHz. This filter circuit has been used satisfactorily with IF frequencies from 10.7 to 96 MHz.. The inductor has a value of 2.2 uH for 48 MHz. Increase or decrease for other frequencies.

See other reports on:

MSB ( Very Minimum Sideband Keying ), BER Measurements, Multipath Testing, Filter Summary, Filter Overload and Automatic Frequency Control.

Latest: See MSB Transmitter for receivers and transmitters that work at higher frequencies.



Phase detector for all MSB methods.