RECENT DEVELOPMENTS AND APPLICATIONS OF METASURFACES FOR TERAHERTZCOMMUNICATIONS: PROGRESS AND CHALLENGES

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ABSTRACT:

Bandwidth is the ever demanding requirement for high data rate transmission in a communication system. Most of the electromagnetic transmission including mobile, TV, radio, satellite, radio astronomy and radar applications happens in the radio frequency (RF) band. Due to limited spectra or bandwidth in RF range, modern communication requirement pushed technological and research community to utilize the terahertz and sub-terahertz frequency band (30GHz to 10 THz) which is left idle and unusable for microwave radio communication since a long time back, but there are a number of challenges such as absorption due to water vapour, high range of attenuation, increase in dispersion, issues of synchronization and decrement in the received power level at such higher frequencies. This paper reviews the available modern technological developments in the 2D metamaterials, metasurfaces and graphene metasurfaces which have turned the THz frequency band realistic for microwave applications.

Keywords: metamaterials, metasurfaces, graphene, terahertz band, dispersion, attenuation, bandwidth, Spectrum.

I. INTRODUCTION

Most of the communication system we came across in day to day life such as mobile, radio, TV, satellite, Radar, GPS, Wi-Fi etc. are comes under radio frequency or radio wave channel category. In modern days most of the wireless communication system utilizes the bandwidth up to 95GHz. However the optical fiber communication system having wavelength span 1.7µm to 0.8µm operates above 10GHz. From this observation it can be calculated that a huge amount of bandwidth between 'microwave band' and 'optical fiber band' is left idle with no uses. Since this frequency band in very low for photonics community and very high for microwave community that's why it does not got the significant attention from both the communities. Since most of the photons emitted (around 98%) and half of luminance since big bang comes under this frequency band, some of advanced telescopes and satellites from ESA and NASA have been developed so far, and are operational.

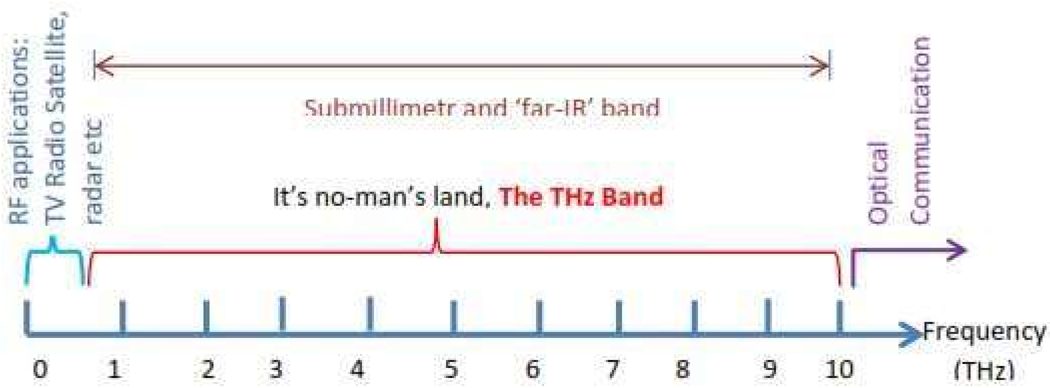

Figure 1: An illustration of frequency bands in different domains of applications

II. PHYSICS OF METAMATERIALS

In the past several years Most of the technological development happened in microwave band, leavingbehind the submillimetre and far-IR bands. With the introduction of modern materialistic techniques and 2D metamaterials, technocrats and researchers are considering to utilize this unused bandwidth. Since the channel capacity is directly proportional to channel bandwidth as $C = B\log_2(1 + SNR)$, more the information can be transmitted with high bandwidth with better encrypting and security.

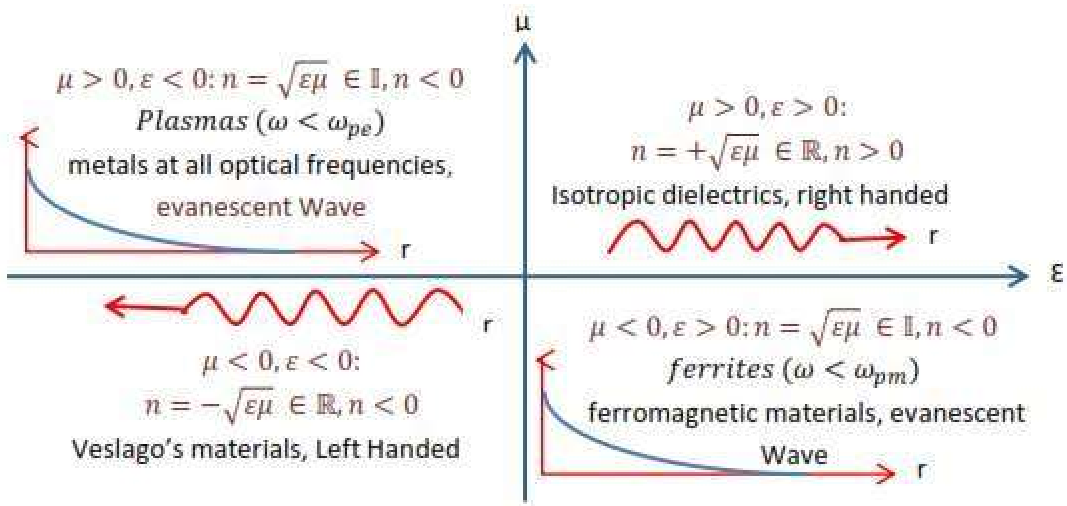

Figure 2: An illustration for the refractive index(n) and permittivity-permiability (Ɛ-μ)diagram

Homogeneous structure can be obtained if the cell size is smaller than the guided wavelength λ_g., and In order to maintain the effective homogeneity the structural cell size should be less than $\lambda_g/4$, the refractive index of materials can be expressed mathematically as $n = \pm\sqrt{\mu_r \varepsilon_r}$ where μ_r and ε_r are relative permeability and permittivity of the materials respectively. Metamaterials are humanly engineered materials with unique properties which are not found in the nature. All the known

materials found in the nature have the positive refractive index but these materials have negative
refractive index posing the specific behaviour for wave optics.

III. THz ANTENNA DESIGN

Antenna design and testing with the frequencies above 95GHz have got increased attention in recentyears, because of advancement in metamaterials technology, new metasurface based 'antennapropagating' achieving a pace in new devolvement which can work even at higher frequencies. Awideband high gain circularly polarized antenna was demonstrated in [10] with 2×2 CP metasurfacesto produce a CP polarization a microstrip line fed antenna was coupled with 4×4 truncated squarepatches. This design produce the result with |S11| <10 dB of 7.88-12 Ghz. The design testing andpropagation was carried out for 50 × 50 × 2.032 mm^3 (~1.60 × 1.60 × 0.065 λ_0 at 9.6 GHz), Figure3(d) illustrate linearly polarised electromagnetic wave propagating along the z-axis is incident on atransmissive quarter-wave plate with an angle of 45^0 with respect to the x-axis, and then it iseffectively converted into a circularly polarised wave. figure 3(c) In this illustration, a stronglyanisotropic metasurface composed of strips of different materials is used to control the emission from a localized source in the near-field and guide the resulting surface waves in desired directions along the surface.[9]

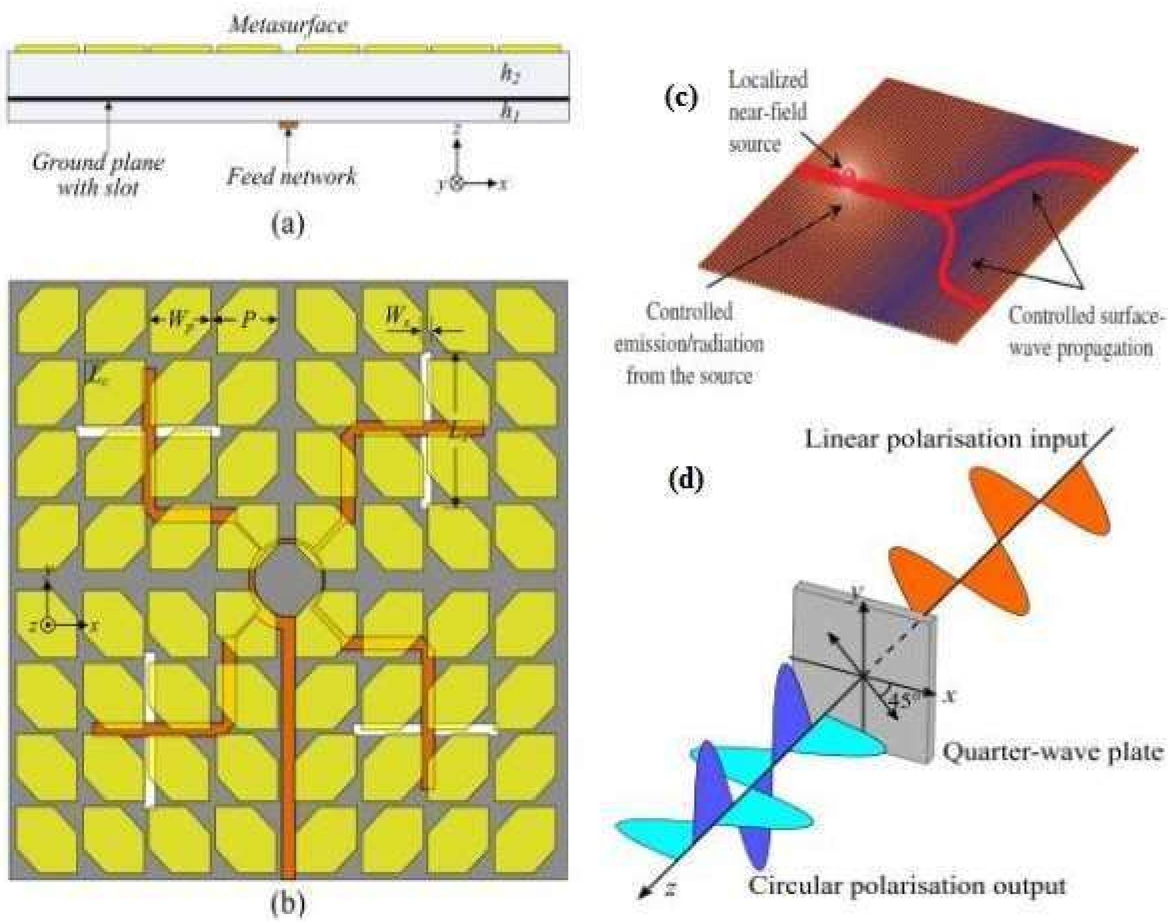

Figure 3: antenna arry for sequentially fed slot coupled metasurface (a) cross sectional view (b) top view of the 2×2 array. The slots are eached on ground plane which is sandwiched between two substrate without air gap (c)an engineered metasurface (d) Quarter-wave plate operation illustration [9, 10]

IV. GRAPHENE METASURFACES

With the relatively advanced properties of new 2D materials grapheme and novel physics such as plasmonics are in the category which comes on both in electronics and photonics domain, due to which modulators & demodulators, plasmonic source and detector and the antenna array that operates in THz band becoming the reality.

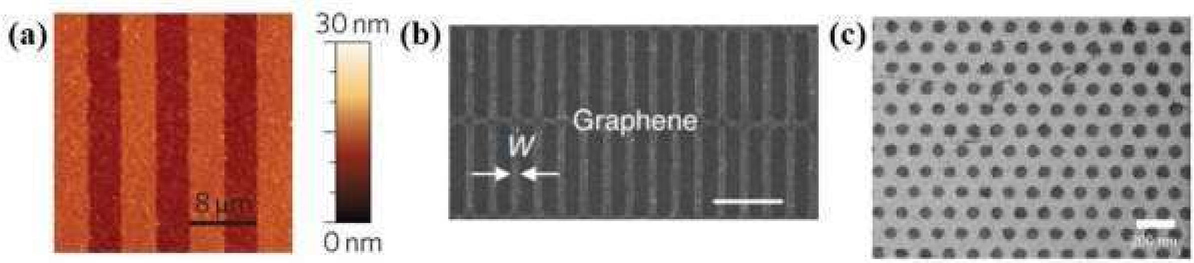

Figure 4: (a) AFM and (b) SEM images of a graphene micro-ribbon array and a nano-ribbon array. (c) SEMimage of graphene nano-disk array. [11,12,13].

Graphene is best suitable plasmonic material having with adjustable plasma frequency, these materials can be formed in different micro/nano ribbon sand disks. [11,12,13] which can be operated at infrared and THz frequencies to achieve tuneable plasmons. Figure 4(a) and 4(b) illustrate the AFM and

Scanning electron microscopy (SEM) for nano and nano ribbon array which represents excitation of plasma resonances in grapheme. Figure 4(c) illustrates the exploration of nano disk array, representingsimultaneous achievement of geometrical and electrical tuning of plasmonic dipoles.

V. CONCLUSION

New technological developments, communication techniques and networking strategies are growing interest of microwave community to design and develop such kind of instrument and device that may operate at THz frequencies. Since the losses at such high frequencies increases exponentially, metatamaterials have played an important role to make it possible. However there are still many challenges such as phase and frequency of Tb/s signals as well as synchronization issues at the receiver end. Newly developed metasurce technologies made possible to design compact size of devices with greater signal strengths supporting wide range of bandwidth.

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