Circuits at high Frequencies

I. HF Systems

Tutorials

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HF Systems : equations

From lectures

- Noise and noise figure

$$F = \frac{SnR_i}{SnR_o} = 1 + \frac{N_a}{GN_i}; \quad NF = 10 \cdot \log_{10}(F)$$

  - N_a = noise contribution of element
  - N_i = noise power on input
  - G = power gain of the element

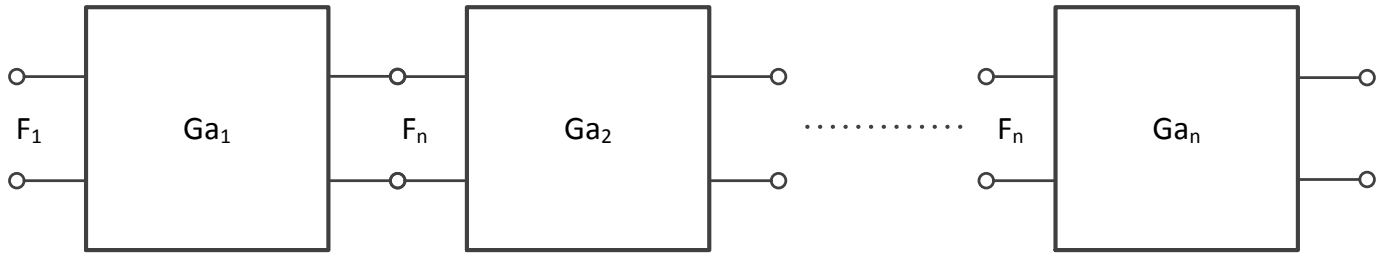
- Noise temperature

$$T_e = \frac{N_a}{kG\Delta f}; \quad F = 1 + \frac{T_e}{T} \; or \; T_e = (F-1) \cdot T$$

  - T is ambient temperature of noise source and it is for
    - Antenna on earth T=290 K
    - Antenna on satellite T= from 30 K to 50 K
    - for PIN diode T > 290 K

HF Systems : equations

From lectures



Quadrupoles cascade

- Total noise for cascade is

$$F = F_1 + \frac{F_2 - 1}{Ga_1} + \cdots + \frac{F_n - 1}{Ga_1 \times Ga_2 \times \cdots Ga_{n-1}}$$

- Noise temperature

$$T_e = T_{e1} + \frac{T_{e2}}{Ga_1} + \cdots + \frac{T_{en}}{Ga_1 \times Ga_2 \times \cdots Ga_{n-1}}$$

HF Systems : equations

From lectures

- Receiver sensitivity S_i
  - System on earth

$$S_i(dBm) = -174dBm + NF(dB) + 10\log\Delta f + SNR(dB)$$

  - System on satellite

$$S_i(dBm) = -184dBm + NF(dB) + 10\log\Delta f + SNR(dB)$$

- SNR for different modulations at BER=10^{-6}
  - BPSK SNR = 12,5dB
  - QPSK SNR = 14dB
  - 16QAM SNR = 21dB
  - 64QAM SNR = 27dB

HF Systems : equations

From lectures

- Ratio between basic signal and interference component
  - Basic equation

$$IIP_n = \frac{P_o}{IM_n}; P_o = 10\log(G) + P_i; IM_n = S_i - C$$

    - P_o – power of basic component, IM_n – power of interference component
  - Derived equations

$$IIP_n = \frac{nP_i - IM_n}{n-1} \; or \; IIP_n = \frac{nI_i - (S_i - C)}{n-1}$$

Where C presents lowest power which can be received, I_i - power of i-th component

HF Systems : equations

From lectures

- Noise rate for cascade

$$M = \frac{F_i - 1}{1 - \frac{1}{Ga_i}}$$

- Linearity of cascade

$$\frac{1}{IIP3} = \frac{1}{IIP3_1} + \frac{Ga_1}{IIP3_2} + \frac{Ga_1 \times Ga_2}{IIP3_3} + \cdots + \frac{Ga_1 \times Ga_2 \times \cdots Ga_{n-1}}{IIP3_n}$$

$$\frac{1}{OIP3} = \frac{1}{OIP3_n} + \frac{1}{Ga_n \times OIP3_{n-1}} + \frac{1}{Ga_n \times Ga_{n-1} \times OIP_{n-2}} + \cdots + \frac{1}{Ga_2 \times \cdots Ga_n \times OIP3_1}$$

- Optimization of cascade dynamic range

$$Ga_i = \sqrt{\left(\frac{F_{i+1} - 1}{F_i}\right)\frac{IIP_{i+1}}{IIP_i}}$$

HF Systems : tasks

1. 5GHz wireless LAN

The receiver has next parameters:

- Noise figure 6dB,
- QPSK modulation,
- Bit Error Rate 10^{-6},
- Bandwidth 20MHz.

What is sensitivity of the receiver?

HF Systems : tasks

2. 12GHz satellite receiver

Satellite receiver has next properties:

- Temperature of antenna is 30K
- Noise figure measured at 293K is 1dB
- 64QAM modulation,
- Bit Error Rate 10^{-6},
- Bandwidth 6MHz.

What is sensitivity of receiver?

HF Systems : tasks

3. 60GHz receiver

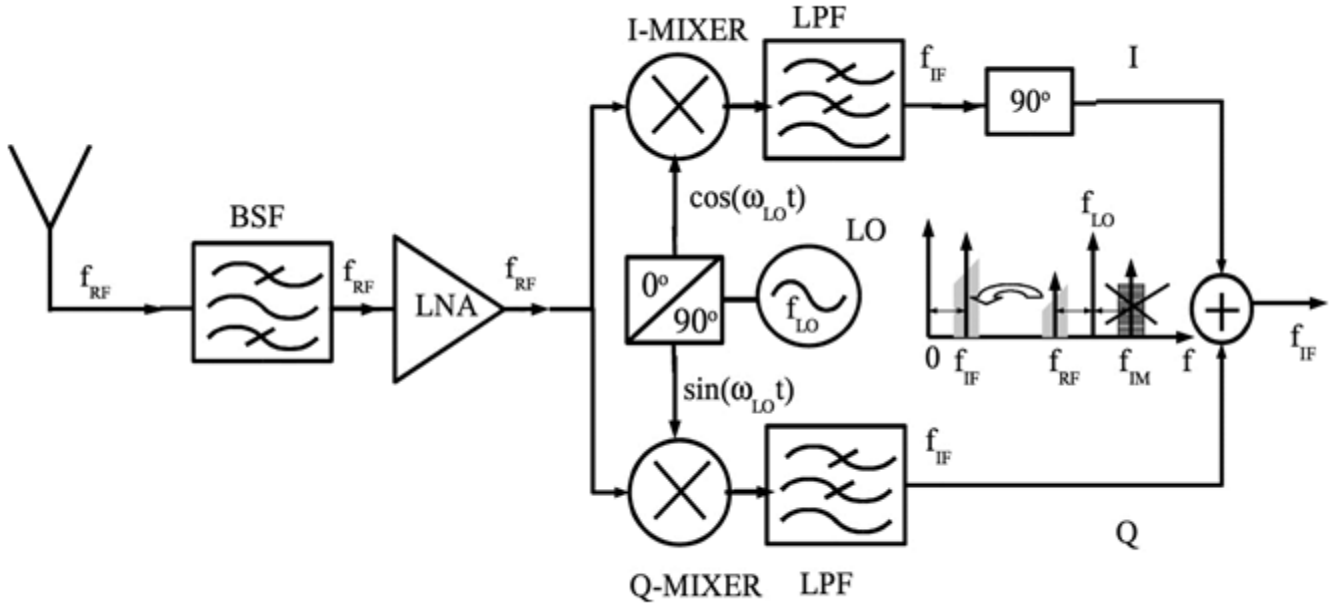
The receiver has next parameters:

- important signal is at 60GHz
- interference components are at 64GHz and 62GHz,
- power of the interference components is -38dBm,
- sensitivity of receiver is -60dBm
- lowest power which can be received 14dB.

Calculate IIP_3.

HF Systems : tasks

4. Hartley receiver



How the block diagram changes if f_{IF} is lower than f_{LO} and f_{RF} higher then f_{LO}?

HF Systems : tasks

5. 50Ω GaAs MESFET LNA operates with central frequency of 12GHz at 29,3K

The LNA parameters are:

- noise figure measured at 293K is 2,3dB
- bandwidth is 8MHz
- requested signal to noise ratio is 6dB

What is sensitivity of receiver?

How the sensitivity changes if current LNA is changed with GaAs p-HEMT LNA with noise figure 1dB or 0,6dB?

HF Systems : tasks

6. Receiver operates on earth

It has next parameters:

- it consists from three amplification stages, each with 6dB gain and 10nV/√Hz of noise
- at antenna output (input of first amplifier) it is 1mV signal and 10μV of noise
- Frequency bandwidth of receiver is 10MHz.

Calculate A. Total noise figure

B. Total noise temperature

C. Noise rate