AVIONICS & SPACIONICS

- Telemetry - Data communication –systems
- Nuno Borges Carvalho - nbcarvalho@ua.pt

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WHAT IS TELEMETRY?

•**Definition:**
Telemetry is the automated process of collecting data from remote or inaccessible points and transmitting it to a receiving system for monitoring and analysis.

•**Key Features:**

- Real-time monitoring
- Remote operation
- Essential for safety and efficiency in aviation

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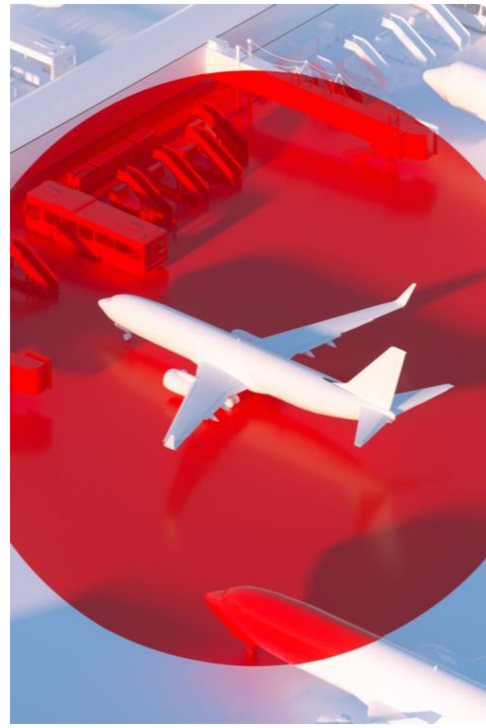
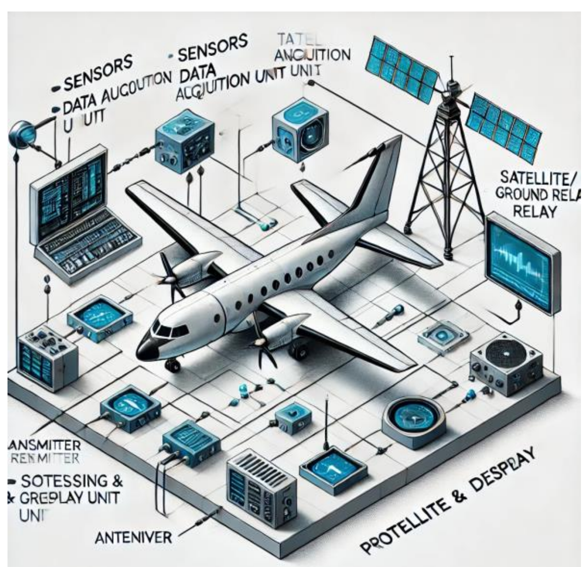
THE ROLE OF TELEMETRY IN AVIONICS

- **Applications in Aviation:**
  - Monitoring aircraft systems (engine health, flight dynamics, etc.)
  - Navigation and flight path adjustments
  - Early warning for system malfunctions
- **Benefits:**
  - Enhanced situational awareness
  - Improved safety and maintenance planning
  - Data-driven decision-making



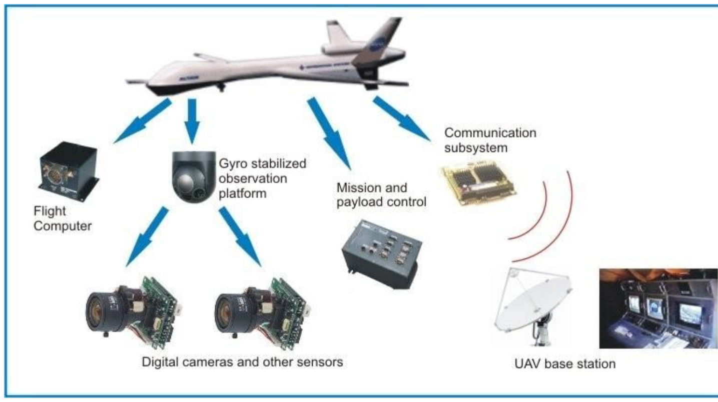
COMPONENTS OF A TELEMETRY SYSTEM

1. **Sensors:** Collect data (e.g., temperature, pressure, speed).
2. **Transmitters:** Send data wirelessly or via wired connections.
3. **Receivers:** Capture transmitted data at the ground station.
4. **Processors:** Analyze and visualize the data for actionable insights.
5. **Data Storage:** Archive for future analysis and reporting.



DATA TRANSMISSION PROTOCOLS

- **Common Protocols in Avionics Telemetry:**
  - ARINC 429: Standardized for aircraft systems.
  - MIL-STD-1553: Common in military applications.
  - Ethernet/IP: High-speed communication for modern avionics.
- **Frequency Bands Used:**
  - VHF, UHF, and satellite communication for long-range telemetry.



EXAMPLES OF TELEMETRY IN MODERN AVIATION

1. **Engine Performance Monitoring:**
   1. Sensors transmit data on turbine temperature, pressure, and vibrations.
2. **Flight Data Recording:**
   1. Black box telemetry for post-flight analysis.
3. **Drone Operations:**
   1. Real-time telemetry for navigation, payload control, and battery management.

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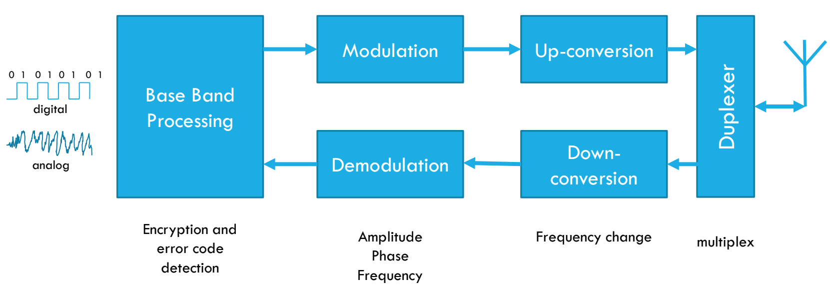
ANTENNAS



Antenna Interface: “A mean for radiating or receiving radio waves”
@ IEEE IEEE Standard Definitions of Terms for Antennas

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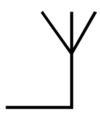
ANTENNA BASICS

The antenna is a passive device that can be characterized using a predetermined gain, matching, and diagram radiation pattern. It can be classified in:



Forms and Geometry:
- ← Linear antennas: Dipole, Monopole, helicoids, etc.
- ← Aperture antennas: Horn or Slot.
- ← Planar Antennas: Patch

Gain:
- ← High Gain: Parabolic
- ← Medium Gain: Horns
- ← Low Gain: Dipoles and Patches

Radiation diagram:
- ← Omni directional
- ← Directive

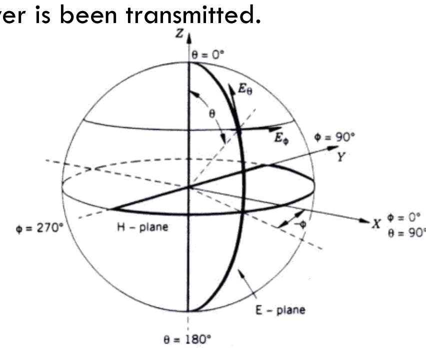
ANTENNA BASICS

The most well know antenna parameters are:

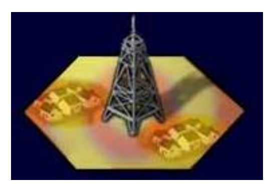
- ⇦ VSWR and input impedance
- ⇦ Bandwidth
- ⇦ Radiation diagram
- ⇦ Secondary radiation lobes
- ⇦ Directivity, gain and efficiency
- ⇦ Polarization
- ⇦ Effective area
- ⇦ Beam efficiency
- ⇦ back-front relationship

ANTENNA BASICS

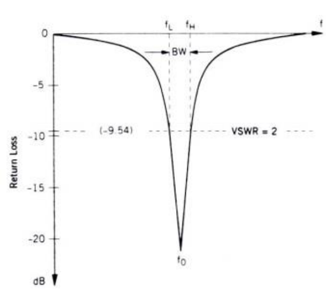
The received or transmitted power is a function of the distance and angular position in relation to the antenna. The power diagram in relation with the angular position is called the radiation diagram. This diagram is constant in respect with the distance, but allow us to understand how and where the radiation power is been transmitted.



ANTENNA

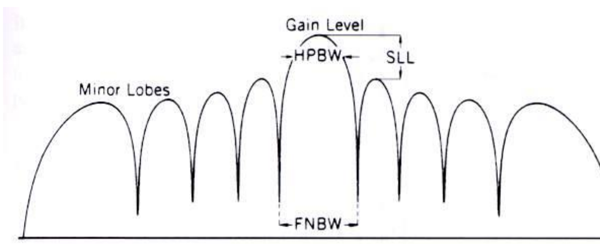


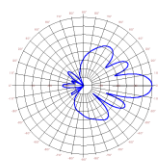
The bandwidth of an antenna is rather complicated to calculate, this is why it is usually defined as the frequency range for which the antenna has VSWR value > X, wherein X is a certain optimum value, typically 2.

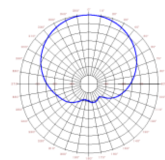


ANTENNA

The width of the beam at half power is the value in degrees that should be moved so that the power is decreased by 3dB. The side lobe level is the value in dB that is below the main lobe, this value is very important in cellular systems, since it imposes the interference on adjacent cells. You can also define the back-radiation, which is a measure of the potency of rear lobes.

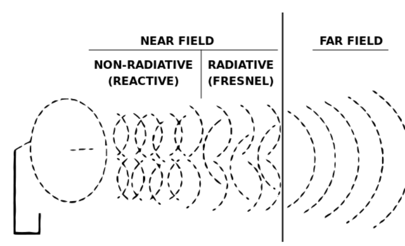






vertical **horizontal**

ANTENNA BASICS - FIELD REGIONS



The space around an antenna is usually divided into three regions:

- Reactive Near Field

  The reactive near-field region is defined as "that region of the field immediately surrounding the antenna wherein the reactive field predominates." For most antennas, the outer boundary of this region is commonly taken to exist at a distance $R < 0{,}62\sqrt{D^3/\lambda}$ from the antenna, where λ is the wavelength and D is the largest dimension of the antenna.

- Radiating Near Field (Fresnel)

  The radiating near-field (Fresnel) region is defined as "that region of the field of an antenna between the reactive near-field region and the far-field region wherein radiation fields predominate and wherein the angular field distribution is dependent upon the distance from the antenna." The radial distance R over which this region exists is $0{,}62\sqrt{D^3/\lambda} < R < 2D^2/\lambda$ (provided D is large compared to the wavelength).

- Far-field (Fraunhofer)

  The far-field (Fraunhofer) region is defined as "that region of the field of an antenna where the angular field distribution is essentially independent of the distance from the antenna." In this region, the real part of the power density is dominant. The radial distance R over which this region exists is $R \geq 2D^2/\lambda$ (provided D is large compared to the wavelength).

From balanis

ANTENNA BASICS

The radiation density radiated by an antenna can be:

$$S_{density} = \frac{P_r}{4\pi R^2} \qquad S(r,\theta,\phi) = \frac{1}{2}\left(E \times H^*\right) \left[\mathrm{W/m^2}\right]$$

P_r is the radiated power

Usually we consider that the antenna is radiating in the far field, since only there we can approximate the propagated wave in a plane.

The far-field is given by: $d_f \gg D \wedge d_f \gg \lambda$

$$d_f = \frac{2D^2}{\lambda} \text{ (Fraunhofer distance)}$$

D –maximum antenna height

ANTENNA

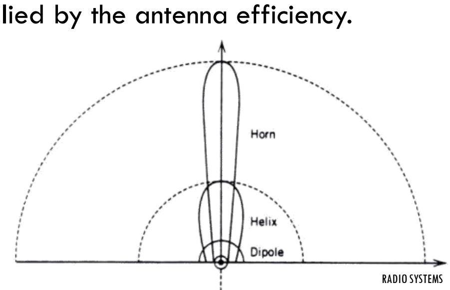
The directivity of an antenna is defined as the maximum gain at a predetermined angle orientation.

$$D(\theta,\phi) = \frac{\text{Maximum radiation value}}{\text{Average radiation value}} = \frac{\overbrace{S(\theta,\phi)}^{\text{Power density, poyinting vector}}}{\underbrace{P_r / 4\pi R^2}_{\text{Isotropic power density}}}$$

The antenna gain is the directivity multiplied by the antenna efficiency.

$$G = \eta D_{\max}$$

$$\eta = efficiency = \frac{P_r}{P_{in}}$$

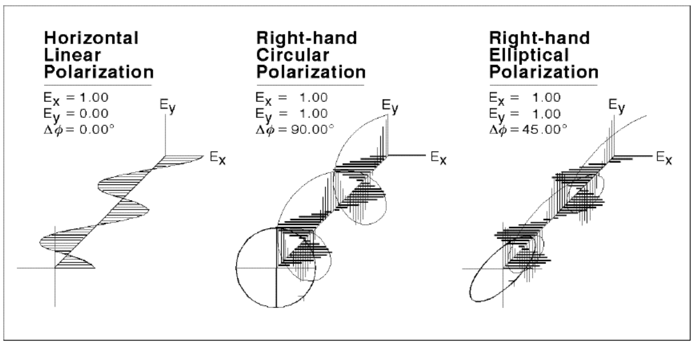


ANTENNA - POLARIZATION

Polarization is due to the change in the electromagnetic field. Antennas are classified as:

- Linear polarization
- Circular polarization

Polarization can allow the transmission in two neighbor channels at the same frequency



ANTENNA

Effective area in a given direction is defined as "the ratio of the available power at the terminals of a receiving antenna to the power flux density of a plane wave incident on the antenna from that direction, ***the wave being polarization matched to the antenna.*** If the direction is not specified, the direction of maximum radiation intensity is implied."

$$A_e = \frac{\text{Received power by the antenna}}{\text{Power density in the direction of maximum directivity}} = \frac{P_r}{S(\theta,\phi)_{Max}} =$$

$$= pq\frac{\lambda^2}{4\pi}G_0$$

p – polarization loss factor
q – impedance matching efficiency $q = (1 - |\Gamma_{in}|^2)$

ANTENNA

This can be related with the gain as:

$$G_{A_i} = \frac{4\pi A_e}{\lambda^2} \quad (\mathrm{dB_i})$$

$A_e \rightarrow$ Effective antenna area
$\lambda \rightarrow$ Wavelength

For instance, an ideal point isotropic antenna, of null dimensions will have an effective area of $A_e = \lambda^2/(4\pi)$, which in the GSM (900 MHz) band as the value of A_e=8.8x10^{-3} m^2.

FRIIS FORMULA

If the Tx antenna is isotropic, and transmits a power of P_r, it produces, at R distance, an uniform superficial power density of:

$$S_{av} = \frac{P_r}{4\pi R^2}$$

Since the antenna is not isotropic, but has a certain directivity, then in the direction of maximum gain it will transmit a power density that is G_t times bigger.
If that density is now received by a receiving antenna, which as the effective area of A_{er}, then we will collect a certain amount of received power:

$$P_{received} = G_t \frac{P_r}{4\pi R^2} A_{e_r}$$

FRIIS FORMULA

If the effective area is substituted by the gain formula, that is, $A_{er}=G_r.\lambda^2/(4\pi)$ we finally get the Friis formula:

$$P_r = G_t\, G_r \left(\frac{\lambda}{4\pi\, R} \right)^2 P_t$$

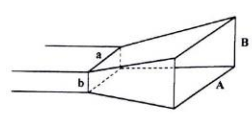
This formula give us the received power in terms of the transmitted power and the wave length (frequency of the signal)

Open space losses: $\left(\frac{\lambda}{4\pi\, R} \right)^2$

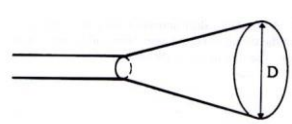
ANTENNA

Depending on the type of antenna, typical gains are:

- Short dipole: G=1.5dB
- Horn: $G = 8.1 + 10\,log\left(\frac{AB}{\lambda^2}\right)$

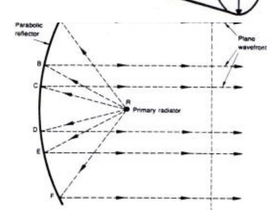


- Circular horn: $G = 20\,log\left(\frac{\pi D}{\lambda}\right) - 2.82$



- Parabolic: $G = 10 * \log\left(\frac{4\pi^2}{\lambda^2} \eta \left(\frac{D}{2}\right)^2 \right)$

$\eta \approx 55\% a 75\%$



ANTENNA

PROBLEM

Consider that an antenna has an $Ae = 0.1m^2$ and that is fed with 12W, calculate at a distance of 100m, the received power, assume a receiving antenna with 0dBi, f = 900MHz.

RADIATION FUNDAMENTALS

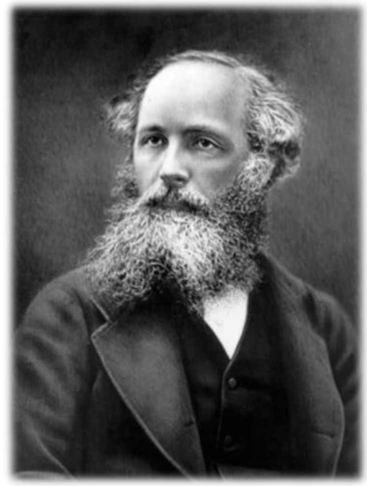
Maxwell Equations govern antenna calculations

$$\nabla \times E = -\mu \frac{\partial H}{\partial t} \text{ (Faraday's Law)}$$

$$\nabla \times H = J + \varepsilon \frac{\partial E}{\partial t} \text{ (Ampere's Law)}$$

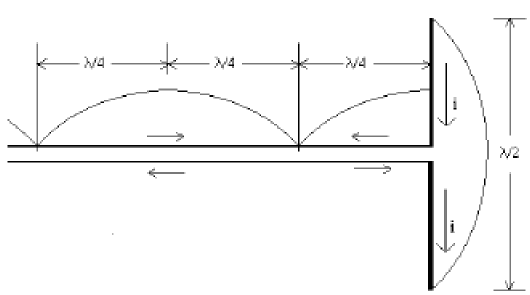
$$\nabla \cdot E = \frac{\rho_\upsilon}{\varepsilon} \text{ (Gauss' Law)}$$

$$\nabla \cdot H = 0 \text{ (Gauss' Law for Magnetism)}$$



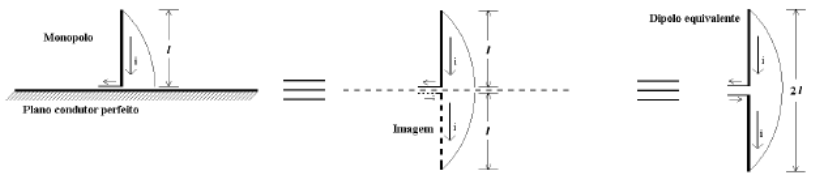
FINITE ELECTRIC DIPOLE ANTENNA

Finite electric dipole consists of two thin metallic rods of the total length L, which may be of the order of the free space wavelength.



MONOPOLE ANTENNA

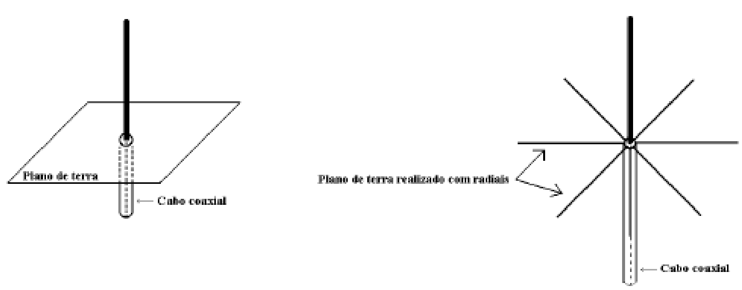
A monopole is a wire section, length l, placed vertically on a perfect conductor plane and fed between its base and the plan. It can be modeled by an equivalent dipole length 2l, located in free space.



(a) – Monopolo (b) – Monopolo e a sua imagem (c) – Dipolo equivalente

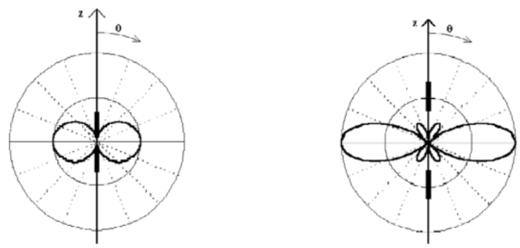
MONOPOLE ANTENNA

Some monopole examples:



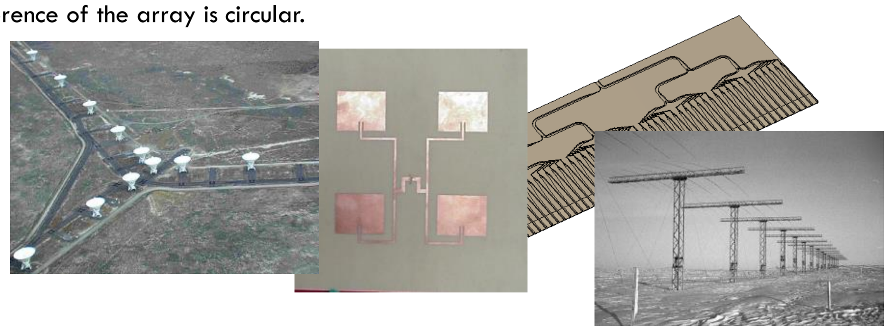
ANTENNA ARRAYS

Sometimes a simple antenna can not produce the desired power density for a certain location. One way to address this issue is through the use of a set of simple identical antennas, grouped and fed in order to direct the energy to the desired location, and thus producing the desired power at that site density. A set of grouped antennas for this purpose is called an antenna array.



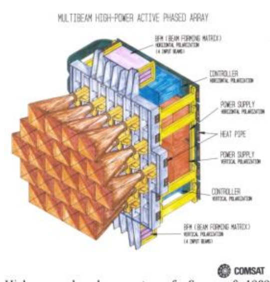
ANTENNA ARRAYS

An antenna array consists of identical elements arranged in a regular geometric arrangement. When the elements are placed along an axis the array is linear, if hey are arranged in accordance with a square plan, the array is planar, if they are disposed along a circumference of the array is circular.

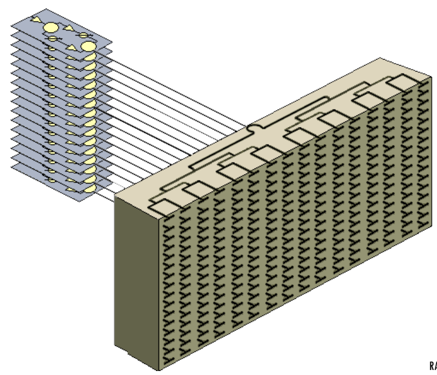


ANTENNA ARRAYS

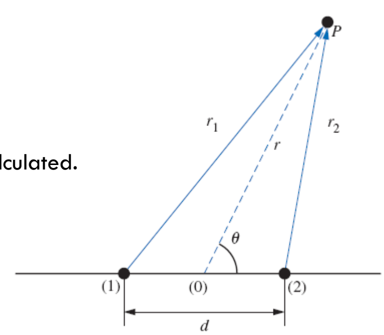
By varying the feed of the individual elements, namely the phase, it is possible to drive the main lobe to different directions of space very quickly. These arrays that are beam scanning are known in the Anglo-Saxon literature as phased arrays.



High-power phased array antenna for Spacecraft, 1989. Culmination of 8 yrs R&D at Comsat Labs.



ANTENNA ARRAYS



Using the individual element patterns $F_1(\theta,\phi)$, the overall field can be calculated.

Taking into account the phase difference due to physical separation and difference in excitation, the total far zone electric field is:

$$E(r) = E_1(r)e^{j\psi/2} + E_2(r)e^{j-\psi/2}$$

Field due to antenna 1   Field due to antenna 2

where: $\psi = \beta d\cos(\theta) + \delta$

The phase center is assumed at the array center. Since the elements are identical

$$E(r) = 2E_1(r)\frac{e^{j\psi/2} + e^{-j\psi/2}}{2} = 2E_1(r)\cos\left(\frac{\psi}{2}\right)$$

Relocating the phase center point only changes the phase of the result but not its amplitude.

ANTENNA ARRAYS

The radiation pattern can be written as a product of the radiation pattern of an individual element and the radiation pattern of the array (array pattern):

$$F(\theta,\phi) = F_1(\theta,\phi)F_a(\theta,\phi)$$

where the array factor is:

$$F_a(\theta,\phi) = 2\cos\left(\frac{\beta d\cos(\theta)+\alpha}{2}\right)$$

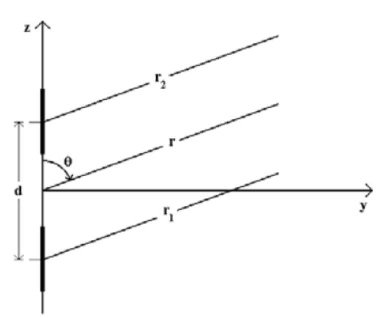
α is the phase difference between the two antennas. The array factor depends on the array geometry and amplitude and phase of the excitation of individual antennas.

ANTENNA ARRAYS – TWO DIPOLE CASE

In the far field the Poyting vector can be calculated the same way as was done for elementary antenna, but assuming both antenna fields will overlap.

$$E_{1\theta} \cong j\eta\frac{I_1 e^{-j\beta r_1}}{2\pi r_1}\left[\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\mathrm{sen}\theta}\right]$$

$$E_{2\theta} \cong j\eta\frac{I_2 e^{-j\beta r_2}}{2\pi r_2}\left[\frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\mathrm{sen}\theta}\right]$$



ANTENNA ARRAYS – TWO DIPOLE CASE

Changing the phase between dipoles we will obtain:

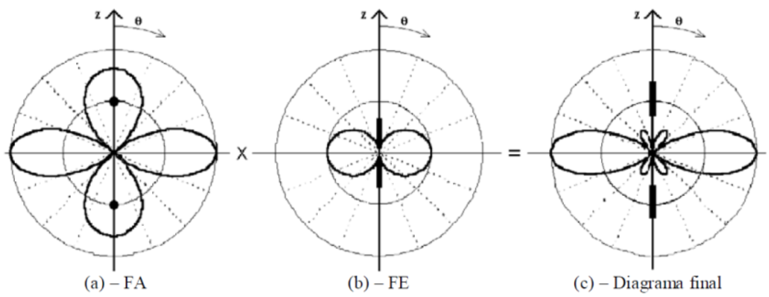
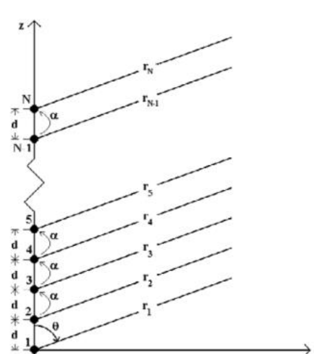


Figura 4.3 Ilustração do conceito de multiplicação de diagramas para o caso em que α=0º e d=0.8λ.

ANTENNA ARRAYS – LINEAR AND UNIFORM

An array of identical elements arranged equidistant along an axis fed with currents of equal amplitude and the same phase difference is a linear and uniform array. As the phase difference between successive current is the same, there is a period of gradual phase change.



ANTENNA ARRAYS – LINEAR AND UNIFORM

Consider that we have an isotropic source, its field is given by:

$$E = \mathbf{I}\frac{e^{-j\beta r}}{4\pi r}$$

Where I is the excitation source characterized by $I = Ie^{j\phi}$.
In the case of an uniform array the excitations are:

$$I_1 = Ie^{j\phi_1}; I_2 = Ie^{j\phi_2}; I_3 = Ie^{j\phi_3}; \cdots ; I_{N-1} = Ie^{j\phi_{N-1}}; I_N = Ie^{j\phi_N}$$
$$\text{where } (\phi_2 - \phi_1) = (\phi_3 - \phi_2) = (\phi_4 - \phi_3) = \cdots = (\phi_N - \phi_{N-1}) = \alpha$$

ANTENNA ARRAYS – LINEAR AND UNIFORM

Thus, we have several sources for the following fields:

$$E_1 = Ie^{j\phi_1}\frac{e^{-j\beta r_1}}{4\pi r_1}; E_2 = Ie^{j\phi_2}\frac{e^{-j\beta r_2}}{4\pi r_2}; E_3 = Ie^{j\phi_3}\frac{e^{-j\beta r_3}}{4\pi r_3}; \ldots ; E_N = Ie^{j\phi_N}\frac{e^{-j\beta r_N}}{4\pi r_N}$$

The phases may be presented as:

$$\begin{cases} \phi_2 = \phi_1 + \alpha \\ \phi_3 = \phi_2 + \alpha = \phi_1 + 2\alpha \\ \phi_4 = \phi_3 + \alpha = \phi_1 + 3\alpha \\ . \\ \phi_n = \phi_{n-1} + \alpha = \phi_1 + (n-1)\alpha \\ . \\ \phi_N = \phi_{N-1} + \alpha = \phi_1 + (N-1)\alpha \end{cases} \quad \text{and} \quad \begin{cases} r_2 \approx r_1 - d\cos\theta \\ r_3 \approx r_2 - d\cos\theta = r_1 - 2d\cos\theta \\ r_4 \approx r_3 - d\cos\theta = r_1 - 3d\cos\theta \\ . \\ r_n \approx r_{n-1} - d\cos\theta = r_1 - (n-1)d\cos\theta \\ . \\ r_N \approx r_{N-1} - d\cos\theta = r_1 - (N-1)d\cos\theta \end{cases}$$

ANTENNA ARRAYS – LINEAR AND UNIFORM

If we add all the fields we obtain:

$$E_T = \underbrace{I e^{j\phi_1} \frac{e^{-j\beta r_1}}{4\pi r_1}}_{FE} \underbrace{\left[1 + e^{j(\beta d \cos\theta + \alpha)} + \ldots + e^{j(n-1)(\beta d \cos\theta + \alpha)} + \ldots + e^{j(N-1)(\beta d \cos\theta + \alpha)}\right]}_{FA}$$

The added factor can be written in a more compact form:

$$FA = \sum_{n=1}^{N} e^{j(n-1)\psi} \quad \text{where } \psi = \beta d\cos\theta + \alpha$$

This expression can be further simplified considering that not more than one geometric progression, so that:

$$FA = \frac{\sin\left(N\frac{\psi}{2}\right)}{\sin\left(\frac{\psi}{2}\right)} \quad \text{where } \psi = \beta d \cos\theta + \alpha$$

ANTENNA ARRAYS – LINEAR AND UNIFORM

The array factor radiation diagram will be:

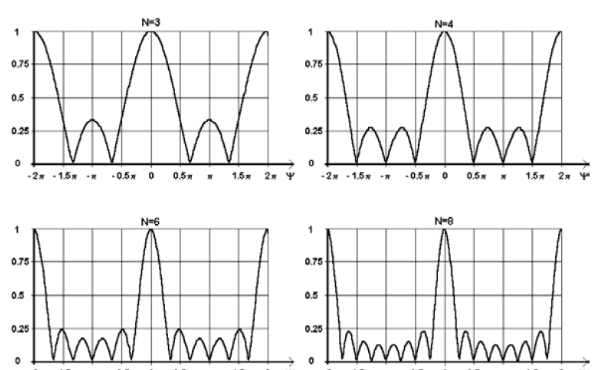


Figura 4.5 Amplitude do factor de agregado dum agregado linear uniforme para 4 valores de N.

ANTENNA ARRAYS – LINEAR AND UNIFORM

From these graphs we can derive some properties of the FA, such as:

1. The main lobe is narrower, i.e., the array becomes more directive when N increases.

2. The number of lobes increase as N increases. In each period (0 to 2π) there are (N-2) secondary side lobes.

3. The power level of the side lobes decreases as N increases.

ANTENNA ARRAYS – LINEAR AND UNIFORM

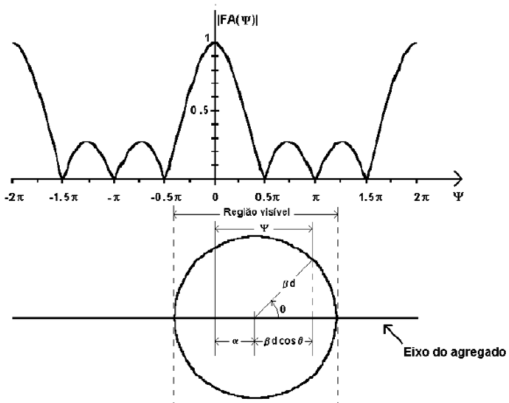
It is also possible to calculate the direction of the zero and the maximum, as well as other factors of merit, transversal case:

Direcção dos máximos	$\theta_m = \pm\cos^{-1}\left(\pm m\frac{\lambda}{d}\right)$ com m=0,1,2,3,…
Direcção dos nulos	$\theta_n = \pm\cos^{-1}\left(\pm\frac{n\lambda}{Nd}\right)$ com n=1,2,3, e $n \neq N, 2N, \ldots qN$
Direcção dos lobos secundários	$\theta_s \approx \pm\cos^{-1}\left[\pm(2s+1)\frac{\lambda}{2Nd}\right]$ com s=1,2,3,…
Largura do lobo principal a 3dB - LFMP	$\Theta_h = 2\left\|90^0 - \|\theta_h\|\right\|$ com θ_h expresso em graus e dado por: $\theta_h = \pm\cos^{-1}\left(\pm\frac{2.782\,\lambda}{2\pi d N}\right)$
Directividade (aproximada)	$D \approx 2N\frac{d}{\lambda}$ para N>5 e d<λ/2

Tabela 4-2 Resumo das principais características dos agregados transversais.

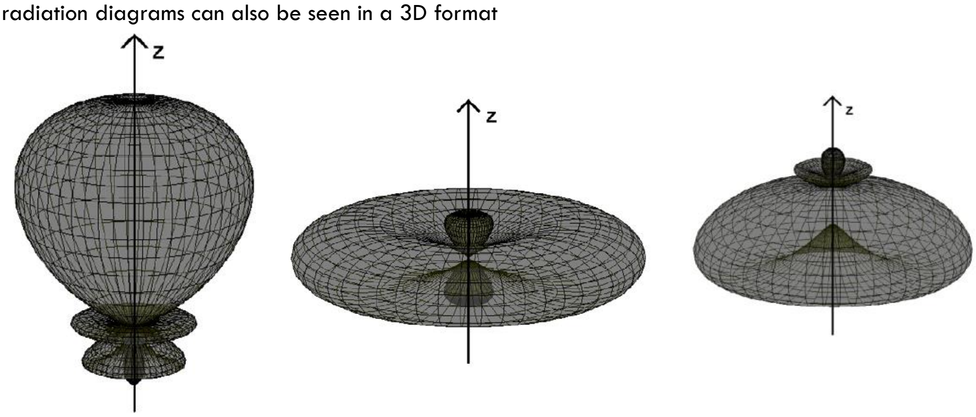
ANTENNA ARRAYS – GRAPHICAL TECHNIQUES

The graph of the radiation diagram can be made directly from the presented expressions. However there are much simpler graphical techniques that can be applied:



ANTENNA ARRAYS – GRAPHICAL TECHNIQUES

These radiation diagrams can also be seen in a 3D format



ANTENNA ARRAYS – PLANAR ARRAY

In a planar array the FA will turn into two multiplicative factors, one folowing the direction of the x's and the other in the direction of the y-axis's.

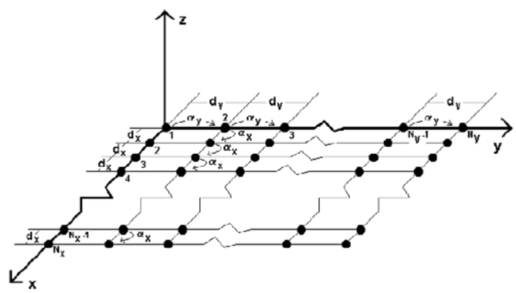
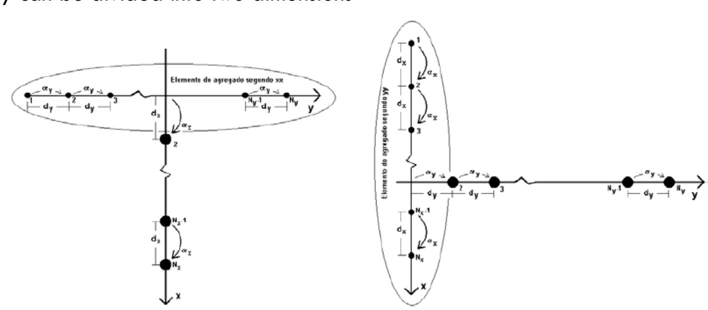


Figura 4.18 Agregado planar colocado no plano x-y

ANTENNA ARRAYS – PLANAR ARRAY

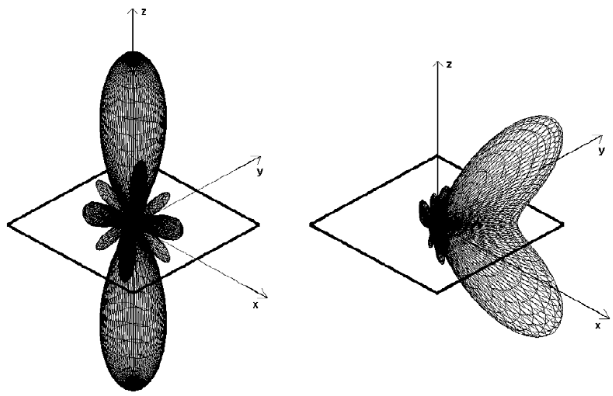
This type of array can be divided into two dimensions



(a) (b)

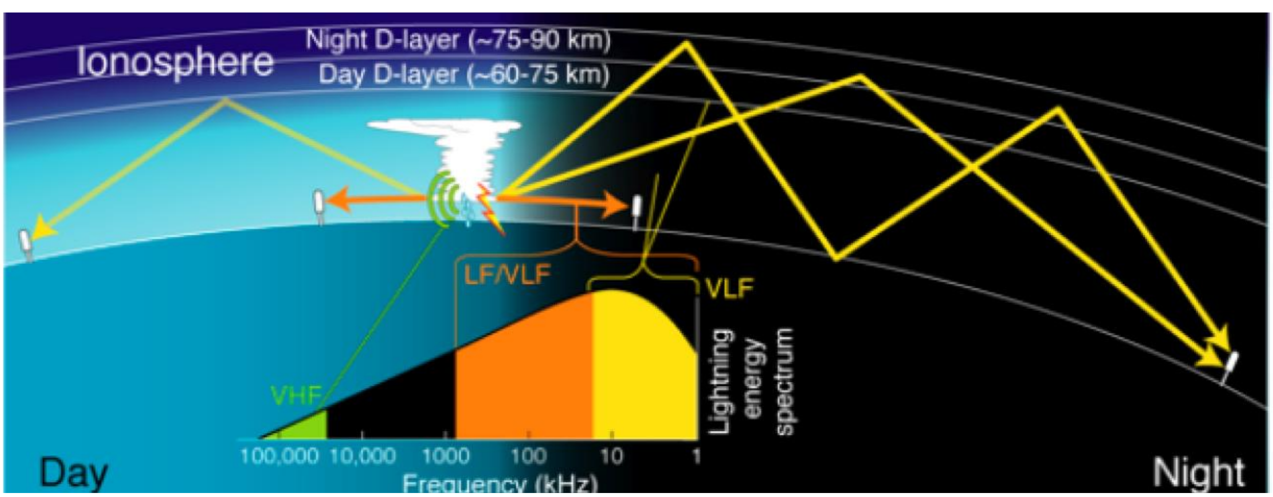
Figura 4.19 Interpretação dum agregado planar. (a) - Visto como um agregado de N_x elementos alinhados segundo o eixo dos xx em que o elemento é um agregado de N_y elementos alinhados segundo o eixo dos yy. (b) – Visto como um agregado de N_y elementos alinhados segundo o eixo dos yy em que o elemento é um agregado de N_x elementos alinhados segundo o eixo dos xx

ANTENNA ARRAYS – PLANAR ARRAY



(a) - N_x=5,dx=0.5λ e N_y=5,dy=0.5λ (b) - N_x=5,dx=0.5λ e N_y=8,dy=0.25λ

Figura 4.20 Diagramas de radiação obtidos com agregados planares situados no plano x-y.

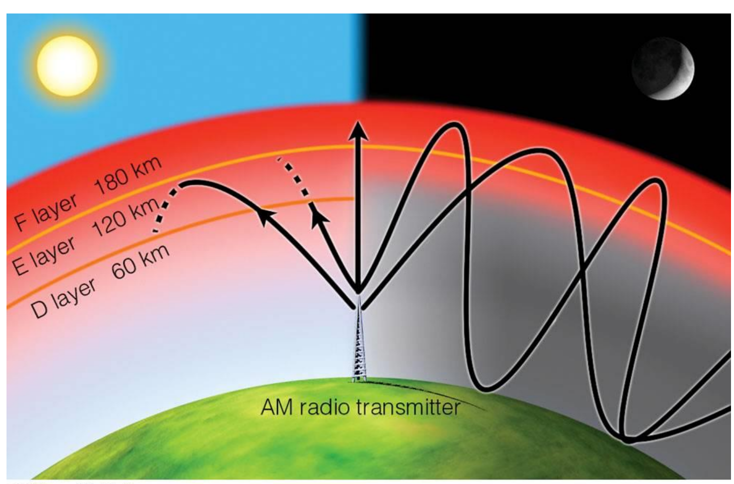


PROPAGATION

Table (1) Electromagnetic Spectrum Nomenclature

Frequency Rang	Designation	Classification
30-300 Hz	ELF	Extreme Low Frequency
3-30 KHz	VLF	Very Low Frequency
30-300 KHz	LF	Low Frequency
0.3-3 MHz	MF	Medium Frequency
3-30 MHz	HF	High Frequency
30-300 MHz	VHF	Very High Frequency
0.3-3 GHz	UHF	Ultra High Frequency
3-30 GHz	SHF	Super High Frequency
30-300 GHz	EHF	Extremely High Frequency

IONOSPHERE PROPAGATION



HF PROPAGATION – GROUND WAVES

- Generally speaking the Ground Wave is used to communicate over short distances usually less than 50 Km.
- Because Ground Waves follow the contours of the Earth it is affected by the type of terrain it passes over.
- Ground Waves are therefore rapidly reduced in field strength when they pass over heavily forested areas or mountainous regions.

HF PROPAGATION - SKY WAVES

- Used to communicate over medium to long distances, up to 3000Km.
- Whilst it's nature of propagation eliminates signal reduction from ground terrain factors, as in Ground Waves, the Ionospheric characteristics can affect the received signal quality.
- Correct frequency selection is critical to establishing and maintaining reliable communications.

HF PROPAGATION - DIRECT WAVE

- Line of sight between transmitter and receiver
- May interact with the earth-reflected wave depending on terminal separation, frequency and polarization
- May not be a dependable way to communicate between two stations.

FACTORS WHICH AFFECT HF /SSB COMMUNICATIONS

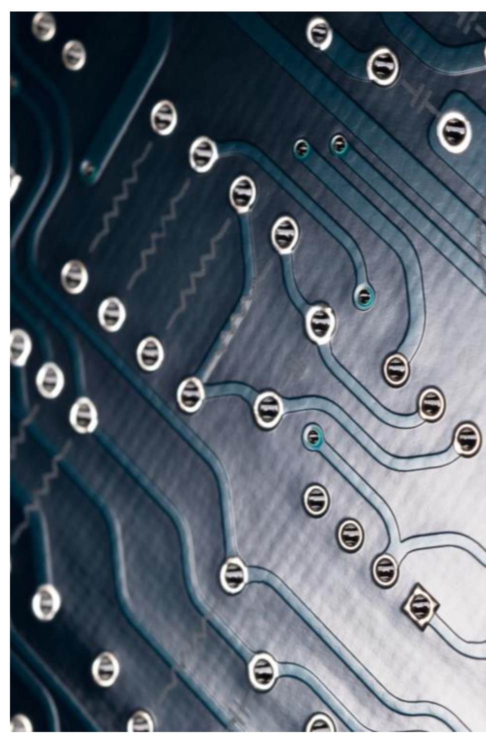
Frequency Selection

Time of Day

Weather Conditions

Man-made electrical interference

Poor system configuration and installation



TIME OF DAY

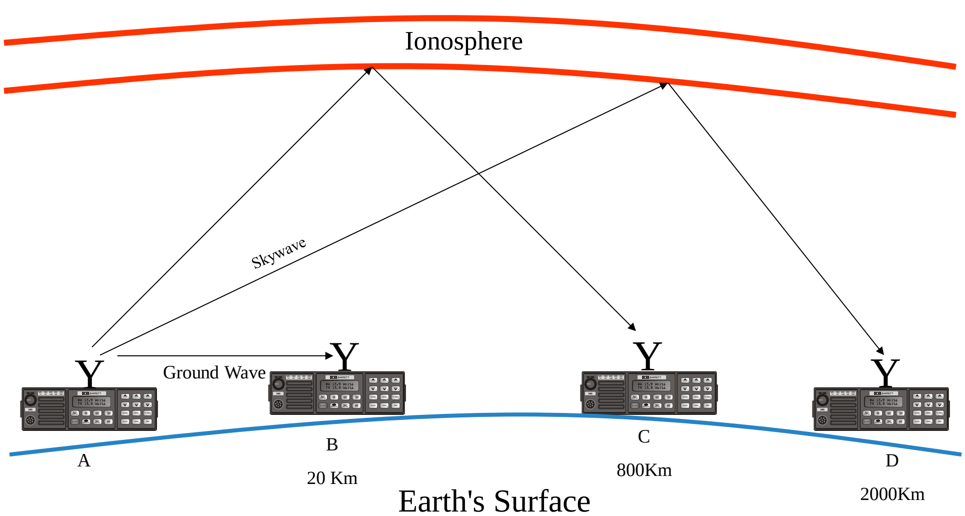
Frequencies are normally higher during the day and lower at night.

With dawn, solar radiation causes electrons to be produced in the ionosphere and frequencies increase reaching their maximum around noon.

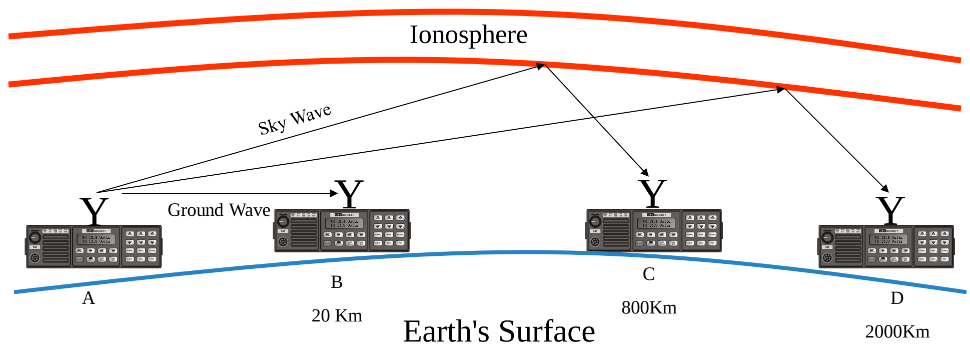
During the afternoon, frequencies begin falling due to electron loss and with darkness the D, E and F1 regions disappear.

Communication during the night is by the F2 region and absorption of radio waves is lower. Through the night, frequencies gradually decrease, reaching their minimum just before dawn.

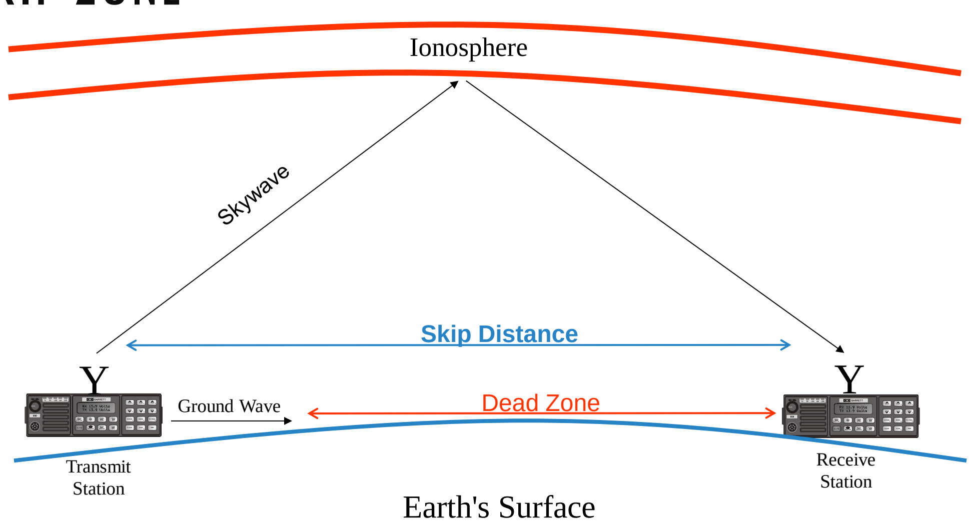
USING HF DURING THE DAY



USING HF DURING THE NIGHT



SKIP ZONE



'ORDINARY' PROPAGATION

To travel a long distance, the signal must take off at a LOW angle from the antenna

- – 30 degrees or less

This is so that it can travel the maximum distance before it first arrives at the Ionosphere

Long gap before signal returns to earth – the part in between this and the end of the ground wave is the so-called Skip (or Dead) Zone

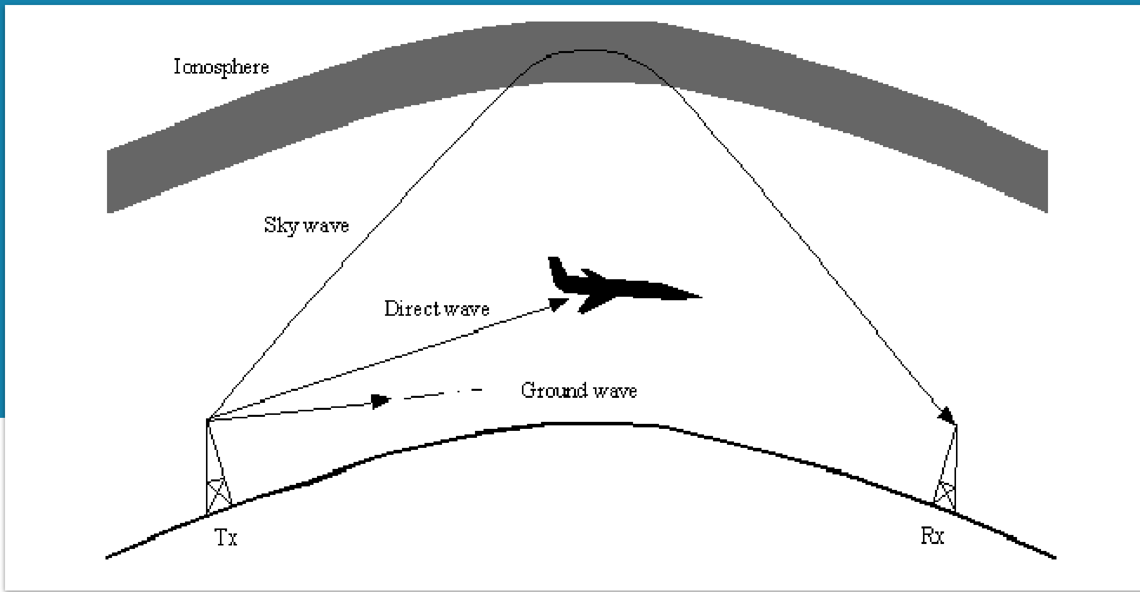
WEATHER CONDITIONS

Certain weather conditions will also affect HF / SSB communications.

- Stormy conditions will increase the background noise as a result of 'static' caused by lightning.

Atmospheric noise, which is caused by thunderstorms, is normally the major contributor to radio noise in the HF band and will especially degrade circuits passing through the day-night terminator.

Atmospheric noise is greatest in the equatorial regions of the world and decreases with increasing latitude. Its effect is also greater on lower frequencies, hence it is usually more of a problem around solar minimum and at night when lower frequencies are needed.

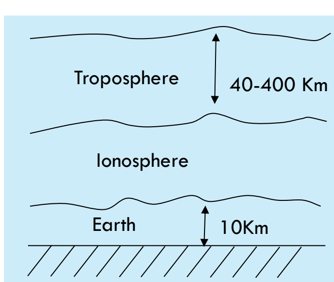


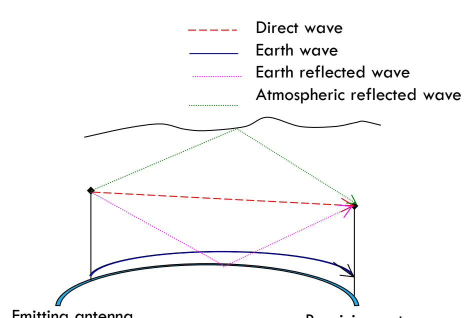
PROPAGATION

Modeling of the propagation channel is fundamental, so we can understand what can be expected from our communication path

Only the lower layers of the atmosphere are involved into radio communications.
Accordingly to frequency we could have:
- Propagation due to superficial wave, follow the earth.
- Propagation due to reflection in the troposphere or ionosphere - Reflection coefficient depends on the wave length

Direct Radiation, only when we have a geometric horizon





FRIIS FORMULA

$$P_r = G_t G_r \left(\frac{\lambda}{4\pi R} \right)^2 P_t$$

POWER BUDGET

- The performance of any communication link depends on the quality of the equipment being used.
- ***Link budget*** is a way of quantifying the link performance
- ***Power budget*** is a component to arrive at the link budget
  - Computes all the gains and losses from the transmitter, through the propagation medium to the receiver.
  - Also taken into the account are the attenuation of the transmitted signal due to propagation, and the loss or gain due to the antenna.

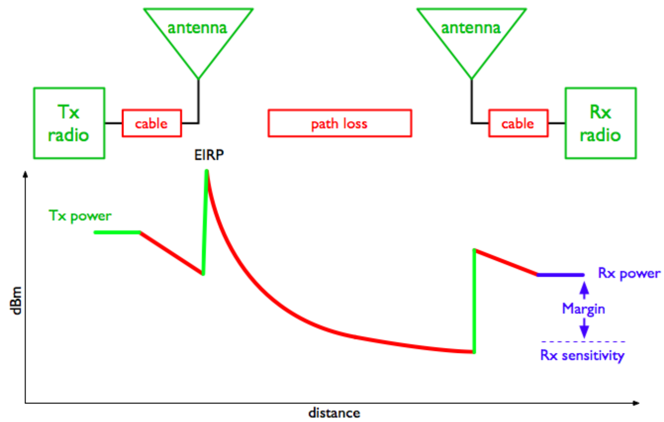
POWER BUDGET

- The received power is determined by three factors: ***transmit power***, ***transmitting antenna gain***, and ***receiving antenna gain***.
- If that power, minus the ***path loss*** is greater than the ***minimum received signal level*** of the receiving radio, then a link is possible.
  - In mobile communications there will be fading → outages
  - Necessary to include some margin to minimize them

POWER BUDGET

- The difference between the minimum received signal level and the actual received power is called the ***link margin***.
- The link margin must be positive, and should be maximized
  - (should be at least 10dB or more for reliable links).

POWER IN A WIRELESS SYSTEM

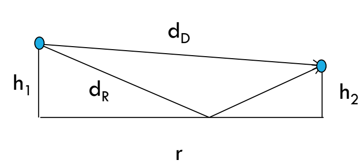


PROPAGATION

Most of the nowadays mass market wireless communication use direct radiation

Other propagation mechanisms can be ignored

Possible model for line of sight communications



d_D= direct line of sight length
d_R= reflected line of sight length
h_1= antenna height
h_2= antenna height
r = direct length between antennas

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ARINC 429 TRANSMITTERS AND RECEIVERS

- **A**eronautical **R**adio, **Inc.** (ARINC) was a privately held corporation started in 1929, ultimately acquired by Collins Aerospace in 2013. This corporation was founded by and comprised of various airlines and airline manufacturers (components and equipment) with the goal of producing sets of specifications (standards) for avionics hardware for global aircraft use.
- ARINC-429 is the standard for local area networks on commercial and transport aircraft.
- Communications, guidance, altitude, altitude reference, flight management, and more are all needed to work together to accomplish a successful flight.
- ARINC-429 was designed in the 1970's to accomplish this goal.

Understanding the RTX SPA429 Adapter and its Software Interface

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What is ARINC 429?
A standard data bus used in aviation to transmit avionics data.

Key Features:

32-bit data word structure

One-way communication (simplex)

Supports up to 120 devices per bus.

OVERVIEW OF ARINC 429

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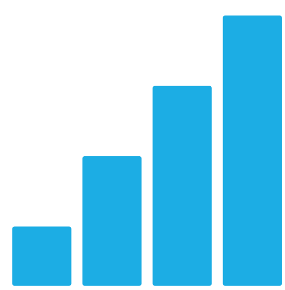
- Hardware consisting of only a single transmitter source supporting 1 to 20 receivers (also known as “sinks”) on a single wire pair.
- Data transmission is one directional. Additional busses are required for multidirectional data transfer.
- A data transmitter can only talk to a defined number of data receivers on a single bus on one wire pair.
- For multidirectional communication, 2 wire pairs are required for data transmission in opposite directions.
- Transmit and receive channels are different ports.
- Data words are 32 bits (most messages consist of a single data word) broken into 24-bits containing the core information and 8-bits acting as a data label describing the data transmitted.
- Messages are transmitted at either low speed (12.5 kbit/s) or high speed (100 kbit/s) to receiver components.



THE ARINC-429 SPECIFICATION ENTAILS THE FOLLOWING

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PARITY BIT

LABEL

DATA

ARINC 429 Word Format																															
P	SSM		MSB									Data									LSB	SDI					Label				
32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1

SSM

SDI

ARINC-429 WORD FORMAT

ARINC-429 WORD FORMAT

PARITY BIT

LABEL

DATA

ARINC 429 Word Format																															
P	SSM		MSB									Data									LSB	SDI					Label				
32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1

SSM

SDI

Data is sent over the ARINC-429 bus in a 32-bit word, with each word representing an engineering unit such as altitude or barometric pressure. The different parts of the message are shown in the image above. The 8-bit label is an important aspect. It is used to interpret the other fields of a message – each type of equipment will have a set of standard parameters identified by the label number, regardless of the manufacturer. For example, Label 372 for any Heading Reference system will provide wind direction and Label 203 for any air data computer will give barometric altitude.

The other bits are reserved for SDI, SSM, data, and parity:

SDI (Source Destination Identifiers): Used by a transmitter connected to multiple receivers to identify which one should process the message. If not needed, the bits may be used for data.

Data: The information that is being communicated

SSM (Sign Status Matrix): Used to indicate sign or direction, and also to test if data is valid

Parity (odd): Used for error detection