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REVIEW ON IMPLEMENTATION OF SILICON-ON-INSULATOR TECHNOLOGY FOR SLOT ANTENNAS

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ABSTRACT

The Antennas like microstrip patch, half wave dipole, slot antenna and Substrate Integrated Antenna (SIW) are traditionally used for radiation of Electromagnetic energy. These antennas provide gain depending on their dimensions and often suffer from radiation loss, ground loss and skin effect. Microstrip patch antennas are easy to integrate and are planar in nature. But they suffer from severe discontinuities at the truncated edges. A slotted waveguide emits directly through the slots. The spacing of the slots is an integral multiple of the wavelength used for transmission and reception. The directionality of the slotted wave guide antenna depends on the dimensions of the slot. Due to the absence of reflector, wave guide slots suffer from leaky waves and unwanted radiations. Substrate Integrated Waveguide (SIW) acts as alternative option to hollow metallic waveguides where the substrate is filled between lower and upper metal plates. The SIW components are light, cheap and easily fabricated due to which one can easily attain compactness. The performance of SIW depends on the substrate. Substrate used in SIW usually generates surface and leaky waves. A high lossy substrate indeed decreases the radiation resistance of an antenna. This problem can be overcome by using Silicon-On-Insulator technology (SOI). This is an emerging technology which is widely being used in microwave devices. A higher performance and lower power consumption microwave devices are fabricated using SOI Technology. High resistivity of SOI makes it suitable for Monolithic Microwave Integrated Circuit (MMIC) applications. This paper reviews the application of SOI technology in detail and their applications in slotted antennas.

Keywords: microstrip antenna, skin effect, SIW, Silicon on Insulator, slotted antenna

A microstrip or patch antenna is a low profile antenna which has numerous advantages over other antennas. It can be easily integrated on a printed circuit board (PCB), light weight, inexpensive etc. The top surface of microstrip antenna is open and hence it can be easily modified according to the designer's application [1]. The unwanted radiations can be reduced by choosing the appropriate substrate and ground plane area. Backward radiations [11] at the bottom of the substrate are highly reduced by the shielding effects of the ground layer. The reduction in the backward radiation is directly proportional to the ratio of patch area to the ground layer area. On need to have the patch area equal to the ground layer area so as to make a smaller product. Because of which there would not be any significant reduction in backward radiation without affecting the gain and directionality of the antenna. Most widely used patch antenna is the rectangular antenna widely used for WLAN systems. Moreover, microstrip patch antennas suffer from discontinuities at the edges due to which they suffer from unwanted radiations at the truncated edges. It is also called as planar antenna as the elements are flat in the patch. However, as applications shift to higher frequencies, microstrip patch antenna designs face several disadvantages such as limited bandwidth, low gain, high reflection losses, dielectric and conductor losses. Modern communications systems are designed to have high bandwidths and data rates. The manipulation of dielectric makes the patch antenna to fit for different applications. Slotted waveguide antennas are used instead to overcome all the limitations faced by patch antennas. Substrate material plays an important role in antenna design, the properties of the antenna highly dependent on the thickness and dielectric constant of the substrate. The substrate in microstrip antenna is primarily required for giving mechanical strength to antenna [20]. Different types of slotted microstrip patch antennas were proposed in order to achieve low VSWR and high bandwidths [20]. A slot waveguide antenna consists of a waveguide, with a hole or slot usually of half wavelength cut out on its walls. When the waveguide is excited with a source

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at a particular frequency, the slot starts radiating electromagnetic waves in similar way to a half wave dipole antenna according to the Babinet's principle. The shape and size of the slot and the input frequency determine the radiation pattern. Array of slots will increase the gain with the reduction in bandwidth [12]. One way to improve the bandwidth is to use slots with geometries that can provide larger bandwidth such as wide rectangular slots or so-called dumbbell slots [13]. The positions of the slots along the length of the waveguide are chosen to be at the standing wave peaks. The last slot should be placed a quarter wavelengths (guided wavelength) away from the waveguide short circuited end to sit on the standing wave peak; this also makes the input impedance seen from the last slot to be infinite. Designer can easily change the polarization of slot antenna by orienting the slot position. By decreasing the distance between the slots, one can easily suppress the side lobes [14]. Many mathematical analysis like Finite Difference Time Domain method (FDTD), Method of Moments (MoM) are carried out on slotted waveguides to analysis scattered and radiated fields. Many optimization methods are proposed in order to achieve the required aperture distribution and reduce the reflection coefficients [16]. Slot antennas are often used at UHF and microwave frequencies instead of conventional antennas or microstrip patch antennas when greater control of the radiation pattern is required. Slot antennas are often found in Radars [2] and standard microwave bench sources used for research purposes. Slot antenna's main advantages are its sizes, design simplicity and its robustness. Due to the absence of reflector, wave guide slots suffer from leaky waves and unwanted radiations. Substrate Integrated Waveguide antenna (SIW)[3, 4] acts as alternative option to slotted hollow waveguide antenna where the substrate is filled between lower and upper metal plates by densely arraying metalized posts or via-holes which connect the upper and lower metal plates of the substrate. The SIW components are light, cheap and easily fabricated due to which one can easily attain compactness. The performance of SIW depends on the dielectric substrate. Moreover, SIW antennas can produce focused beams in one plane and wide beams in another plane [5]. Many researches were carried on SIW microstrip patch antenna crossovers where a circular shaped microstrip patch antenna design based on SIW technology combined with grounded coplanar waveguide structure is chosen. Thus, it would suppress the surface waves, thus obtaining very high isolation from the surroundings, low or negligible coupling, better matching, and wide scan [18]. Even slotted SIW microstrip patch antennas were proposed in order to reduce spurious backward radiations and leaky waves [19].In [21] a textile cavity backed SIW slot antenna for UWB RFID Tags is proposed where it is extremely suitable for on-body deployment and it is designed in such a way that the antenna radiates in the hemisphere when the slot is oriented away from the body and thereby increasing front-to-back ratio. In [22], the proposed antenna replaces rectangular slot by a modified dumbbell-shaped slot which creates a current distribution in the cavity at higher frequency according to the designer's requirement. Modes in the proposed antenna [22] excite the unique slot structure to radiate at resonant frequency resulting in compact, cavity-backed slot antenna. One attractive feature of the proposed antenna is that the frequency ratio (FR) of the resonant frequency can be tuned by simply changing the slot antenna dimension while retaining same cavity dimensions But, generally SIW antennas suffer from leakage and dielectric losses due to the dielectric substrate [6] and indeed decrease radiation resistance.SIW antennas usually exhibit lower cut-off frequencies. The above problems can be overcome by using Silicon-On-Insulator technology (SOI). This is an emerging technology which is widely being used in microwave devices. SOI technology has gained much attention in RF microwave device designs for various wireless applications. It is now recognized to be one of the emerging technology options due to its capability to deliver high throughput while offering ultra large scale integration integration , and providing a lower cost solution [23, 24, 25]. SOI consists of silicon dioxide substrate sandwiched between two silicon wafers which reduce the parasitic capacitance. All the devices are fabricated on the top of the upper silicon wafer [10]. A higher performance and lower power consumption microwave devices are fabricated using SOI technology. High resistivity of SOI makes it suitable for Monolithic Microwave Integrated Circuit (MMIC) applications [7].

SOI PATCH ANTENNA

Slotted antennas are fabricated using the SOI technology to achieve compatibility and high throughput. The rectangular microstrip patch as shown in figure 1 is designed using a standard design procedure given in [9, 10]. For excitation, a microstrip feed line is used at the center, with slots for achieving impedance matching. Using a relative permittivity of 11.7 for Silicon and a substrate thickness of 't' µm, the antenna dimensions are assumed to have a resonant length of 'l' µm and width of 'w' µm (see figure 2). The impedance matching slots are assumed to have a length of's' µm. The microstrip patch with inset feed line of appropriate width, extends up to the outer edge of the silicon.

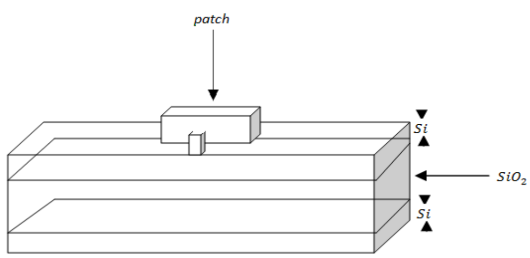

Figure 1: Silicon on Insulator

Moreover, a very thin silicon dioxide substrate is used as it presents low loading to the input signal and hence avoids the excitation of unwanted modes within a relatively large bandwidth. A thin substrate also suppresses surface waves and improves the antenna radiation pattern.

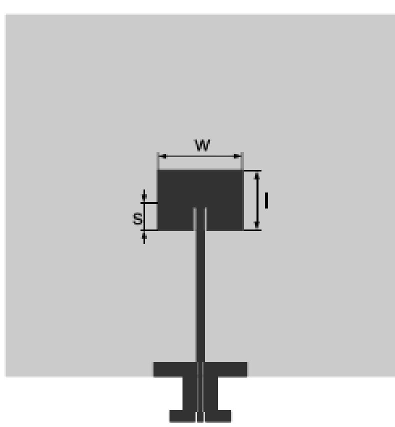

Figure 2: Implementation of Patch antenna using SOI Technology

Choosing the proper thickness of substrate facilitates SOI Patch antenna to work at Terahertz range. SOI patch antenna provides maximum gain of 5dBi and efficiency of 70% with the maximum surface wave loss of 30%. The conventional inset feed microstrip patch antenna face huge surface wave losses, poor gain and very less radiation efficiency at Terahertz frequencies.

SOI SLOT ANTENNAS

SOI substrate as shown in figure 3.in figure 1 consisting of a highly resistive silicon layer, six metals layers, buried oxide layer and finally a passivation layer. SOI device can be used as a cavity resonator similar to a waveguide resonator. Slotted SOI consists of a cavity, slot aperture, and a passivation layer, on top of a silicon substrate. The slot aperture is implemented on the top of the dielectric substrate which consists of series of metallic surfaces (Figure 3). The cavity is formed by the lower lying metal connected to the upper metal through posts. Minimum gap between adjacent posts will reduce the leaky and surface waves. The antenna is fed from the edge of the cavity by an inset microstrip line with appropriate width on the metallic surface. The slot is excited by the inset microstrip line and also by the back cavity. The cavity, besides interacting with the slot, is also excited by the radiated electric field of the microstrip patch. By adjusting the slot length, width and cavity lengths of SOI slotted antennas, one can achieve high gains and efficiencies at Terahertz range. The cavity size, location and size of the slot affect the antenna gain at higher frequencies.

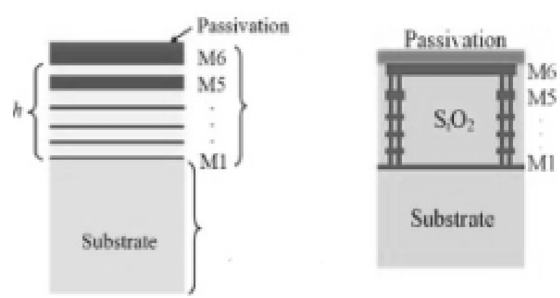

Figure 3: SOI resonant cavity

SOI slotted antennas can also be implemented on chip with cavity backing. Passivation improves the gain of antenna to a great extent. By introducing multiple slots, antenna parameters like gain, directivity, beam width and impedance over a bandwidth can be modified. There is also a restriction on the number of slots to be introduced. The basic operation of SOI slot antenna depends on the change the dimensions of an antenna in order to achieve the center frequency without disturbing the antenna impedance. For a folded slot antenna the resonant condition arises from the coupling effects of the folded slot, which is proportional to the dimensions of the fold and guided wavelength around this length. For the twin slot antenna consisting of driven and parasitic elements, the resonant conditions depend on the dimensions of the slot, also proportional to the guided wavelength. Sometimes, the parasitic elements help in achieving the designer's specifications.

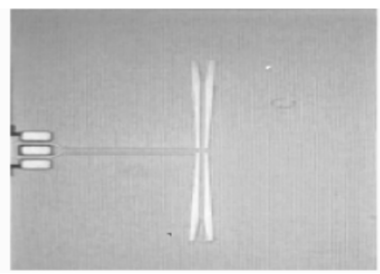

Figure 4: SOI Slotted Antenna

The maximum gain of 5dBi can be achieved for a SOI slot antenna in the Terahertz range. The maximum radiation efficiency of 60% can be achieved in the Terahertz and sub-terahertz ranges.

CONCLUSION

The integration of antennas using SOI technology highly enhances the gain, radiation resistance and efficiencies when compared to that of conventional patch antennas and conventional waveguides which are prone to high leakage losses. The usage of SOI technology further enhances the compactness without affecting the antenna's performance.

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