Circuits for UWB Signal Generation and Radiation

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Abstract- In this paper, simple circuits for ultra-wideband (UWB) pulse generation and radiation using MESFET and BJT are presented. A novel method was investigated to generate the extremely short pulses with fast rise and fall times having a very broad spectrum and appropriate energy content. Circuits terminated resistively as well as by a UWB antenna covering the 3.1-10.6 GHz frequency band are considered. The transient and frequency domain simulations were carried out and it was found that the results conform to most of the FCC's regulation for UWB systems. The operating principle of the circuits was experimentally verified for a scaled down frequency band.

1. Introduction

Ultra-wideband (UWB) is one of the most promising technologies for future high-data-rate wireless communications, high-accuracy radars, and imaging systems. A UWB antenna should be effective in transmitting very short and low-power pulses in the 3.1-10.6 GHz range. Ideally, the UWB antenna should be compact, planar, low-cost, and reliable [1-3]. Planar monopole antenna have been found to be excellent candidates to operate in UWB systems, since they present a low-cost, very compact structure. Recently, coplanar waveguide fed printed antenna that offers attractive advantages, such as wide bandwidth, planar configuration and ease of integration with active devices has been reported, e.g. [3].

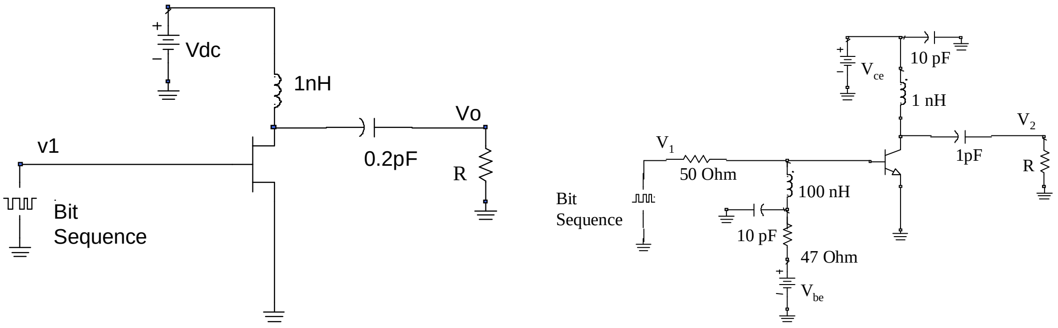
In order to keep this interference to a minimum the FCC and other regulatory groups specify spectral masks for different application which show the allowed power output for specific frequencies [4]. Furthermore, according to the FCC, a large contiguous bandwidth of 7.5 GHz is available between 3.1 GHz and 10.6 GHz at a maximum power output (EIRP) of -41.3dBm. There are further refinements to the allowable spectrum of UWB transmissions for indoor and outdoor uses [4].

While many applications and processing of UWB signals are known, very few practical circuits have been described which can conveniently generate UWB pulses. As far as we are aware, all proposed circuits either use step-recovery diodes[5] or fairly sophisticated pulse-shaping techniques [6]. Some other potentially useful techniques have been proposed [7] but not yet demonstrated as complete circuits. Also many UWB antennas have been proposed, but the the combined effect of such antennas and circuits has not been investigated till date as far as we can tell.

In this paper, UWB radiators using BJT and MESFET are proposed. Short sub-nanosecond pulses were generated and either dumped into a 50Ω load, or radiated through a coplanar fed antenna. The antenna has been previously developed following [3] and had a measured 10-dB impedance bandwidth of 2 – 20 GHz. The results presented in the following sections (other than Fig. 6) are all simulated results, using Agilent's ADS software. The device models for the parts NE662M04 (for BJT) and NE32S01 (for FET) have been used. The measured antenna input impedance (not shown for lack of space) is used as a data-file in these simulations.

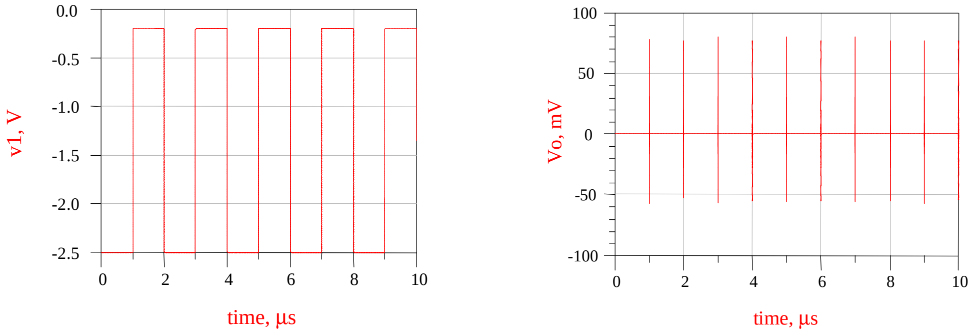
2. UWB pulse generating circuits:

The new schemes proposed for the generation of short pulses is shown in Fig.1. The pulses are synchronized to a digital waveform (the data stream) which is the input to the circuit. The pulse train has the following parameters for the MESFET-based circuits: data-rate = 0.5MHz, V_{low}= -0.2V, V_{high}= -2.5V, rise time=1nsec, fall time=1nsec. V_{dc}=2.0V for biasing and load impedance R=50 ohm as shown in Fig.1. Fig.2 shows the input waveform and the output pulses (barely visible on the same scale as the input). It is seen that UWB pulses are produced at rising and falling edges of the input. If this is not desirable, appropriate signal processing may be incorporated, to ignore or invert the falling (or rising) edge output. Expanded view of a pulse waveform is shown in Fig.3(a) and the spectrum of the output for a 500 MHz pulse–train in Fig.3(b). This increased data-rate is used to bring the peak power levels to around –40 dB which is the maximum allowed. In this, as well as subsequent spectra, the Y-axis shows power in dBm (as would be observed on a spectrum analyser).



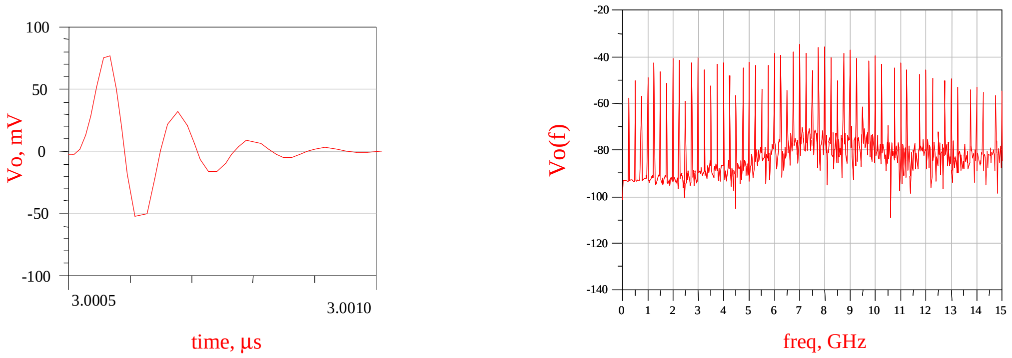
(a) (b)

Fig. 1. (a) Generation of UWB pulses using MESFET, (b)Generation of UWB pulses using BJT



(a) (b)

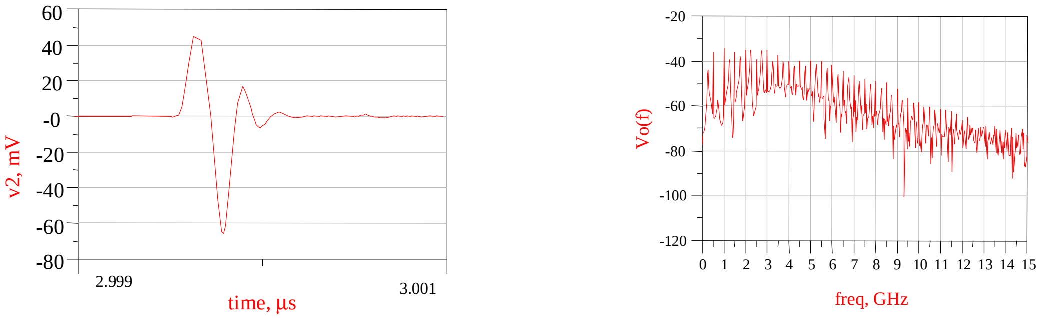
Fig. 2: (a) The Input and (b) Output Wave Using MESFET in Time-Domain.



(a) (b)

Fig. 3: (a) Expanded view of pulse. (b) Spectrum of pulse, using MESFET.

The generation of UWB pulse using BJT shown in the Fig.1(b). The input and output waveforms are very similar to the MESFET case, and these are not repeated. The only difference is in the input voltage levels : V_{high}=1.0V, V_{low} = 0.1V. The bias V_{ce}=3.5V , and load impedance R=50 ohm as shown in the Fig.1(b). The zoomed-in view of a single pulse, and the spectrum for an increased data-rate of 500 MHz, are again shown in Fig. 4.



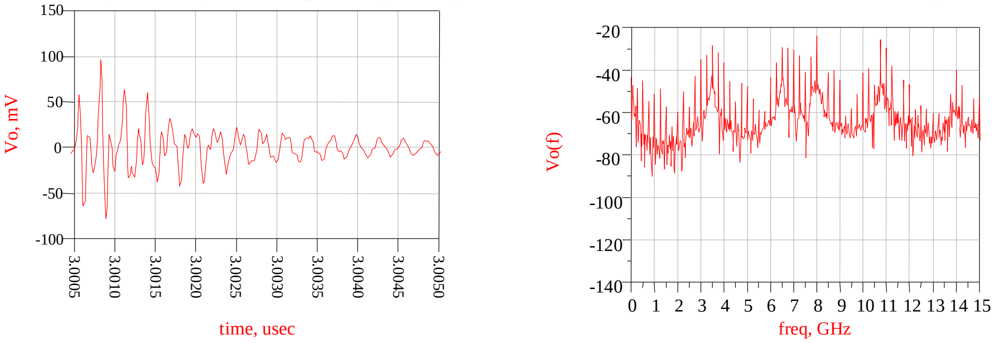
(a) (b)

Fig. 4: (a) The output wave form of short pulse using BJT in time-domain. (b)The spectrum of short pulses at 500 MHz data-rate using BJT.

3. Effect of UWB Antenna

The resistive loads of Fig.1 are replaced by the UWB antenna. Now the responses are somewhat different, and are shown in Fig. 5. The spectrum is of the total power input to the antenna (calculated from : $P_{in} = |I(f)|^2 R_{in}(f)$). It should ideally be plotted for EIRP, but for such a physically small, broad-beam antenna, the difference is small. For lack of space, the BJT results are omitted.

It is seen that the spectrum below 3 GHz is lowered, which is desirable, following the standardized spectral masks, but there are sharp peaks in the spectrum. It is clear that substantial wave-shaping will be required before this circuit and this antenna can work together. The decay time for the pulse in time-domain is also excessive. The next aim of this work is to bring these parameters under control, by suitably tailoring the input impedance of the antenna over the desired frequency range.



(a) (b)

Fig. 5: (a) The wave form generation from active UWB antenna using MESFET in time-domain. (b) The spectrum of active UWB antenna using MESFET with increased data-rate.

4. Low-frequency scaled circuit:

In order to verify the principle of operation of the circuits, the BJT-based circuit (Fig. 1(b)) was tested at a frequency scaled down by 1000. Thus the L and C values were increased by 1000. The input and output voltages were observed on a CRO, and have the expected waveforms, as shown in Fig.6 . The time-scale is 1 μs / div , giving a carrier frequency ~ 7MHz.

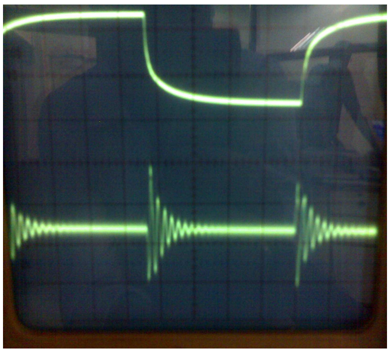


Fig. 6: Wave-form of low-frequency circuit using BJT in observed on a CRO.

5. Conclusion:

MESFET and BJT based circuits have been proposed for generation of UWB signals, and simulated results are quite satisfactory. The circuits can be easily fabricated in MMIC, and for MIC, the L and C values are suitable for easy translation to distributed form. These have been integrated with a coplanar UWB antenna and the simulated results show that many UWB antennas proposed till now will not serve the purpose unless additional wave-shaping is done.

References

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