北京航空航天大學
BEIHANG UNIVERSITY

Avionics Technology

B31353551

— *Aero Communication*

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V. Aero Communication

（1）Some concepts

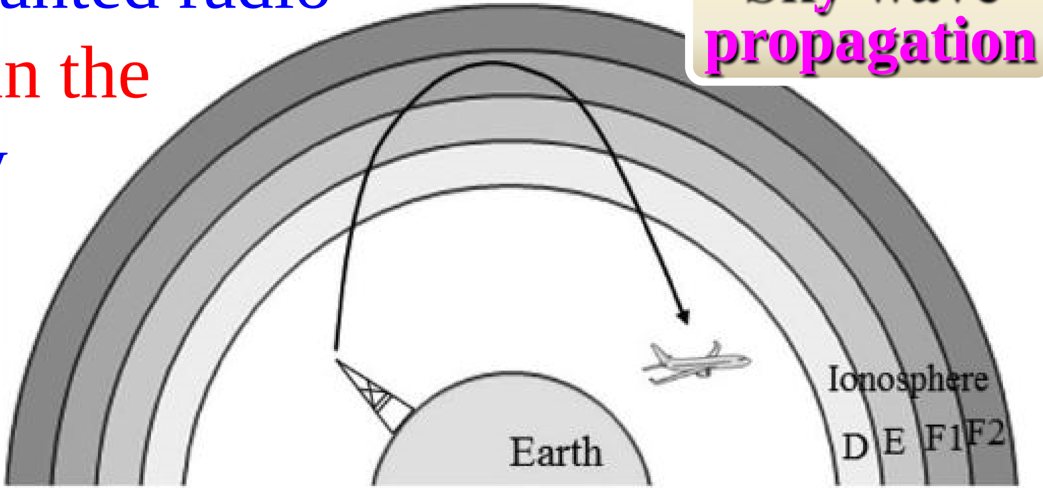
（2）VHF Communication

（3）Long-distance Communications

(3) Long-distance Comms

- The HF band lends itself to extensive range propagation with a low loss of reflection possible from the ionosphere, enabling various ‘modes’ to propagate thousands of kilometers. However it can also equally be a hindrance in that unwanted radio transmissions (e.g. lift in the noise floor) can equally propagate a long way.

Sky wave propagation



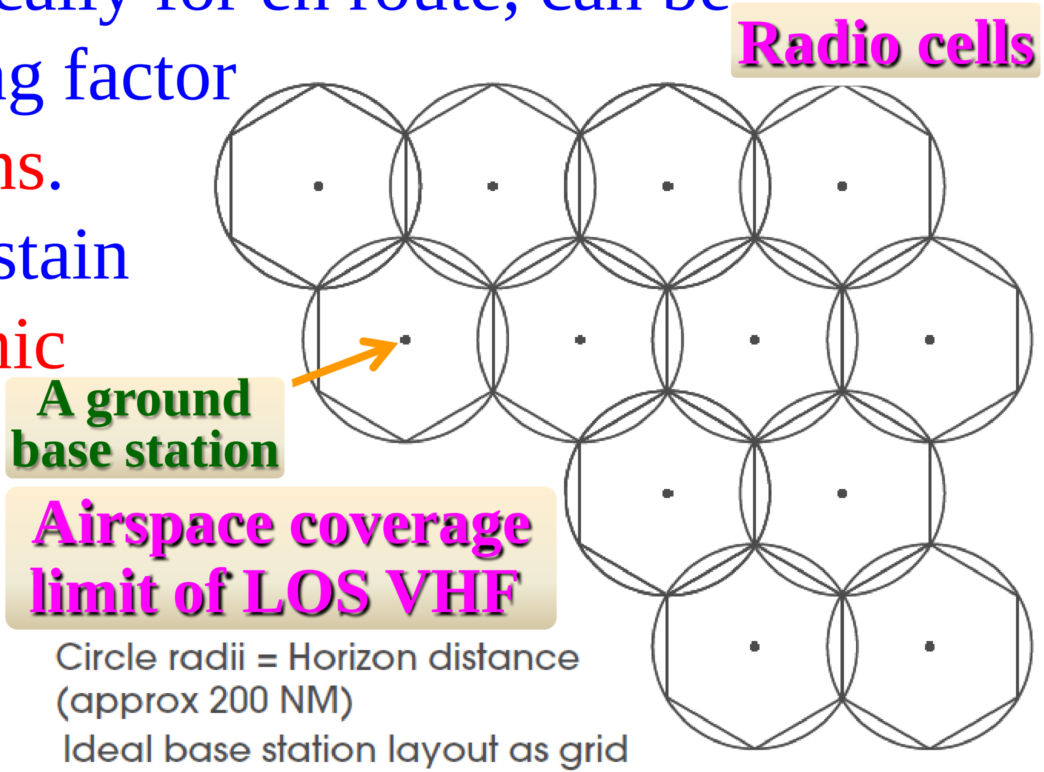
‘Over the horizon’ comms achieved by HF radio system

(3) Long-distance Comms

- The ionosphere extends nominally from 60 to 400 km above the earth's surface. It is so called as the particles in this region are easily ionized, giving it special electrical properties. Under certain conditions the radio waves will refract, and the waves that rely on the refractive properties of the ionosphere to propagate long distances are considered as sky waves (non-LOS propagation). The HF band (3 ~ 30 MHz) is well suited for this and aviation exploit this band (2 ~ 22 MHz) for this very purpose.

(3) Long-distance Comms

- In general terms, the LOS distance, which is up to 200 NM (nautical mile) basically for en route, can be considered as the limiting factor for VHF communications.
- It is uneconomical to sustain a VHF network in oceanic areas or remote regions. And the HF system can also act as an backup to VHF communications.



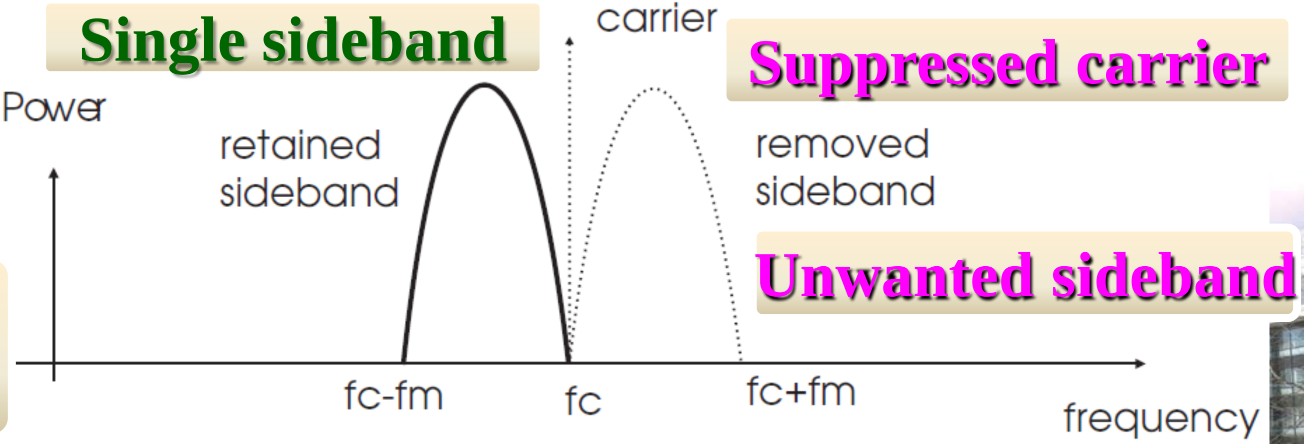
（3）Long-distance Comms

- Aviation has been awarded spectrum allocations right across the HF band between 2.8 and 30.0MHz. In approximately 27MHz of spectrum, civil aviation has been allocated 1.5MHz in total.
- With DSB-AM, it is found that the upper sideband is a perfect reflection of the lower sideband; i.e. the same information is carried by both. By removing one of the sidebands and by removing the carrier, therefore, no information is lost.

- Single sideband amplitude modulation (SSB-AM): Removing one of the sidebands and the carrier of DSB-AM, and the SNR (signal-to-noise ratio) increases for a given transmit power as all the transmitted energy is concentrated into the information signal.

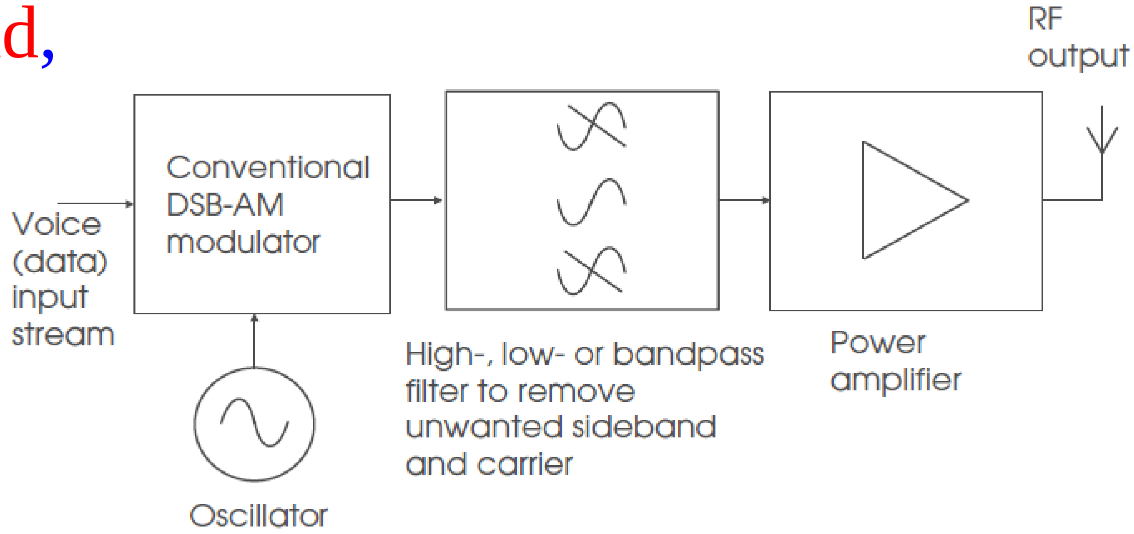
One half of the DSB-AM bandwidth

SSB-AM modulation illustration



（3）Long-distance Comms

- The construction of a SSB-AM signal is fractionally more complicated than that of DSB-AM.
- A SSB-AM signal can be synthesized by using basic DSB-AM modulator and filtering out the unwanted carrier and sideband, usually done at a intermediate frequency (IF).

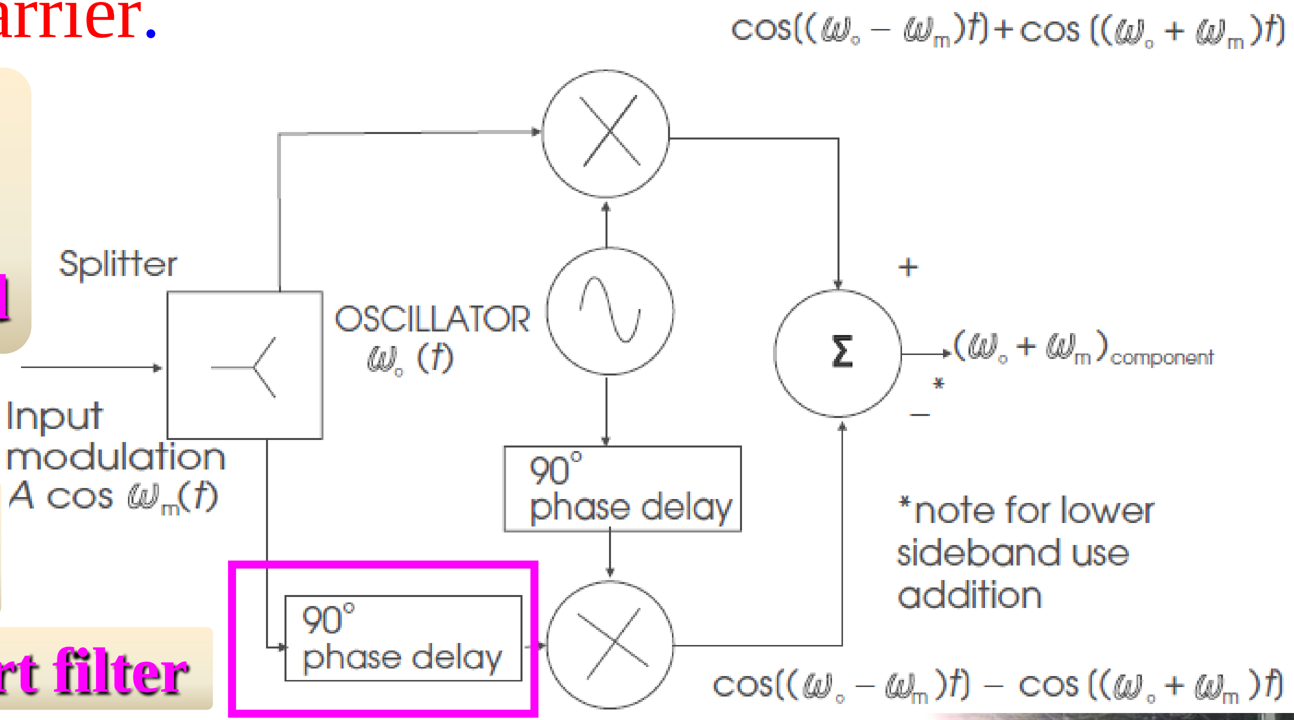


SSB indirect synthesis and filtering

(3) Long-distance Comms

- A SSB direct synthesis method is to use Hilbert modulator, which essentially cancels out the unwanted sideband and carrier.

Hilbert transform: it changes the phase by π /2, leaving the amplitude unchanged



SSB direct synthesis (Hilbert modulator)

Hilbert filter

(3) Long-distance Comms

- Input signal: $m(t) = A\cos(2\pi f_m t) \xrightarrow{90^o \text{ shift}} m_H(t) = A\sin(2\pi f_m t)$
- $m(t)$ multiplies with local oscillator's signal component $\cos(2\pi f_o t)$: $v_I(t) = 0.5A\{\cos[2\pi(f_o - f_m)t] + \cos[2\pi(f_o + f_m)t]\}$
- $m_H(t)$ multiplies with local oscillator's signal component $\sin(2\pi f_o t)$: $v_Q(t) = 0.5A\{\cos[2\pi(f_o - f_m)t] - \cos[2\pi(f_o + f_m)t]\}$
- Then, the output signal of modulator:

$$v_{out}(t) = v_I(t) - v_Q(t) = A\cos[2\pi(f_o + f_m)t]$$

Single (retained) sideband

- SSB demodulation: $f_c(t) = A\cos[2\pi(f_o + f_m)t]$

Multiplying with the locally generated signal $\cos(2\pi f_c t)$

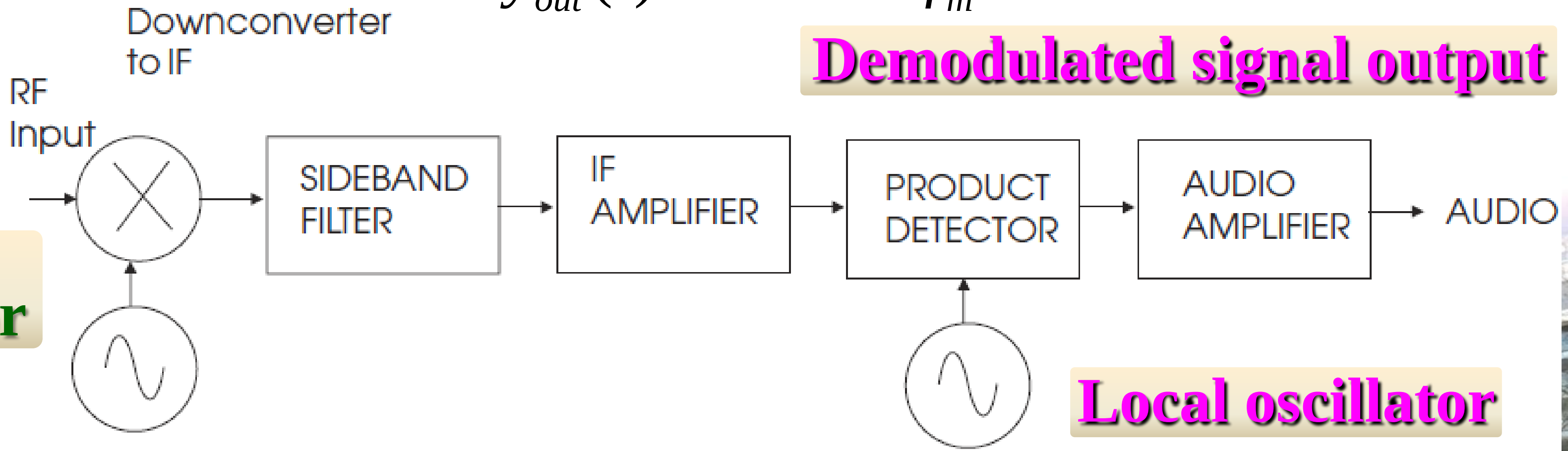
$$v(t) = A\cos[2\pi(f_o + f_m)t]\cos(2\pi f_o t)$$

After low-pass filtering

$$y_{out}(t) = A\cos 2\pi f_m t$$

Demodulated signal output

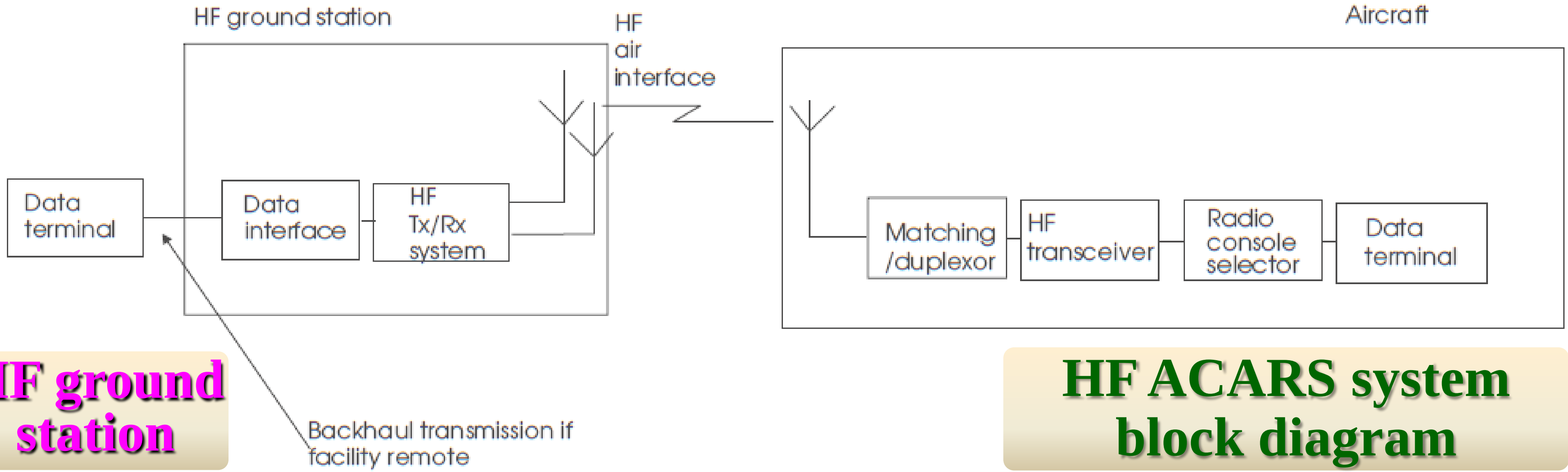
Coherent demodulator



Local oscillator

(3) Long-distance Comms

- HF Datalink (HFDL): ACARS for HF is used to pass messages between aircraft and the ground (or other aircraft) for long-range flights. And PSK modulation is employed at a bit rate of 0.3, 0.6,1.2 or 1.8 kbps optional.



HF ground station

HF ACARS system block diagram

（3）Long-distance Comms

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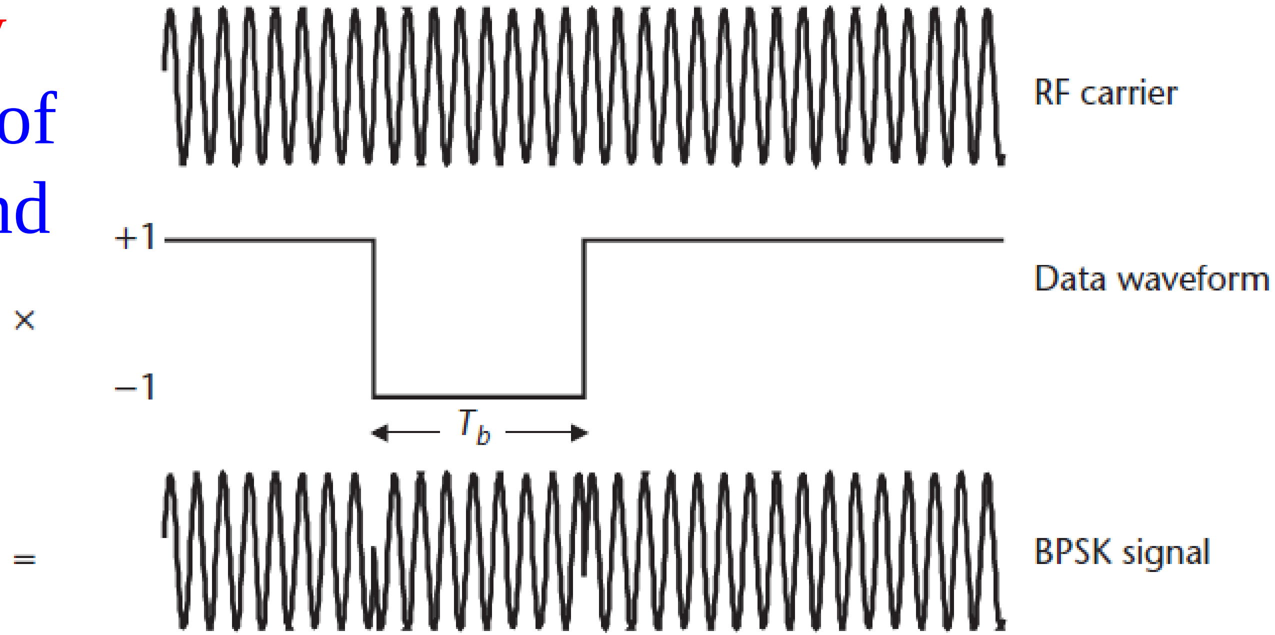
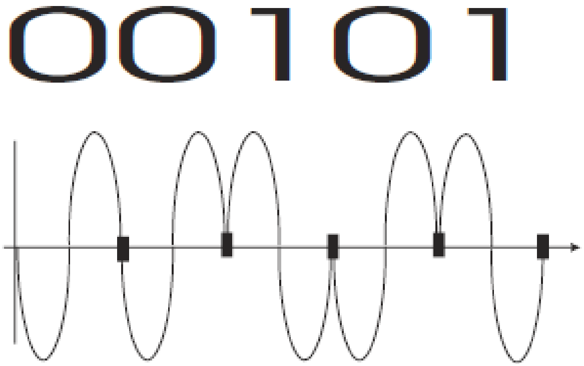
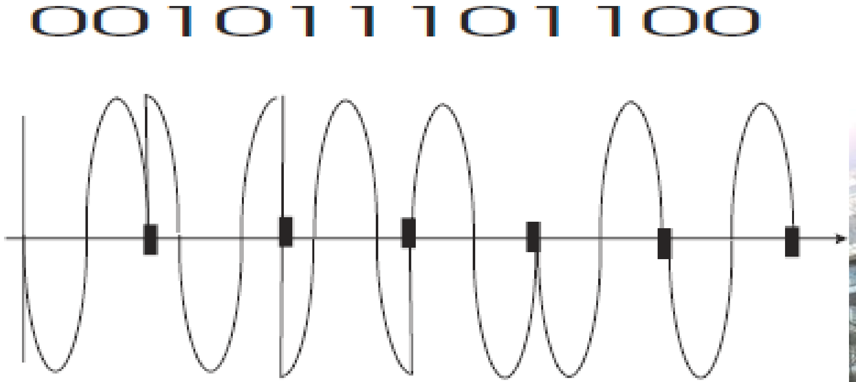
- PSK (Phase shift keying) modulation: The carrier phase is changed to represent a change in bit states. In the binary PSK modulator, the carrier is instantaneously phase shifted by 180° at the time of a bit change. And the continuous phase indicates no bit change.



Binary PSK (2PSK)

- *M*-ary PSK modulation, e.g. 4PSK (sometimes called quadrature PSK or QPSK): As with binary PSK, information is contained in the phase. In particular, the phase takes on one of four equally values, e.g. 0 (retains 0), π/2 (transits from 0 to 1), π (retains 1), and 3π/4 (transits from 1 to 0).





BPSK vs. QPSK

（3）Long-distance Comms

- PSK-based modulation schemes generate the transmitted signals having constant envelopes, which are not sensitive to amplitude distortions, but only to phase distortions.
- Coherent demodulation:

Modulated signal with discrete phases

$$f_c(t) = A\cos(2\pi f_c t + \phi)$$

Multiplying with the locally generated signal $\cos(2\pi f_c t)$

$$v(t) = A\cos(2\pi f_c t)\cos(2\pi f_c t + \varphi)$$

Using low-pass filtering

Demodulated signal output

$$v_o(t) = \frac{1}{2}A\cos\varphi$$

(3) Long-distance Comms

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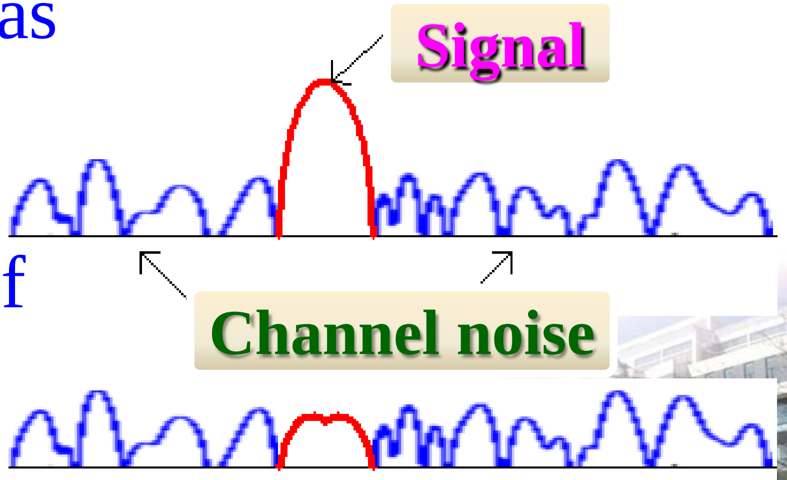
- The noise analysis of communication systems is customarily based on an idealized form of noise called white noise, the power spectral density of which is independent of the operating frequency. And signal-to-noise (SNR) is basically defined as the ratio of the average power of the modulated (or demodulated) signal (S) to the average power of the (measured) noise (N).



Low SNR channel condition

（3）Long-distance Comms

- Channel capacity (the theoretical limit for error-free transmission): The maximum data rate that can be attained over a given channel, a function of bandwidth and SNR, as shown by

$$C = B \log_2\left(1 + \frac{S}{N}\right)$$

Shannon's theory

where C is channel capacity in bps (bits/second), B is bandwidth in Hz, S/N is SNR, and $\log_2(\cdot)$ is logarithm to base 2.

(3) Long-distance Comms

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- The availability of radio channels in the HF band is a function of which channels are 'open' and 'closed' at the time. This is ultimately dependent on time of day or night, sunspot activity, solar flares (which are to a degree random and can wipe out HF communication ability) and range.
- The semi-random element to availability (reliability) makes HF engineering sometimes more of a black art than a science. Different countries and airlines use or do not use HF to different extents.

(3) Long-distance Comms

- To date, civil aviation mainly uses satellite services from geostationary satellites. That is, satellites in a stationary orbit above the earth's equator at a distance from the earth's surface of 35,790 km or 42,160 km from the center point of the earth's sphere. These satellites seem stationary with regard to the position of the earth.

(3) Long-distance Comms

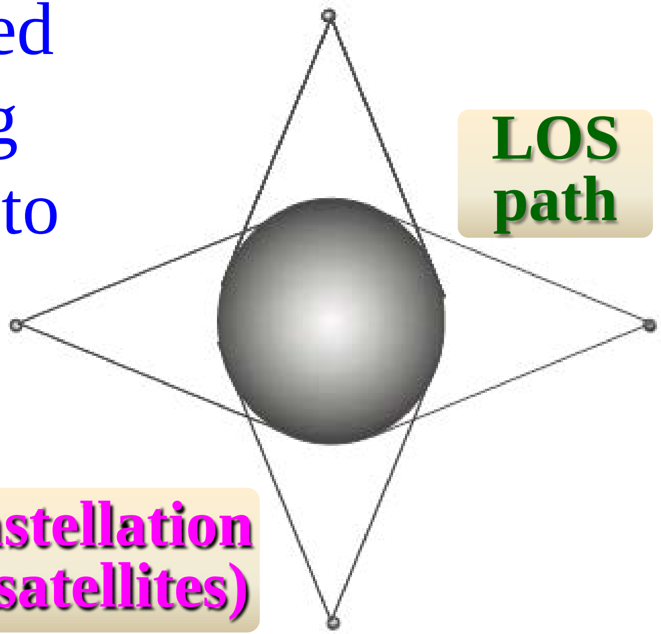
- In particular, aviation widely uses the Inmarsat services for safety and regularity of flight applications. The service is called the aeronautical mobile satellite (route) service, i.e. AMS(R)S.

Global coverage of Inmarsat system satellites

Inmarsat: International maritime satellite (communication system)

（3）Long-distance Comms

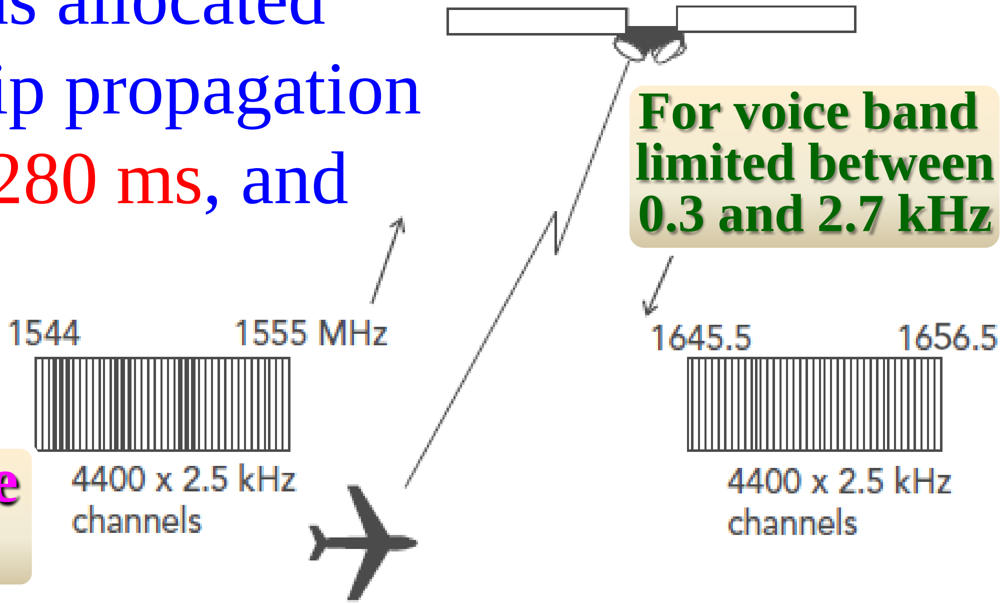
- Probably the most significant factor for Inmarsat satellite communications is the distance between the satellite and the earth. This introduces significant delay time between transmitted and received signals. Also this has a direct bearing on the path attenuation, which tends to be relatively large in satellite communications, i.e. an apparent lift in the noise floor, or relatively lower SNR.



Inmarsat constellation (4 operating satellites)

(3) Long-distance Comms

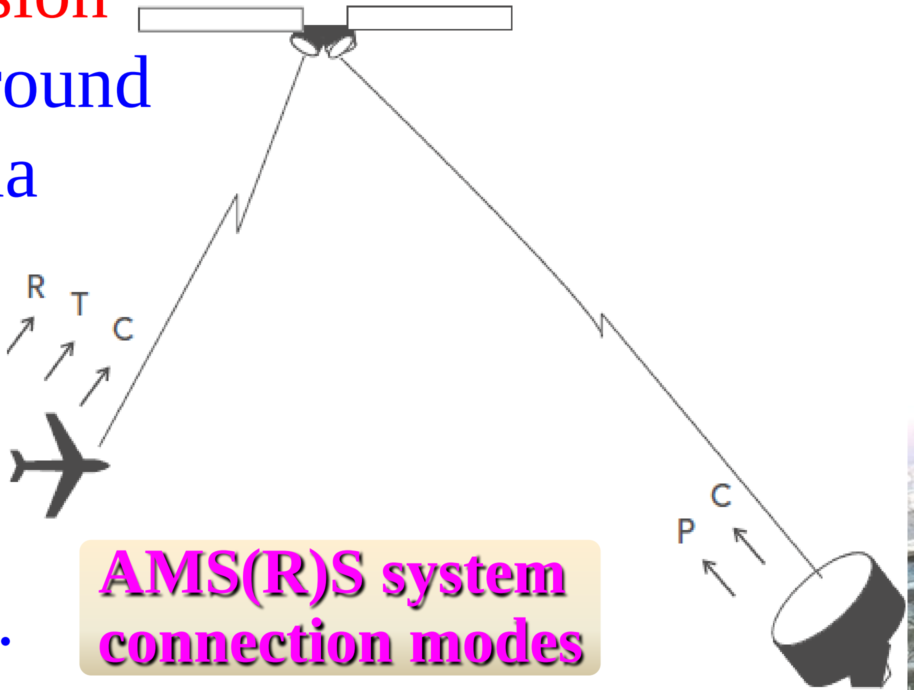
- The up (to geostationary satellites) and down (from geostationary satellites) mobile links use the frequency bands around 1.55 and 1.65 GHz respectively in the L band where AMS(R)S was allocated exclusively. The round trip propagation delay varies from 240 to 280 ms, and call set-up times are consequentially a few seconds typically.



AMS(R)S satellite channel plan

(3) Long-distance Comms

- Call set-up is facilitated by the P and R channels (protocol modes). The P channel operates in (data) packet mode using time division multiplexing (TDM) from ground earth station to the aircraft via satellite. The R channel is a random access protocol, which is transmitted from the aircraft when initiating a call or data message set-up.



AMS(R)S system connection modes

（3）Long-distance Comms

- The C channel(s) are for voice transmission. And the T channel is a data channel using TDM from the aircraft only.
- For the lower bit rate service provisions, the data modulation is specified to be binary phase shift keying (BPSK) running at a gross system bit rate of 0.6, 1.2 or 2.4kbps. For higher bit rates of greater than 2.4 kbps, quadrature phase shift keying (QPSK) is deployed.

The end of *Aero Communication*