Antennas for Ultra Wideband Use: A Literature Study

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ABSTRACT

In this paper a review to antennas for ultra wideband applications is given. The spectrum of an UWB signal is spread over several GHz due to a short pulse excitation. Large bandwidth excludes the use of typical resonating antennas and sets challenging demands for antenna design. One of the functions of CWC is to arouse research activities around the ultra wideband topics in Finland and also within Europe. This paper is one part of the work.

I. INTRODUCTION

An ultra wideband (UWB) technology is a promising asset for future short-range data and voice communications. Currently, this technique is used mainly in radar and sensor applications. Signal is said to be ultra wideband if its fractional bandwidth $B_f = 2(f_H-f_L)/(f_H+f_L)$ is greater than 0.25 [1]. UWB technology utilizes short pulse or fast frequency chirp transmissions that spread the signal in frequency domain from few MHz to several GHz. UWB signals have very good time and range resolutions and the transmission is covert. Short review to ultra wideband communication concept, called impulse radio, can be found e.g. in [2]. Wide passband sets special demands for antenna design. Antennas are called impulse-radiating radiators, due to the short pulse excitation. One cannot apply narrowband resonator antenna structures any more but antenna structures with wider bandwidths have to be found.

II. ANTENNA RESPONSE FOR UWB EXCITATION

Antennas act as filters and they are critical component in radio systems. Basic effect of antennas in time domain is that they cause derivative operations to the pulse waveform when the pulse is passing through the antenna [3]. This increases the transmitted and received pulse widths and decreases time and range resolutions of UWB systems.

Because of the very large bandwidth of an UWB signal, the properties of antennas are more emphasized. In antenna design terminology, to be ultra wide the frequency range demand is 6:1 or greater [1], which means that the upper frequency is at least six times the lower frequency of the passband.

Ringing effect of an antenna is a problem that will come up when short impulse is used as an antenna excitation. Radiated signal does not have impulse characteristics, but it is spread in time domain, as mentioned above. The antenna response resembles something what is presented in Fig. 1, where the ringing effect is modeled using simple Bessel function.

To avoid ringing, resistive antennas with low Q-value can be used. One can increase the antenna bandwidth making the Q-value small because the bandwidth is inversely proportional to Q-value. Because of the low Q-value, the efficiency of a resistive antenna is in general quite bad. New antenna structures and feeding are obviously needed for ultra wideband use.

III. UWB ANTENNA ELEMENTS

In the literature, there have been presented some antenna types for UWB radiation. An introduction to those antennas is given here. Those antennas mentioned in the literature are basically for radar applications. Small UWB antenna structures have not been published, yet.

Bowtie antenna's bandwidth is very wide and these antennas can be used in UWB applications [4]. In Fig. 2, few examples of different bowtie antenna types are shown. Bowtie antenna is one type of biconical antenna. Beamwidth and bandwidth of bowtie antenna depend directly on the physical dimensions of the antenna and they are nearly constant over the frequency range. The wider the aperture of a conical element the smaller is the beam of an antenna. If the aperture is less than 0.6λ the biconical antenna is like a dipole with conical arms and if the aperture is greater than 0.6λ the antenna can be referred to horn antenna [1]. To avoid the lack of balanced and wideband feed of bowtie antenna the hybrid antenna construction with slotline antenna can be used [4]. The bandwidth of bowtie antenna depends on the length of the plate (see Fig. 2). In the case of folded bowtie antenna the flare angle and the length of the plate define the lower frequency of an antenna. The elevation radiation pattern of bowtie antenna depends linearly on the flare angle in folded bowtie case or the apex angle of cone in non-folded case [4]. The azimuth radiation pattern of bowtie antenna is omnidirectional [1].

Biconical antennas belong to the family of fat dipole antennas. These antennas basically act like a broadband antenna [9]. Other antenna types in fat-dipole family are spherical and spheroidal antennas.

Monopole conical antenna, on the contrary, is not so suitable for UWB use because the arm length of the cone gives a lower frequency limit (due to the impedance matching) and the deformation of radiation pattern limits the higher frequency, simultaneously [11].

In [5] a folded horn antenna for ultra wideband high power applications is introduced. The idea of the folded horn antenna comes from subhorns inserted in a main horn. Subhorns divide the initial horn aperture into two equal parts, maintaining its electrical dimensions as can be seen in Fig. 3. Using this technique the size of the antenna can be reduced.

In Fig. 4 there are presented a bicone dipole antenna and a conformal reverse bicone (magnetic) antenna for UWB applications [6]. The magnetic antenna structure presented in Fig. 4b decreases unbalanced currents excited on the outer feed cable. The magnetic antenna exploits the duality of electrical and magnetic fields.

In UWB radar, planar antenna arrays may be formed with very sparsely spaced elements. This enables economical, high resolution and quite simply steered beam phased arrays [7]. Wideband peak-sidelope-level to peak-mainlobe-level ratio is a function of the number of antenna elements not that of the element spacing, which is why sparse spaced wideband arrays do not create significant grating lobes [7]. If the number of antenna elements is increased the sidelobe levels will be reduced to almost arbitrary low levels.

Fractal antennas have also very wide frequency band [8]. Using printed circuit fractal loop antennas one can achieve ultra wideband performance and the antenna size can be reduced quite small [10].

Also dipoles, log-periodic dipole arrays (LPDA), conical monopole (with reservations), spirals, notched, ridged or TEM horn antennas can be used in UWB applications [1]. In Table 1 there is a summary of different types of antenna elements for UWB radar picked from [1].

In the UWB literature at the moment, the main focus in UWB antenna technology have been the high power radar antennas. There are products or demonstrative radio applications for communications, intelligent sensors and surveillance etc. areas, which utilize low power consumption. These applications will benefit from an antenna technology that can be produced in very small size. Currently the problem is a low publicity of those antenna structures.

IV. FEEDING

Feeding of UWB antennas can be done by using e.g. coaxial cable, waveguide or microstrip line. The antenna matching is done by balun, if necessary [4].

The wide frequency band used in UWB applications also demands a lot on feeding lines. For example, the geometry of feeding waveguide sets the frequency bounds to the transmitted signal.

A balanced ultra wideband hybrid antenna can be realized using a bicone antenna fed by a tapered slotline antenna. This structure provides low voltage standing wave ratio and ultra wideband radiation pattern. It also has low side- and backlobes [4]. Fig. 5 illustrates some electrical and magnetic radiation patterns of this type of hybrid slotline/bowtie antenna. In Fig. 6 the corresponding voltage standing wave ratio is shown [4].

The feeding line problem can be circumvented when the impulses are generated in the antenna throat. One possible technique is optical pulse excitation presented e.g. in [3],[12]. In this invention a high voltage potential is stored between metallized layers that act also as antenna plates. A laser pulse triggers photoconductive semiconductor between the plates into a conductive state. The voltage potential is suppressed rapidly, which causes energy to radiate from the antenna [12].

V. CONCLUSION

Based on the literature study, advanced communication and sensor applications are being exploited in the near future, and the challenges in ultra wideband antenna technique call for intensive research.

There are a number of different antenna structures suitable for ultra wideband applications. Extremely wide frequency band of UWB signal makes the antenna design an interesting research area.

VI. ACKNOWLEDGEMENT

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Figure 1. *The response of an antenna to impulse excitation.*

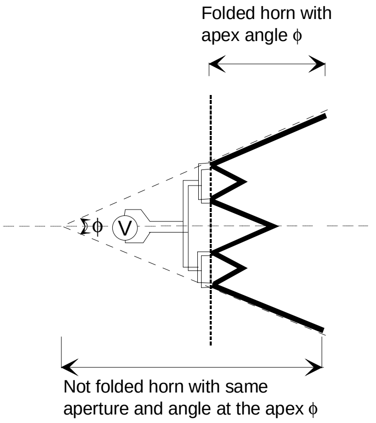


Figure 3. Folded horn antenna.

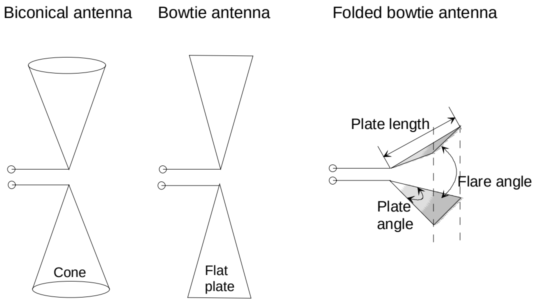
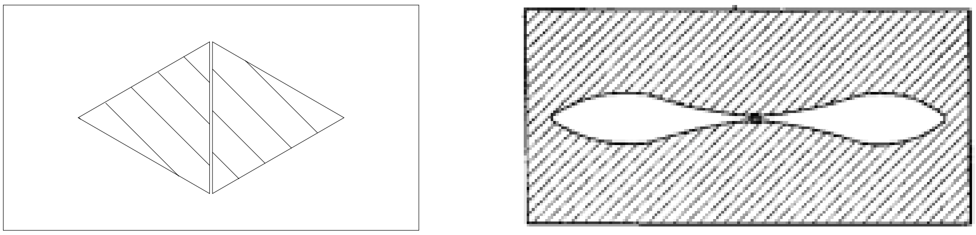


Figure 2. Few wideband bowtie antenna types.



a) *b)*

Figure 4. a) Bicone antenna, b) Conformal reverse bicone antenna (magnetic antenna).

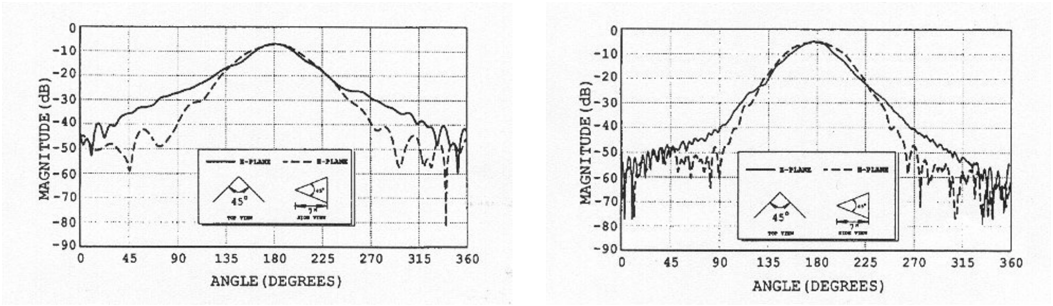


Figure 5. E- and H-plane pattern for slotline/bowtie hybrid in 3 GHz and 10 GHz.

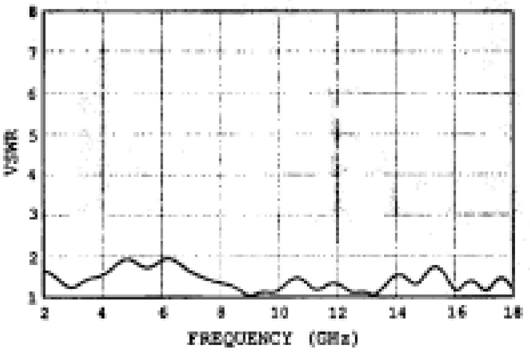


Figure 6. Voltage standing wave ratio for slotline/bowtie hybrid antenna.

Table 1.Summary of typical UWB antenna elements.

	Band-width	Gain [dBi]	Const. gain	Max BW VSWR	Rad. pattern	Polariza-tion
Loaded dipole	10:1	1.5 to 2.15	yes	10:1	omni	Linear
Biconical	5:1	1.5 to 15	no	5:1	omni	Linear
TEM horn	12:1	2.5 to 15	no	12:1	unidir.	Linear
High gain notch	5:1	6 to12	no	10:1	unidir.	Linear
Low gain notch	5:1	3 to 6	no	10:2	unidir.	Linear
Ridged horn	5:1	6 to 8	no	6:2	dir.	Linear
Spiral	20:1	2	yes	40:2	dir.	Circular
LPDA	20:1	7 to 15	yes	6:2	dir.	Linear