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Very Wide Band, Flat Omnidirectional Antenna

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Abstract- In this paper we present a novel type of wideband omnidirectional antenna which can be used in small thin transducers like a cell phone. This antenna operates in a wide continuous spectrum. There are well known articles on small printed wideband antennas. This paper, unlike other articles, defines ratio of triangle radiator sides and dimension of ground plane. Dipoles and monopoles are a well-known linear antennas used in many applications; however, they cannot work in all frequencies of a wide band. And these antennas cannot be implemented as an internal antenna in small devices which include a Printed Circuit Board (PCB). In many communication devices, such as cellular handsets, there is a grounding problem. For example, in cellular handsets and other mobile device with RF communication capabilities that use a small "ground" plane such antennas cannot be used because a small "ground" plane cannot provide zeroing of potential. The proposed antenna has two new important features: it works at all frequencies in very wide band and it can be a part of common terrestrial and satellite systems.

Keywords- antenna; cell phone; omnidirectional; triangular; nullifier.

I. INTRODUCTION

One can read in Britannica: "A. S. Popov is credited (1896), however, with being the first to use an antenna in the transmission and reception of radio waves". This antenna was monopole. This antenna is widely used in many communication applications due to its omni-directional radiation pattern and small profile. However, conventional monopole antennas have limited continuous bandwidth. Monopole has optimal parameters if its height equals quarter wave length or to an odd number of quarter wave lengths.

At the same time, modern communication applications, for example future cellphones, need wideband antennas. In near future the required wideband may be 0.7 - 18 MHz And maybe wider, if cell phone will communicate with satellite. As now, in future it will be desirable to have a small number of antennas in cell phones, preferably a single antenna. And this antenna must work at all frequencies its band, it must be flat and near to omni-directional.

These demands are known for a long time. There is patented antenna PIFA (Planar Inverted-F Antenna) [1]. But this antenna can work at small numbers of frequencies. In addition, there is an antenna type based on one wire method of electrical signal transmitting [2], which allows to work at quarter wave lengths and at all their harmonics [3]. However, in this antenna case parameters at frequencies between harmonics are not optimal.

In linear antennas, wire as well as printed, such as dipole, monopole, PIFA, log-periodic, and fractal antennas, the current distribution is limited to a narrow path along one or few direct or broken (folded) lines. The working frequencies of these antennas depend on their height or the trace length of their radiators. Therefore, these antennas can operate only at certain frequencies, but not in a continuous band of frequencies.

In these antennas, the current direction is designed so as the desired radiation parameters are obtained. Since the number of such current paths is limited, even a multi-band antenna does not work in a continuous spectrum. The known log-periodical antenna, which is actually a combination of several antennas, is a wideband antenna. However, this antenna is not omni-directional and it is very bulky. In this paper, we present a new type of antenna which has a continuous very wide frequency band including prospective satellite phone systems and can work at all frequencies of its band.

II. THE PROPOSED TYPE OF ANTENNA MAIN IDEA

The proposed type of antenna consists of flat radiator in a form of a scalene triangle, and is fed at one of its corners. Fig. 1 shows a scheme of the unbalance configuration of the proposed antenna, using a nullifier (labeled as Null) for zeroing instead of using grounding [4]

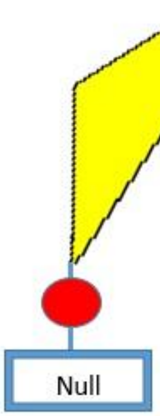


Fig. 1.The shape of the proposed triangle antenna

According to [4] the triangle's longest side should be equal or longer than the quarter wavelength of the lowest frequency in the required frequency range, and its shortest side should be no longer than the quarter wavelength corresponding to the highest frequency of this range. As it will be show below, it is desirable to have ratio sides length 3 : 1. Operation of the antenna can be modeled as follows. When a signal is applied, it can cause many current lines in the triangle radiator flowing in different directions. Each direction is characterized by a certain length and by different impedance .

Here X is the reactive part of an antenna impedance. The maximal current will flow in the direction with the minimal impedance. For each frequency, the current distribution will be concentrated along a narrow path which length is equal to quarter wavelength at that frequency. As for other frequencies, the length of a current path will not be equal a quarter wavelength, the impedance (Z) of this path will be complex and greater than R.

$Z = \sqrt{R^2 + X^2}$

Known types of antennas like dipole and monopole resonate at the fundamental frequency Fo, and at odd harmonics of Fo. The same situation occurs in the proposed type. Thus, if the antenna bandwidth is from Fo till 3Fo, this antenna can work (at least in theory) at an infinitely wide frequency range.

Assume there is current inside of triangle flat radiator. If we use the minimal frequency Fo, then the current actually must flow along the longest triangle site. At higher frequencies, the current must flow inside the triangle. But the current cannot flow along the direction if there is metal on both sides of it. Numerous simulations have shown that in this case the current flows along the sides of the triangle, but lengths of flows correspond to a quarter of the wavelength of a given frequency.

This hypothesis was confirmed by simulation results on Fig 2, showing distribution of currents in antenna at frequency band 0.7 - 2.1 GHz. Input signal has frequency 1.3 GHz. The current must flow along line 1, because its length equals quarter wave length at frequency 1.3 GHz. But we see that currents flow on both sides of triangle (lines 2 and 3). So, they can radiate.

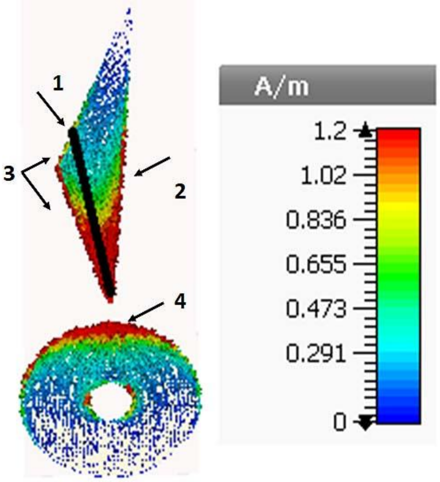


Fig 2. Currents in triangle radiator.

Note that there is current in nullifier input (2) as well. But this current does not make work because input resistance of zeroing scheme is about zero.

III. NULLIFIER AND WITHOUT NULLIFIER

Small mobile transducers usually suffer from lack of a real ground. In order to mitigate this problem, the authors have proposed to use a nullifier [2]. Its goal is to produce a zero-potential point.

The potential nullifying (zeroing) is achieved by summing at the same point two signals of equal amplitude and opposite phase. For this purpose, one can use different techniques such as metallic delay line, strip line, transformer with opposite windings [2]. Nullifier can work at any frequency, but its construction depends on the signal frequency band. For narrow band signals, the nullifier can be implemented by a half-wave delay line, as shown in Fig.3.

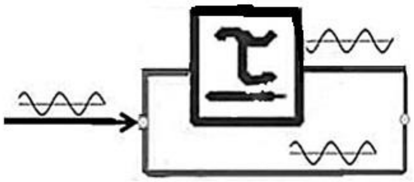


Fig.3. Time delay of the wide band antenna

Wideband nullifier can be realized by a circular ring, as illustrated in Fig. 4. The perimeters of the outer and inner circles are equal to half wavelength of the lowest and highest frequencies, respectively.

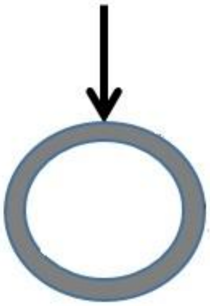


Fig.4. A nullifier of the wide band antenna

The nullifier can be implemented also as a conductive plate such as a metallic layer of a Printed Circuit Board (PCB), as shown in Fig.5. In this case, its perimeter must be more than half wavelength.

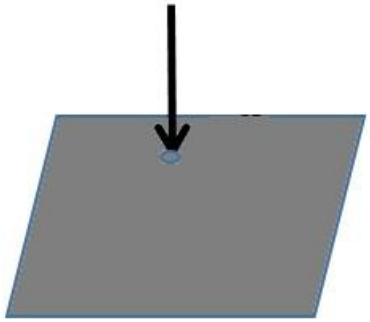


Fig.5. A further nullifier example.

IV. TRIANGLE ANTENNA WITH HORIZONTAL NULLIFIER

The proposed antenna can be implemented in a 3D structure, in which the nullifier is perpendicular to the radiating element, as depicted in Fig. 6. In this case, the total high of the antenna is reduced.

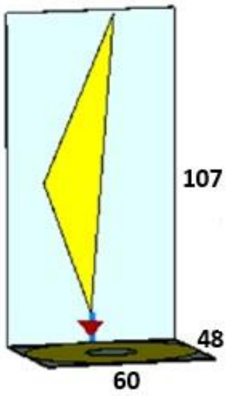


Fig .6. Triangle antenna with horizontal nullifier dimensions example

The simulation results for this antenna are shown in Fig. 7 for VSWR, and in Fig. 8 for the radiating pattern.

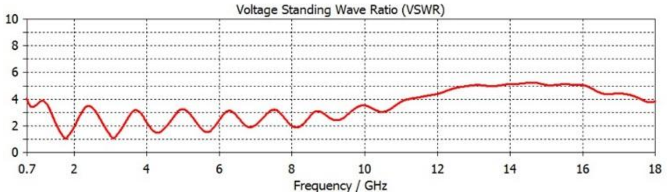
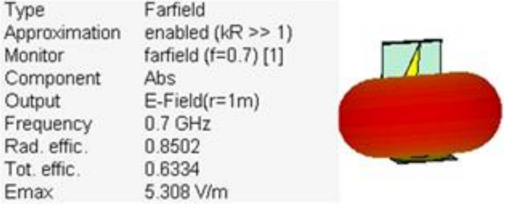


Fig .7. VSWR of triangle non-flat antenna



Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=0.7) [1]
Component	Abs
Output	E-Field(r=1m)
Frequency	0.7 GHz
Rad. effic.	0.8502
Tot. effic.	0.6334
Emax	5.308 V/m

Fig .8. E-pattern of triangle antenna with horizontal nullifier

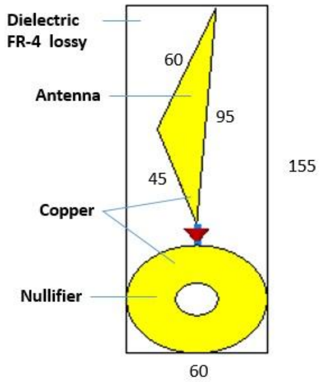


Fig. 9 “Large antenna”

For cell phone we need the flat antenna. Taking into account needed ratio of sides of triangle radiator and dimension of nullifier we receive antenna dimensions as showed on Fig.9. let as name this antenna as a “large antenna”.

The antenna dimensions depend on the lowest frequency. For frequencies from the fundamental frequency up to the 3rd harmonic, there is only one current path. But, for higher frequencies, radiation can stem from several current paths, i.e. the fundamental frequency and its odd harmonics. This leads to the fact that with increasing frequency, the antenna impedance is no longer pure resistive.

The parameters of the antenna of Fig 9 are obtained using a 150Ω source. But, for the 9 - 18 GHz range, it is needed to add a series 3 nH inductor to this source. In this case, VSWR is practically frequency independent (see Fig.10)

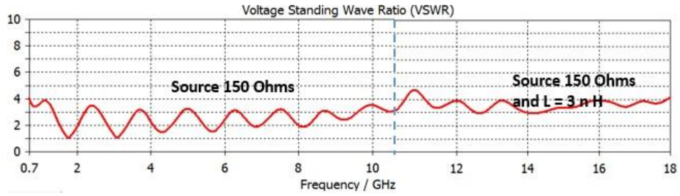


Fig.10 VSWR after compensation at f=10-18 GHz

The more the antenna height is reduced, the more its parameters are deteriorated. Some compensation of this deterioration can be achieved using a horizontal metallic rod
wire at the top of antenna (see Fig. 11).

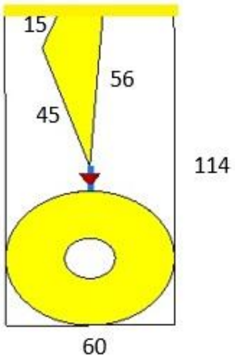


Fig.11 The “small” triangular antenna

V. TRIANGLE ANTENNA AT HIGH FREQUENCIES

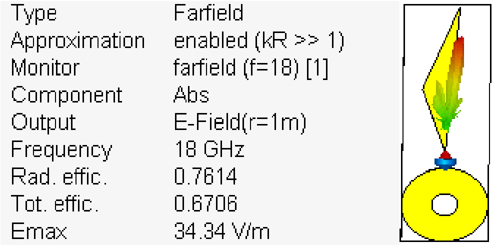
Any linear antenna can work not only at its resonant frequency correspond to quarter of wavelength. But and at non odd harmonics of this basis frequencies. In case of proposed triangular antenna this fact gives very important advantages.

As showed above triangle antenna has wide band of basis frequencies. This give opportunity using several basis frequencies for transmitting or receiving signal at high frequencies.

Using basis frequencies 0.7 - 2.1 GHz we will give 18 GHz as:

2GHz * 9; 1.64GHz * 11; 1.38GHz * 13; 1.2GHz * 15; 1.01GHz * 17; 0.95GHz * 19; 0,86GHz * 21; 0.78GHz * 23; 0.72GHz * 25

So, in case of this antenna at frequency 18 GHz are working not one antenna, but nine antennas. Simulations results see on Fig.12



Type	Farfield
Approximation	enabled (kR >> 1)
Monitor	farfield (f=18) [1]
Component	Abs
Output	E-Field(r=1m)
Frequency	18 GHz
Rad. effic.	0.7614
Tot. effic.	0.6706
Emax	34.34 V/m

Fig.12. E-patterns after compensation at f=18 GHz

Simulations show that when going from monopole to triangle antenna maximal field density increases by 5 times and gain increases by 15 dB. This effect of “large antenna” as showed on Fig 9, one can see on figure 13.

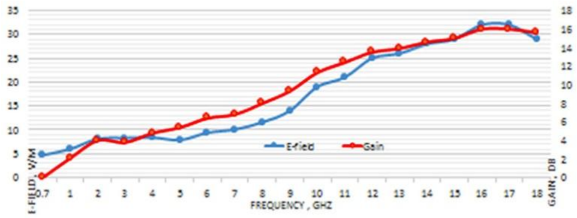


Fig .13 The gain (in dB) and far field (at distance 1m in V/m)) of “large antenna” at frequency band 0.7 – 18 GHz

Increasing antenna gain with increasing frequency confirm that in this case antenna stopped to be omni-directional and turns into a sharply directed, as can see on Fig 12

How can see on Fig 13 the cause increasing field density and gain on high frequencies is that the pattern is very narrow and is directed upwards. This fact gives disadvantages and advantages.

VI. TRIANGULAR ANTENNA DIRECTIVITY IN DIFFERENT CONDITIONS

The proposed triangle antennas have an omni-directional pattern at frequencies of 0.7 - 9 GHz. The non-omnidirectional pattern at higher frequencies is attributed to the fact that at high frequencies the antenna resonates at different paths corresponding to odd harmonics besides the fundamental harmonic. This disadvantage not always is important. If this antenna is in cell-phone we need take part into consideration the influence of hand and hyad. Influence of hand to triangular antenna E-patterns and dipole one shown in Fig.14.

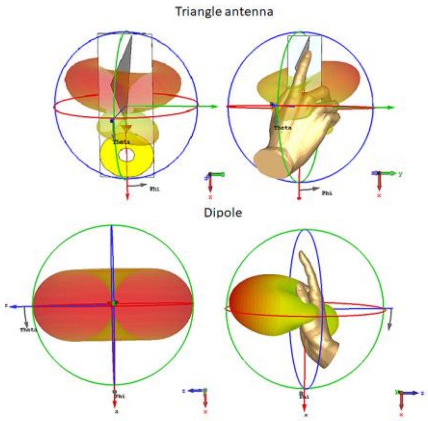


Fig. 14 Triangle antenna radiation with hand influence

Now about advantages of radiation pattern at high frequencies. The future of mobile internet and phone is satellite system. Frequencies will be from 1.2 till 31 GHz [12]

Proposed here triangle method allows developing phone antenna, which can work at all frequencies beginning from 0.7 GHz. At frequencies up to 2 - 3 GHz antenna will get good parameters in horizontal direction. At frequencies more than 3 GHz will get good parameters in vertical direction. Both radiating pattern one can see on Fig 15

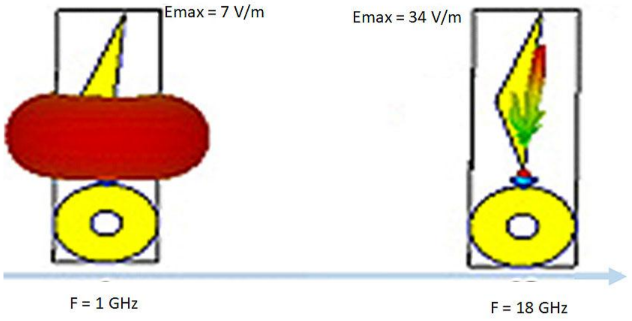


Fig 15. The triangle antenna at frequencies 0.7 and18 GHz.

The basis of advantages of proposed triangle antenna are small dimensions and high gain. Therefore, this antenna allows received signal from flying object without using bulky parabolic reflector.

Beside this at high frequencies this antenna has nonlinear polarization. This conclusion allows to get simulations results which showed on Fig 16.

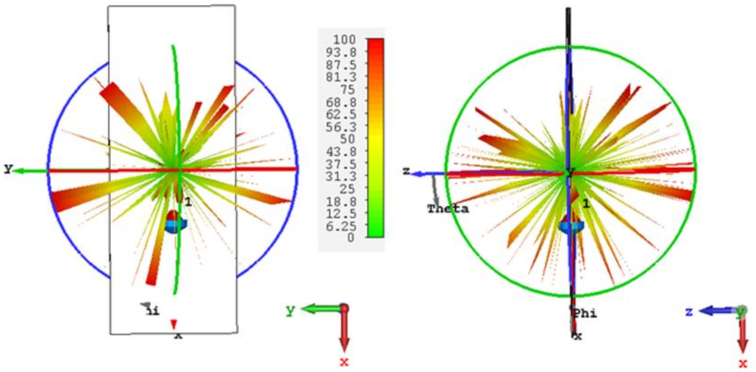


Fig 16 On the question of the type of polarization at high frequencies of a triangular antenna.

The simulations at frequency 15 GHz give maximal field density 31.2 V/m and gain 15.3 dB. In this case, there is a different distribution of fields in two mutually perpendicular regions, which indicates nonlinear polarization. So, we have a change in the radiation pattern from radiation in a horizontal plane at low frequencies (below 3 GHz) to radiation in a vertical plane at high frequencies. This allows you to use the same antenna for communication with ground objects and with flying objects.

VII. REAL ANTENNA PARAMETERS MEASUREMENTS.

Example antenna, which showed on Fig 9 and its photo on Fig 17 was checked in Antennas Laboratory of firm MTI WIRELESS EDGE LTD. Were measured the radiation pattern and gain at various frequencies.

Fig 17 Measured antenna

The figure 18 shows examples of the results obtained.

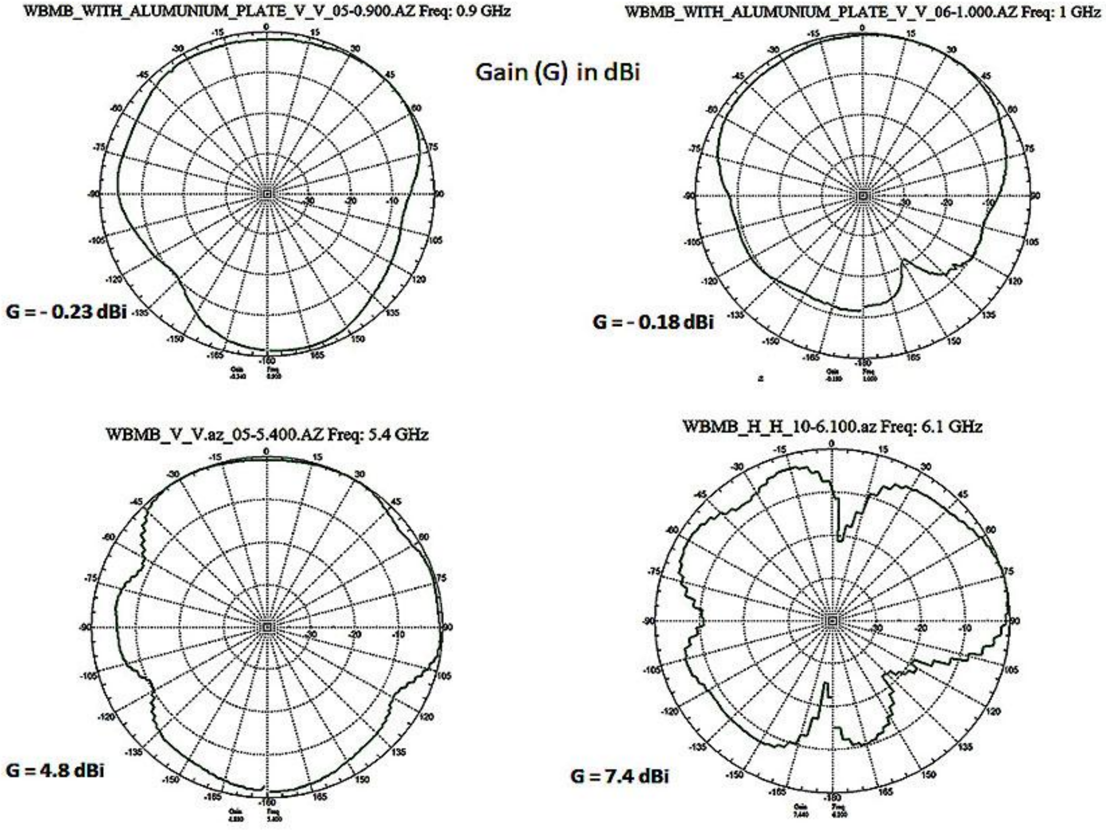


Fig 18 Antenna on Fig.17 measurements results

The measurements confirmed the results obtained in the simulation. Namely at frequencies from 0.7 to 5-6 GHz, the antenna emits in the horizontal plane and does not have frequencies at which the radiation level drops sharply. At frequencies above 6 GHz, the main radiation of vertical located antenna directed upward. In this case, the gain antenna increases.

VIII. CONCLUSION

The important results one can see from Fig 19, where shown radiating field density from well-known normal monopole and from new triangle antenna. Both antennas have the same dimensions and the same parameters of signal source. The monopole is working at frequencies correspond to odd number of quarter wavelength and don't working at frequencies correspond to even number of quarter wavelength.

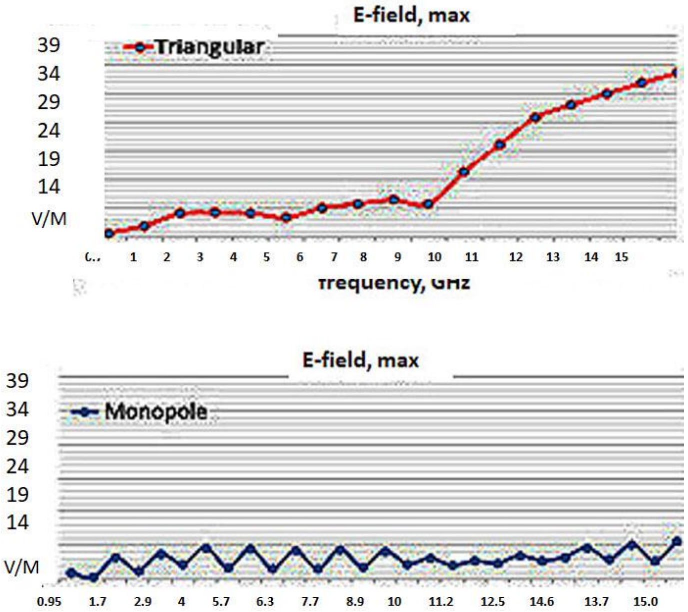


Fig .19 Final comparison results

Proposed here antenna triangle form allows getting ultra-wide band antenna. The main advantage of it that it can work at all frequencies of its frequency band, but not at several frequencies. So, it is possible to say that this antenna is not resonance antenna.

For using in cell phone this antenna has flat form and small dimensions. This form allows you to use various options for combining the antenna and the printed circuit board of the phone.

The proposed type of antenna gives opportunity building one cell-phone for terrestrial and satellite systems with one antenna.

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