Radiation of Modulated Ultra wide band (UWB) Signals by Switched Resonant Patch Antenna

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ABSTRACT— Design of planar antennas which provide large impedance bandwidth and also large radiation bandwidth is a challenge in UWB systems. Although ultra wide impedance bandwidth is readily achievable, radiation pattern rotation and phase centre variations are unavoidable characteristics of conventional passive antennas. Introducing an active element in the antenna structure and using its nonlinearity may overcome these limitations. In this paper, we use some diode switches integrated with a microstrip patch antenna. A modulating signal controls the switches states and a Direct Antenna Modulation (DAM) is established. The results show that the switched antenna radiates modulated signals with stable radiation pattern and constant phase center over a 1GHz bandwidth.

KEYWORDS: diode switch, direct antenna modulation, patch antenna, Ultra wide band (UWB).

I. INTRODUCTION

In spite of the fast movements observed in the area of ultra wideband (UWB) systems, design of an antenna capable of the all needed requirements in these systems is still under research [1].

For instance, conventional UWB antennas such as spiral and Vivaldi have a relatively constant radiation pattern but they are rather bulky and also have variable phase centre. In recent years, multi-resonance planar monopole antennas have been proposed as a low cost and low profile candidate for UWB applications which provide a large impedance bandwidth [2]. However, they suffer from radiation pattern rotation which corresponds to different resonant modes. In contrast, microstrip patch antenna as single resonant radiator has never been proposed as a UWB antenna due to their narrow impedance bandwidth.

In this paper, feasibility of UWB radiation by a microstrip patch antenna is studied. To overcome the effects of limited bandwidth on the radiation, the idea of direct antenna modulation (DAM) [3]-[5] is applied. This method focuses on nonlinear transient behavior of the antenna instead of its linear frequency response [3] and directly modulates the output of antenna. Thus high speed switches like diode are integrated on the radiation slots of the antenna to control its transient radiation. When antenna is excited in its RF resonance frequency, by controlling the diode with an additional source, radiation slots are opened and shorted periodically according to diode condition. When diodes are on, slots are shorted and accumulated charges on the patch go to the ground, so the antenna operates in cavity mode and RF energy is stored. On the other hand, when diodes are off, RF energy...
saved from previous cycle plus energy from the new cycle will be radiated into free space efficiently [5]. The result of this interaction is a new radiation process which brings about modulated signals with wider bandwidth. Results from CST and ADS simulator softwares verify that by using this method, resonant antenna with bandwidth of 50 MHz can radiate signals with bandwidth up to 1GHz. In addition, such an antenna benefits from high pattern stability, constant phase center and uni-directional radiation pattern at the same time.

The remainder of this paper is structured as follows. First, an inset feed microstrip patch is selected as basic antenna. In part III, the idea of DAM is applied to the antenna and its operating procedure will be examined. In part IV, simulation results of DAM will be provided and compared with those of the basic antenna in detail.

II. BASIC ANTENNA

Fig.1 shows the structure of inset feed microstrip patch antenna which is printed on FR-4 board with dielectric constant of 4.5 and the thicknesses of 1.5 mm. This type of antenna can be matched only over a narrow frequency bandwidth. Simulation results show impedance bandwidth of 50MHz and resonance frequency of 3.61 GHz for this antenna.

III. DAM AND IDAM IMPLEMENTATION

In fig.2 the structure of DAM is shown. As can be seen, five diodes are mounted on the radiation slots of the antenna which are specified by circles. The radiator part is a rectangular patch which is excited by a 50 ohm feed line. A thin micro-strip line makes the RF path by connecting the patch to the source. To control the diodes, an additional low frequency (LF) source is applied to the antenna by a radial stub to avoid affecting RF path. Also a 10 pF capacitor is used in the RF path to isolate RF source from LF bias. The radiation mechanism of this antenna can be explained as follows. First, the antenna is excited with a 3.61 GHz sinusoidal signal at its resonance frequency. At the same time, a 200 MHz control pulse is applied to the antenna by the LF bias to make the diodes on and off at specific times. When diodes are on, radiation slots become short circuited and accumulated charges are transferred to the ground via negligible on resistance of diodes. In this step patch acts as a resonant cavity with two PEC boundary conditions - shorted slots - and two PMC boundary conditions -non radiating slots- sides, so it stores its input energy until the diodes are turned off by control source. In this step, boundary conditions abruptly change and saved energy from previous cycle plus current input energy are radiated into free space. The periodic and fast charge and discharge of current on the radiation slots results in radiation of narrow time domain signals with
bandwidth beyond original bandwidth of the antenna [3].

Number of diodes and their position, on resistance and off capacitance play an important role in the antenna characteristics such as efficiency, gain and bandwidth. In order to compare the DAM output signals with those of basic antenna, another configuration named indirect antenna modulation (IDAM) is studied. In IDAM we apply the output of mixer to the antenna and compare its radiation with that’s of DAM. In fig.3 the schematic diagram of DAM and IDAM are compared. In the next step simulation results obtained by both CST and ADS commercial simulators are shown and difference between DAM and IDAM are compared in detail.

IV. RESULTS

In this part of paper, simulation results by ADS are provided and will be verified by CST. To simulate the DAM structure in ADS, first the antenna in its resonance frequency is modeled by a RLC tank proposed in [6] and shown in fig.4. To compute the value of R, L and C we use the optimization code to adjust the $S_{11}$ of the circuit with that of exact antenna. So, the radiation behavior of this model will predict the radiation by the antenna. To implement DAM idea, a schottky diode (HSCH-5330) [7] is connected to the antenna and controlled by LF source with 200 and 500 MHz frequency separately. The antenna is excited by a source of frequency 3.61 GHz. For IDAM implementation, instead of using diode, we apply 500 MHz and 200 MHz modulated signals produced by a mixer. In Fig.5 the output signal in two cases are compared in both frequency domain ((a)) and time domain ((b)).

It is clear that output signal in DAM has a spectrum of rich harmonics with 200 and 500 MHz spacing which have higher amplitude compared to IDAM. It must be noted that difference between the carrier peak and the first harmonic peaks in 200 MHz and 500 MHz cases are about -5 dB compared to -20 dB for IDAM. This increments indicate that bandwidth of the antenna has been improved so that it can radiate wider frequency range of 400 MHz (11%) and 1 GHz (25%). This claim is also verified by transient radiated signals shown in fig.5.b.
To further elucidation of radiation process, the diode voltage and radiated signal are shown in Fig. 6. It is clear that in the ‘on’ duration, no radiation exists because the antenna output is short circuited by diodes. On the other hand, when diode is ‘off’ the antenna radiates its energy as plotted signals. To verify the ADS results, we simulate the DAM structure (fig.2) in full wave CST simulator. In fig.7 the spectrum of radiated signals by DAM and IDAM are compared. The carrier is selected to be 3.61 GHz and LF is set on 500 MHz. Again it is obvious that amplitude of harmonics is increased in DAM which indicates higher bandwidth in that case. It is worth pointing out that this antenna has high transient pattern stability (>90%) in both H-plane and E-plane and constant radiation pattern over its bandwidth (Fig.8). The reason is that against multi-resonance UWB antennas [2] where dominant mode in each frequency corresponds to current distribution and radiation pattern (where pattern rotation is unavoidable), antenna used in DAM is inherently a single resonance antenna and so provides a constant radiation pattern. This is the integration of nonlinear element such as diode and fast keying that enables a single resonant antenna to radiate wide band signals.

V. CONCLUSION

In this paper the capability of a switched microstrip patch antenna to radiate UWB signal was studied. Using DAM idea, diodes were integrated on the radiation slots of the antenna. When diodes became on and off periodically, radiated signal by the antenna is modulated directly and also it covers wider bandwidth compared to original antenna. Simulation results show that DAM scheme provides a bandwidth up to 1GHz (25%) for the patch antenna with resonance frequency of 3.61 GHz and original bandwidth of about 50 MHz.

REFERENCES


