DESIGN OF ULTRAWIDEBAND AMPLIFIERS

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The purpose of ultrawideband /UWB/ amplifier is to amplify the signal with little distortion and little additional noise. The design of efficient UWB amplifiers is a process that requires precise report on conditions and networks of signal propagation. Very important is defining of the amplifier parameter: ratio of the signal-to-noise /SNR/, which reflects on the performance of the amplifier. In the paper is presented a methodology for designing of UWB amplifiers by minimizing the effective noise factor and in this way maximizing of the performance. To this target are examined single-stage amplifiers and cascaded amplifier stages.

1. THE ULTRAWIDEBAND TECHNOLOGY

The ultrawideband technology is a relatively new technology that is being pursued for precise measurement of distances or locations, for obtaining the images of objects buried under ground or behind surfaces, for wireless communications, particularly for short-range high-speed data transmissions suitable for broadband access to networks.

The most unique feature of UWB is its ability to operate without a carrier frequency. It relies entirely on individual pulses of RF energy. The pulses can be described as carrier-free baseband impulses. The low duty cycles result in low average energy densities. UWB devices transmit narrow individual pulses across a very broad spectrum. The diagram below shows the range of frequencies used by UWB related to different wireless transmissions.

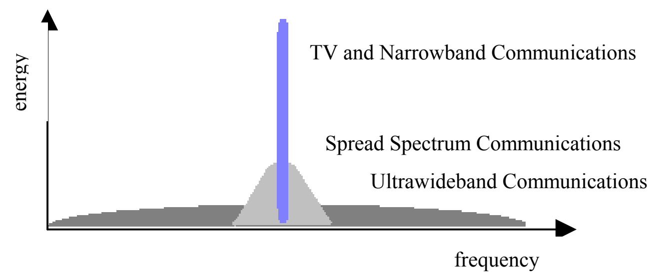

Fig. 1 Wireless Communications

UWB systems transmit signals across a much wider frequency than conventional systems and are usually very difficult to detect. The amount of spectrum occupied by a UWB signal, i.e. the bandwidth of the UWB signal is at least 25% of the center frequency. For instance, a UWB signal centered at 2 GHz would have a minimum bandwidth of 500 MHz. The most common technique for generating a UWB signal is to transmit pulses with durations less than 1 nanosecond.

2. THE PROBLEMS IN UWB AMPLIFIERS

The purpose of UWB amplifier is to amplify the received signal from antenna with little distortion and additional noise. The designing of efficient UWB amplifiers characterizes with some specific features:

- Most amplifiers possess finite gain-bandwidth product.
- The signal bandwidth of UWB amplifiers is several orders of magnitude greater than narrowband amplifiers.
- The noise factor or noise figure in dB /NF/ is difficulty defined.

The amplifier parameter: ratio of the signal-to-noise is important, because it reflects on the performance of amplifier. The noise factor or noise figure in dB is difficulty defined, because in one UWB system, the input signal is broadband and the additive noise may be colored, from difference of a narrowband system, where the SNR is obtained by simply dividing the signal power by the noise power.

Different researchers have proposed different mathematical models for SNR, dependence of conditions and networks for signal propagation. In [2] SNR gives a bit error rate in the presence of an arbitrary random wide-sense stationary external interference. In [1] the SNR is defined as matched filter bound /MFB/. MFB is used to represent an upper limit on the performance of data transmission systems and it at the input and output of the receiving system.

In the paper is presented a methodology for designing of UWB amplifiers by minimizing the effective noise factor and in this way maximizing of the performance. To this target are examined single-stage amplifiers and cascaded amplifier stages.

3. DESIGN OF SINGLE-STAGE ULTRAWIDEBAND AMPLIFIER

1st step: Choice of model of the amplifier as part of a communication channel. We used the next model.

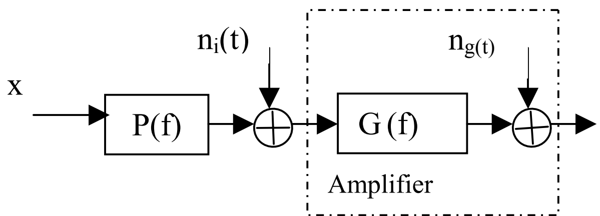

Fig. 2 Model of Single-stage Amplifier

In this model P(f) is a filter with bandwidth B, $n_i(t)$ is the input noise and the internally generated noise $n_g(t)$ are both white with PSD N_i and N_g, respectively, G(f)-amplifier transfer function. In the model an input signal x is filtered by the equivalent pulse response P(f) and then corrupted by the additive noise $n_i(t)$. The resulting corrupted signal is the input to the amplifier. In amplifier is added and internally additive noise $n_g(t)$.

2nd step: Calculation of amplifier power gain by equation:

$$G(f) = \frac{K^2}{f^2 + f^2{}_{3dB}}, \tag{1}$$

K presents the gain-bandwidth product /GBP/, f_{3dB} is the 3dB bandwidth of the amplifier.

3rd step: Calculation of the spot NF:

$$F_s(f) = 1 + \frac{N_g}{K^2 N_i}\left[f^2 + f^2{}_{3dB}\right]. \tag{2}$$

The spot NF is smaller when the frequencies f and f_{3dB} are smaller.

4th step: Calculation of the effective NF:

$$F_{eff} = \frac{\sqrt{F_s(0)\dfrac{N_g B^2}{N_i K^2}}}{a\tan\left\{\sqrt{\dfrac{N_g B^2}{F_s(0) N_i K^2}}\right\}}. \tag{3}$$

5th step: In order to include and the influence of network at signal propagation is necessary to examine the equivalent scheme of the amplifier. For this purpose can be used the model of MOS transistor.

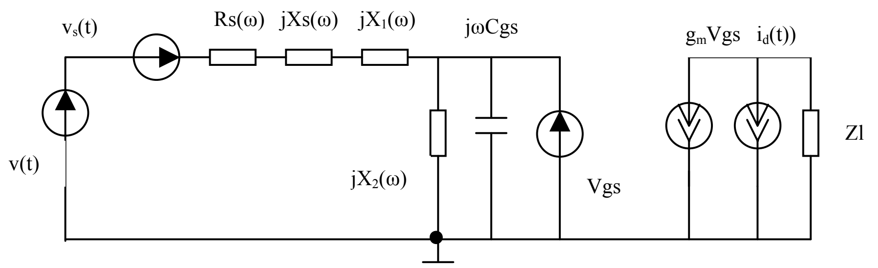

Fig. 3 The Equivalent Scheme

The amplifier is modeled with MOS transistor in common-source scheme. The signal source is antenna, that is represented with a voltage source v(t) and an impedance Zs(ω)=Rs(ω)+jXs(ω). Between antenna and amplifier there is network, which is modeled with reactances X1(ω) and X2(ω). The equivalent load is Zl. In this model there are three noise sources: the thermal voltage noise from antenna vs(t), the MOS gate current noise ig(t) and drain current noise id(t).

6th step: Calculation of power spectral density /PSD/ of the thermal noise from the antenna, the drain and the gate by equations:

$$S_{vs}(\varpi) = 4kTR_s(\varpi) \tag{4}$$

$$S_{id}(\varpi) = 4kT\frac{\gamma}{\alpha}g_m \tag{5}$$

$$S_{ig}(\varpi) = 4kT\delta\alpha\frac{(\varpi C_{gs})^2}{5g_m} \tag{6}$$

7th step: Calculating of noise correlation with correlation coefficient by equation:

$$c = \frac{S_{igid}(\varpi)}{\sqrt{S_{ig}(\varpi)}\sqrt{S_{id}(\varpi)}} \tag{7}$$

From results summarized in Table 1 and from equations can be seen that the effective NF is smaller when f3dB/B is reduced. The best performance is obtained when the amplifier has as narrowband as possible.

$N_gB^2/(N_iK^2)$=5dB		$N_gB^2/(N_iK^2)$=8dB		$N_gB^2/(N_iK^2)$=10dB	
Effective NF, **dB**	f_{3dB}/B	Effective NF, **dB**	f_{3dB}/B	Effective NF, **dB**	f_{3dB}/B
2,3	**0,1**	**3,2**	**0,1**	**4,3**	**0,1**
2,7	**0,2**	**3,9**	**0,2**	**5**	**0,2**
4	**0,5**	**6**	**0,5**	**7,5**	**0,5**
6,5	**0,9**	**9**	**0,9**	**10,8**	**0,9**
7	**1**	**9,5**	**1**	**11,3**	**1**

Table 1

4. DESIGN OF CASCADED AMPLIFIER STAGES

1st step: Choice of model of cascaded amplifier stages and number of stages.

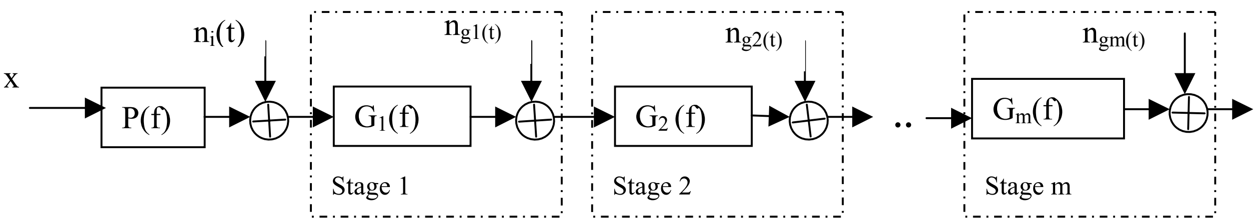

Fig. 4 Model of cascaded amplifier with m stages

In the cascaded amplifier stages there is the internally generated noise $n_{gm}(t)$of the m^{th} amplifier stages.

2nd step: Calculating of total power gain of m stages amplifier.

$$G(f) = \prod_{l=1}^{M} \frac{K_l^2}{f^2 + f_l^2} \quad . \tag{8}$$

3rd step: Calculating the spot NF of the *M*-stage amplifier:

$$F_s(f) = 1 + \gamma_1\left[f^2 + f_1^2\right] + \gamma_2\left[f^2 + f_1^2\right]\left[f^2 + f_2^2\right] + \ldots + \gamma_M \prod_{l=1}^{M}\left[f^2 + f_l^2\right], \tag{9}$$

where $\gamma \equiv \frac{N_{gl}}{N_i} \prod_{j=1}^{l} \frac{B^2}{K_j^2}$, $l \in \{1,,2,\ldots M\}$.

4th step: Calculating of effective NF:

$$F_{eff} = B / \int_0^B \frac{1}{F_s(f)} df \quad . \tag{10}$$

The results for two stage amplifier are summarized in Table 2.

γ1=5dB		γ 1=8dB		γ 1=10dB	
Effective NF, **dB**	f_{3dB}/B	Effective NF, **dB**	f_{3dB}/B	Effective NF, **dB**	f_{3dB}/B
1,8	**0,1**	**2,5**	**0,1**	**3**	**0,1**
2	**0,2**	**3**	**0,2**	**4**	**0,2**
4	**0,5**	**6**	**0,5**	**7,5**	**0,5**
8	**0,9**	**11**	**0,9**	**13**	**0,9**
9	**1**	**12**	**1**	**14**	**1**

Table 2

In case of two stage amplifier is recommended that the first stage to be a narrower amplifier in order to improve F_{eff} and the second stage to be a wider amplifier for achievement the minimum effective NF for a given f_{3dB}.

5. CONCLUSION

The difficulty in amplifying an UWB signal results from its bandwidth being a large fraction of the amplifier gain-bandwidth product.
The design of ultrawideband amplifiers has to be conformed from effective NF and suitable number of stages.

6. REFERENCES

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