rasting Amplitude, Frequency,
n

Modulation

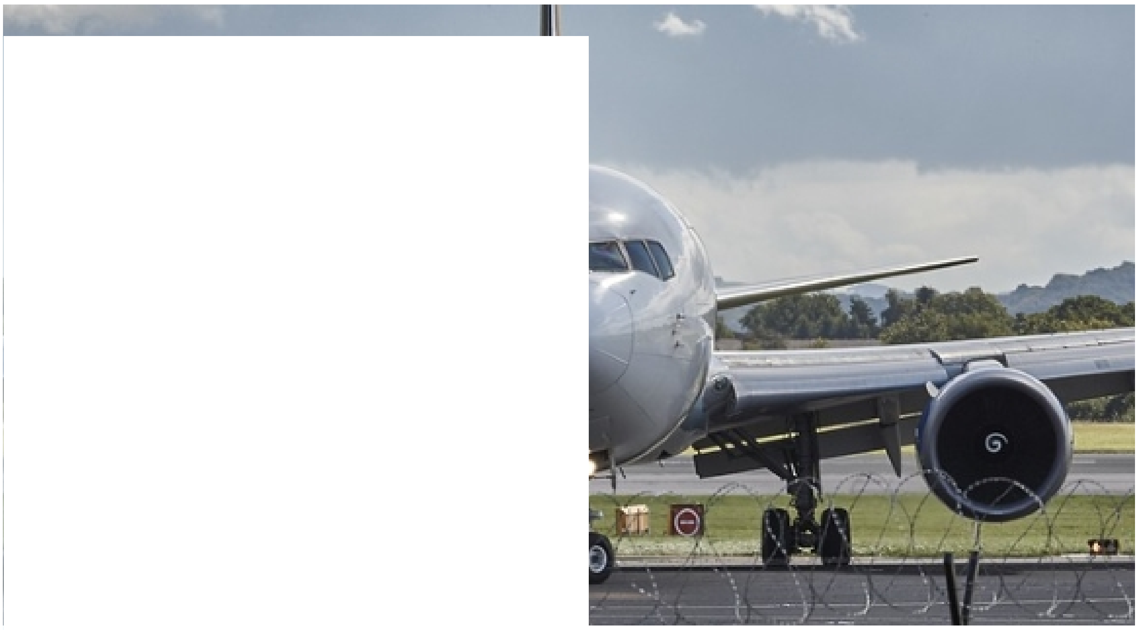
pare in terms of performance and applications? Let's take a look.

eristics of the three types of RF modulation. But this information
real systems that effectively and efficiently meet the
a general idea of which modulation scheme is appropriate for a

Amplitude Modulation

Amplitude modulation is straightforward in terms of implementation and analysis. Also, AM waveforms are fairly easy to demodulate. Overall, then, AM can be viewed as a simple, low-cost modulation scheme. As usual, though, simplicity and low cost are accompanied by performance compromises—we never expect the easier, cheaper solution to be the best one.

It may not be accurate to describe AM systems as "rare," since countless vehicles all over the world include AM receivers. However, the applications of analog amplitude modulation are currently quite limited, because AM has two significant disadvantages.



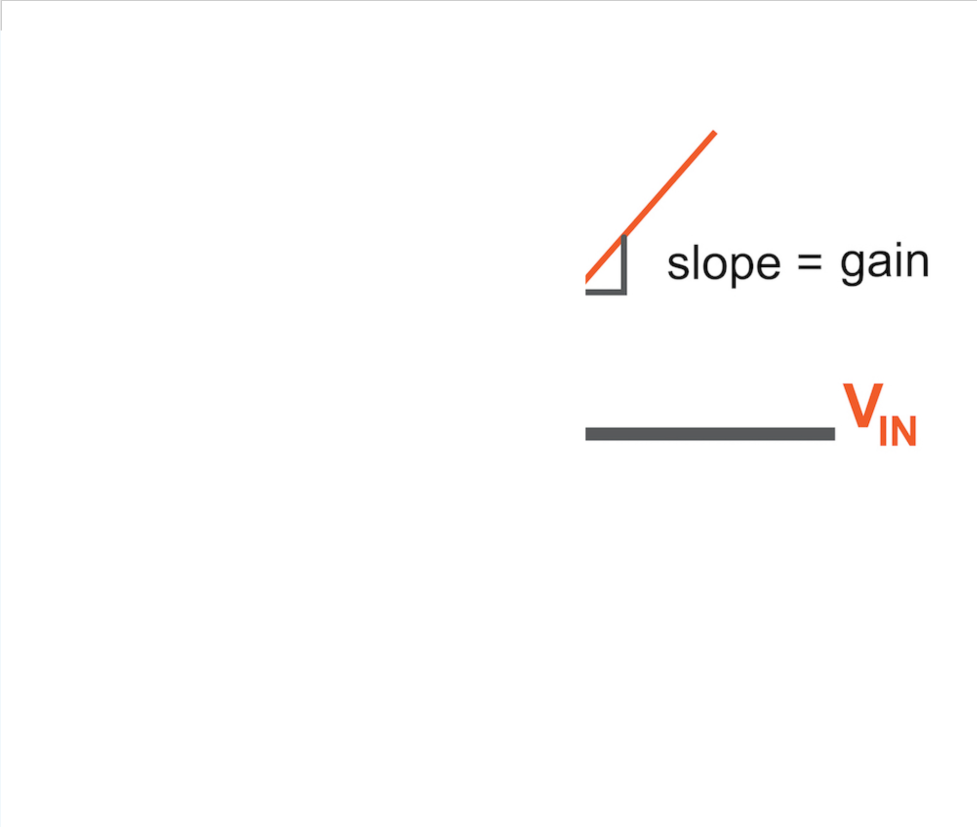
'e modulation is used in civil aviation.

nunication systems. In a certain sense, the quality of an RF
se ratio of the demodulated signal: less noise in the received
systems) or fewer bit errors (for digital systems). Noise is always
a fundamental threat to the overall performance of the system.

:lectrical and mechanical transients—operates on the magnitude
plitude modulation. This is a problem, since the random
not be distinguished from the intentional amplitude modulation
m for any RF signal, but AM systems are particularly susceptible.

Amplifier Linearity

One of the primary challenges in the design of RF power amplifiers is linearity. (More specifically, it is difficult to achieve both high efficiency and high linearity.) A linear amplifier applies a certain fixed gain to the input signal; in graphical terms, the transfer function of a linear amplifier is simply a straight line, with the slope corresponding to the gain.



ear amplifier: the output voltage is always the input voltage multiplied by a

of nonlinearity, meaning that the gain applied to the input signal
gnal. The result of nonlinear amplification is distortion, i.e., the
cies.

We can also say that nonlinear amplification is a form of amplitude modulation. If the gain of an amplifier varies according to the frequency of the input signal, or according to external factors such as temperature or power-supply conditions, the transmitted signal is experiencing unintended (and undesirable) amplitude modulation. This is a problem in AM systems because the spurious amplitude modulation interferes with the intentional amplitude modulation.

Any modulation scheme that incorporates amplitude variations is more susceptible to the effects of nonlinearity. This includes both ordinary analog amplitude modulation and the widely used digital schemes known collectively as quadrature amplitude modulation (QAM).

Angle Modulation

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Frequency and phase modulation encode information in the temporal characteristics of the transmitted signal, and consequently they are robust against amplitude noise and amplifier nonlinearity. The frequency of a signal cannot be changed by noise or distortion. Additional frequency content may be added, but the original frequency will still be present. Noise does, of course, have negative effects on FM and PM systems, but the noise is not directly corrupting the signal characteristics that were used to encode the baseband data.

As mentioned above, power-amplifier design involves a trade-off between efficiency and linearity. Angle modulation is compatible with low-linearity amplifiers, and these low-linearity amplifiers are more efficient in terms of power consumption. Thus, angle modulation is a good choice for low-power RF systems.

Bandwidth

dulation are more straightforward than those of frequency and
dvantage of AM: it's important to be able to predict the

al characteristics of FM and PM is more relevant to the
practical considerations, angle modulation could be considered
aseband bandwidth to a somewhat smaller (compared to AM)

re closely related; nevertheless, there are situations in which one
s between the two are more pronounced with digital modulation.

hen the baseband signal is a sinusoid, a PM waveform is simply
orm. It's not surprising, then, that there are no major FM vs. PM
or noise susceptibility.

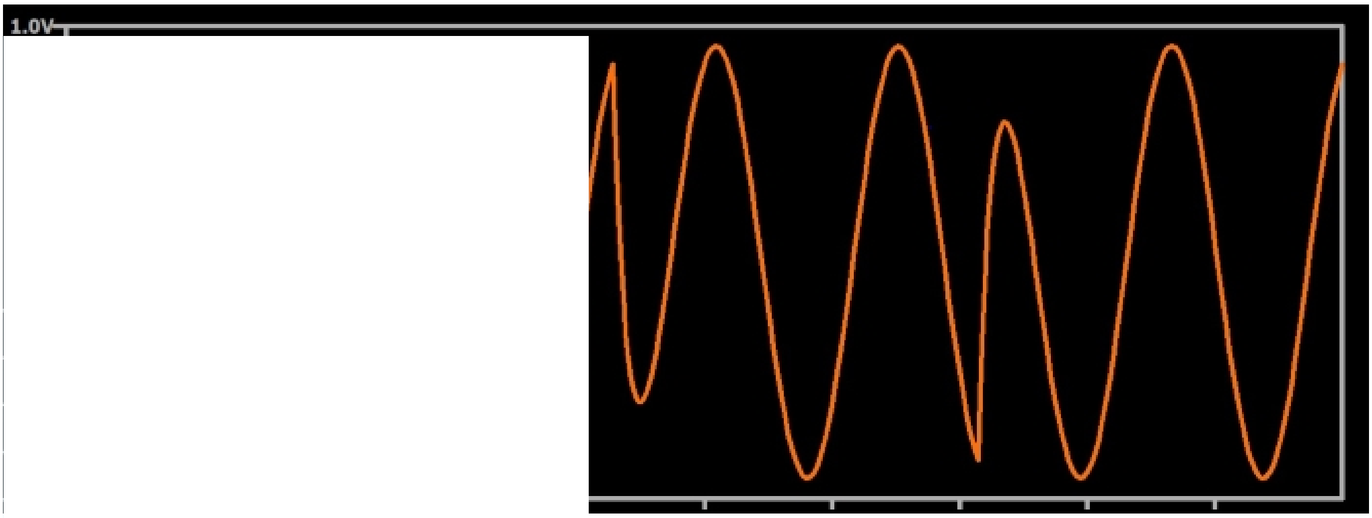
ian analog PM, and the reason is that FM modulation and
. For example, frequency modulation can be accomplished with
d an inductor and a voltage-controlled capacitor (i.e., a capacitor
onse to the voltage of a baseband signal).

Digital Frequency and Phase Modulation

The differences between PM and FM become quite significant when we enter the realm of digital modulation. The first consideration is bit error rate. Obviously the bit error rate of any system will depend on various factors, but if we mathematically compare a binary PSK system to an equivalent binary FSK system, we find that binary FSK needs significantly more transmit energy to achieve the same bit error rate. This is an advantage of digital phase modulation.

But ordinary digital PM also has two significant disadvantages.

- As discussed in the digital phase modulation page, ordinary (i.e., non-differential) PSK is not compatible with noncoherent receivers. FSK, in contrast, does not require coherent detection.
- Ordinary PSK schemes, especially QPSK, involve abrupt phase changes that result in high-slope signal variations, and high-slope sections of the waveform decrease in amplitude when the signal is processed by a low-pass filter. These amplitude variations combined with nonlinear amplification lead to a problem called spectral regrowth. To mitigate spectral regrowth we can either use a more linear (and thus less efficient) power amplifier or implement a specialized version of PSK. Or we can switch to FSK, which doesn't require abrupt phase changes.



ass filtering a PSK signal.

; susceptible to noise and requires a high-linearity power

: to amplitude noise and can be used with higher-efficiency,

eoretical performance in terms of bit error rate than digital advantageous in low-power systems because it does not require a

:, DQPSK