SATELLITE BASED ANTENNA ARRAYS: SOME CHALLENGES AND POSSIBLE SOLUTIONS
(review article)

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Abstract
This paper presents some aspects of multibeam and reconfigurable satellite phased array antennas construction and functionalities, as well as Photonic Band Gap and Micro-Electro-Mechanical Systems (MEMS) technologies, which are used for antennas efficiency and functionality enhancement purposes.

1. INTRODUCTION

Nowadays telecommunication systems are one of the most important fields of humanity and civilization existence in our Earth. One of the most important components of global telecommunication system are satellite telecommunication systems. Because of specific requirements for satellite system operation, satellite antennas also have to obey to special requirements, such as multi functionality, size and weight limitations, energy saving and flexibility [1]. These requirements are fit to the Phased Array Antennas instead of traditional dish antennas with horn feeds. With phased arrays technology it is possible to create multibeam and reconfigurable coverage without big power consumption and with small size antennas. In the direction to decrease energy losses and make phased array antennas tinier, engineers and scientists pay more and more attention to nanotechnology solutions, like Photonic Band Gap (PBG) structures and Micro-Electro-Mechanical Systems (MEMS). An overview of these technologies and their use in antenna systems is presented below.
2. USE OF PGB AND MEMS IN ANTENNA ARRAYS

2.1. Photonic Band Gap Structures

Usually phased array antennas can work as a separate antenna system, or can be feed for dish antenna. In the both cases they can provide multibeam pattern and/or reconfigurability, if needed. Multibeam directional pattern is formed by beam forming network (BFN). This network can be divided into subnetworks and each of these subnetworks can form their own beam with different frequency and pattern. Using this it is possible to realize frequency re-use with good isolation between beams. A good example of this is fourth generation INMARSAT satellite, which has a dish with 9 m diameter, and constructed by 120 elements BFN, using which it can generate 256 beams [2]. However, performance requirements for mobile satellite communication systems are steadily increasing, both in terms of higher antenna gain and frequency re-use capacity. In order to provide the edge of cell edge of coverage (EOC) directivity and the beam roll-off rate, required to achieve inter-beam isolation, the beam size will need to decrease. Photonic Bandgap structures have the potential to increase feed aperture efficiency with constant beam spacing, hence reducing spillover and beam roll-off [3]. It is shown that the EOC gain can be increased by 1 dB and more, over up to 12% bandwidth, for PBG feed arrays in a hexagonal lattice relative to a standard feed array. PBG structures are built to mimic materials where dielectric permittivity varies periodically in space. The appearance of PBG is shown in Fig.1. Because of this PBG show frequency selectivity and some resonator properties. It can act as a passing-through material for one frequency and reflective material for others. These properties stimulate it for controlling the electromagnetic wave propagation over set frequency bands.

![Figure1. Photonic Band Gap structure.](image-url)
The PBG technique has been used in optoelectronics for the fabrication of lasers and in surface wave suppression for antennas. The technique has been further developed and tailored for this application.

2.2. MEMS and Reconfigurability

In the case that beam forming network cell size decreases, much more beam/cells will be required to cover a given geographical area. As a result it will be required to create larger reflectors and feed arrays with many more radiating elements. Due to satellite orbit inclination, fixed cell network is distorts, and it is necessary to re-synthesis of the whole beamset and use new weights many times a day.

Mentioned challenges can be solved by using dynamic beam system instead of fixed system. For example in mobile satellite communication systems it is very useful to have flexible beam system. This allows assigning (allocating) beam for the specific area only when it is required by user. When user is going to use the system, beams configuration changes to have maximum propagation power in user area and minimum in other areas [4]. This helps to solve mentioned problems and also helps to avoid interference between beams. Reconfigurability is a very important feature for radar system antennas also. It can be achieved by either mechanical or electronic reconfiguration strategy. The electronic reconfiguration is obtained by integrating phase-shifters within the array elements, by loading the patches with reactive elements (varactors) and electrically controlling their reactance or by using phase shifters based on the MEMS technology. With the emergence of the MEMS (Micro-Electro-Mechanical Systems), new antenna solutions are arising, which achieves reconfigurability at a moderate cost. The reflectarray antenna with elements controlled by MEMS switches is the most attractive solution [5].

MEMS is the integration of mechanical elements, sensors, actuators, and electronics on a common silicon substrate through microfabrication technology. MEMS switches have displayed excellent RF characteristics, including lower insertion loss (< 0.2 dB), higher isolation (> 40dB), zero power consumption, small size and weight and very low intermodulation distortion, and long battery life. The maximum frequency of the RF carrier is limited only by the maximum MEMS operation frequency, which with today’s technology is about 60 GHz [6]. The minimum control signal period is determined by the
maximum switching speed of the MEMS, determined by the switch's physical dimensions and material properties. Typical switching rate with today’s technology is about 40 kHz. RF MEMS switches are ideal elements for reconfigurable antennas. One of the goals of antenna design is to minimize the reactance of the device by operating the antenna at its resonant frequency. RF MEMS switches can be used in antenna design to modify the resonance frequency by physically changing electrical length (with respect to wavelength) attributed to capacitive and inductive reactance. Reconfigurable antennas using RF MEMS switches have unique advantages. They offer very low loss switching. This means that bias network for RF MEMS switch, which can be extensive in large antenna arrays, will not interfere and degrade the antenna radiation patterns. RF MEMS switches are also used in microstrip antennas. MEMS can be directly constructed and integrated with the antenna wafer during fabrication (Fig. 2. (a)) or is attached to the antenna after fabrication (Fig. 2.(b)).

As we can see MEMS solve also two main problems with solid-state switches: breakdown of linearity and frequency bandwidth upper limits, and the degradation of insertion loss and isolation at signal frequencies above 1-2 GHz.

3. CONCLUSION
As it can be inferred from this article, nanotechnologies have their growing contribution in the Antenna Systems and RF technologies development. In case studies of MEMS’s and PGB’s we can see how much these technologies are tied to each other, in order to solve upcoming technological challenges.
REFERENCES


