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ANALYSIS OF MULTIPLE INPUT MULTIPLE OUTPUT SYSTEM DESIGNS FOR BASE STATIONS AND 5G WIRELESS NETWORK MOBILE APPS

Introduction. *Because of the fast technological development, cellular connection networks are becoming such type of the network domain that could support several frequency ranges of different cellular generations and it needs to have an optimal antenna design structure to have the most efficient signal receiving. So the multiple input multiple output (MIMO) antennas were chosen as the most appropriate instrument to operate at 5G mobile networks. According to purpose, all 5G cellular connection antenna systems could be relatively divided into two types: base station antenna systems and antennas for mobile apps. In one's turn, dependently from the frequency range, each of defined types include two subgroups, such as: lower than 6 GHz and higher than 6 GHz. 5G base station MIMO antenna systems for the range that is lower than 6 GHz are often integrating to the 4G antenna systems that simplifies its accomplishment and its placing on the cell tower.*

Purpose of the paper *is to discover good decoupling and carrying capacity securing in moderate dimensions of the antenna elements during the antenna designing for the 5G mobile apps. 5G system architecture depends on universal antenna design for the millimeter range tasks solving. One of such tasks is large losses overcome on the way of millimeter wave spreading at the free space that weaken signal power significantly.*

Results *of the research is in definition of the most efficient decoupling and carrying capacity support of the MIMO antenna system. Total dimensions, compact location and optimal work parameters are also reasons for the best MIMO antenna system design definition for its usage for the 5G wireless network mobile applications.*

Conclusion. *The most optimal structure design for MIMO antenna system could be a real step forward at cellular technologies. Using advantages of all previous network generations, the brand new MIMO wireless antenna system has abilities to work with minimal losses and in the most flexible and frequency-optimal way ever. Development also demonstrates influence of the dimensions on the base station block location and universality of its usage complexly with antennas of, practically, any possible design.*

Keywords: *cellular network, base stations, multiple input multiple output, 5G.*

INTRODUCTION

Because of the fast technological development, cellular connection networks are becoming such type of the network sphere that could support several frequency ranges of different cellular generations. The first generation (1G) was intended for the analog voice calls support. Afterwards, the second communication generation (2G) received more new features, such as Short Massage Service (SMS) and digital voice calls. The next step to it was the third generation (3G) that has function of the multimedia services, for example, high-speed Internet, high-quality video services and voice calls. At the fourth generation (4G), high-speed Internet services under the complexed multichannel sphere conditions have been presented.

Nowadays, fifth generation (5G) cellular networks are becoming more and more affordable. 5G could assure much higher carrying capacity, wide connection possibilities, low delay level and high dependability level at the multi-pass environment. For such goals achieving, design technology of antenna systems with several inputs and several outputs (MIMO) became one of the most perspective technologies. MIMO antenna systems are considering as the key technology for the 5G perspective cellular antennas and existing 4G cellular antennas construction for the increasing of the data transfer speed [1–5].

Lately, 2 × 2 MIMO antenna systems are effectively using in the 4G cellular networks. Expected data transfer speed for 5G would be 100 times higher [6], then 4G technology that is the most common technology right now. So, such data transfer speed cannot be achieved by usage of the traditional MIMO 2 × 2 or 4 × 4 antenna systems. To achieve wishful data transfer speed, at least 6–8 antenna elements are needed to be integrated in single 5G mobile application [6]. Today several countries and regions have started future 5G cellular standard definition and testing. World Radio Communication Conference (WRC 2015) at November 2015 has allowed using the C-range (3400-3600 MHz) [7] for the 5G cellular network. China is also started developments of the C-range. European Union and Korea have also chosen 3400-3800 MHz and 3400-3700 MHz respectively for the cellular 5G connection [8], [9]. Table 1 shows generalized frequency spectrums for the 5G connection [10, 11].

Table 1. World 5G spectre of frequencies distribution [10, 11]

Country	< 1 GHz	3 GHz	4 GHz	5 GHz	24-28 GHz	37-42 GHz
United States	600 MHz	3.4-3.6 GHz	-	5.9-7 GHz	27.4-28.4 GHz	37-37.8 GHz
China	-	3.3-3.6 GHz	-	-	24-27 GHz	-
United Kingdom	-	3.4-3.8 GHz	-	-	26, 28 GHz	-
Canada	-	3.4-3.6 GHz	-	5.9-7 GHz	27.4-28.4 GHz	37.6-40 GHz
Australia	-	3.4-3.7 GHz	4.4-5 GHz	-	28 GHz	39 GHz
European Union	700 MHz	3.4-3.8 GHz	-	5.9-6.5 GHz	24-27 GHz	-

PROBLEM STATEMENT

Antenna system design problems for fifth generation cellular networks could be conditionally divided into two basic groups (Fig. 1). The first group is basic cellular network station antenna system development, design and construction. The second one is 5G cellular network system mobile app antennas development, design and construction. In one's part, each of such large groups includes two subgroups of antenna design: antenna structure for frequencies that are lower than 6 GHz (frequently integrating with 4G antenna structures) and antenna structures for millimeter range frequencies (24 GHz and higher). Millimeter range frequencies have fundamentally different structure and construction principles comparing to antennas for ranges that are lower than 6 GHz, so its integration with other generation antennas is practically impossible.

Paper [12] shows fundamental problems of antennas for 5G base station systems. Massive Multiple-Input Multiple-Output (M-MIMO) system, as one of the key technologies could provide some significant improvements from the system carrying capacity point of view. High effectiveness of such technology was theoretically and practically proved. Comparing to ordinary 8-port TDD (Time Division Duplex) antennas that are frequently using at 4G LTE (Long-Term Evolution), M-MIMO technology could increase effectiveness of the spectrum usage from 5 to 15 times and increase energy effectiveness and economy in more than 100 times. Apps at the space and polarization areas could be united with more complex usage of time and frequency areas [13].

High rising of the 5G communication technology has increased demands for base station antennas and also opened modernization possibility at the telecommunication sphere. For companies that are doing researches and development of the base station antennas, 5G technology opens new possibilities to enter the global market and also challenging many technological goals.

Low and high frequency bands are using at 5G wireless systems simultaneously for the most effective spectrum usage. Low frequency band is situated at the range that is lower than 6 GHz and M-MIMO antenna at this band is used for basic carrying capacity ensuring. Available frequencies at this range are including bands 3,3-3,8 GHz and 4,4-5 GHz. High frequency range is

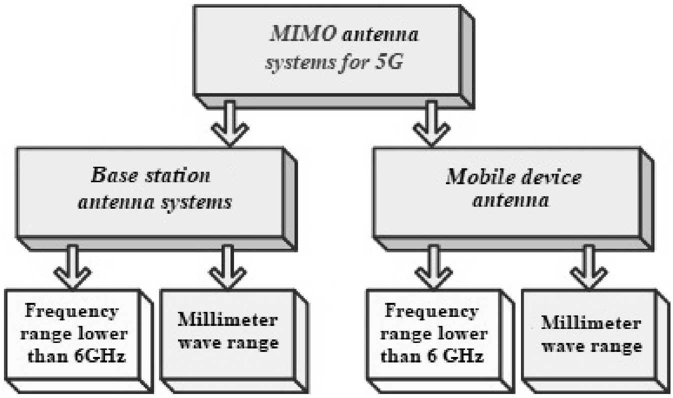

Fig. 1. Multiple-Input Multiple-Output 5G antenna systems conditional classification

situated higher than 6 GHz level. M-MIMO antennas at this range are using for admission points for the indoor coverage and transition network. Many countries have announced following spectrum higher than 6 GHz level for 5G networks recently. This spectrum includes frequency bands 24–29 GHz, 37–40 GHz, 66–76 GHz etc. It is the first case of the millimeter wave technology mass usage at the cellular communication system that, respectively, assists to the millimeter wave antenna technology development.

Developed semiconductor technologies allow developing compact communication systems with high processing productiveness, such as next generation wireless routers and smartphones [14]. As were mentioned before, comparing to the 4G, 5G structure suggests higher channel carrying capacity with smaller delay at the multiway distribution environment. At the 4G networks, four elements of the antenna system is enough for usage [15], but for the 5G network at least eight elements are necessary for the mobile app [16]. Placing of such antenna elements quantity at the smartphone is a quite complex task because radiation structure quantity increasing tends to isolation worsening and to effectiveness level deterioration. Moreover, it adds complexness to the construction itself. For example, antenna system that is represented at [17] has dimensions 60 mm × 15 mm and the neutralization line that acts like outcome structure for two-element MIMO-system. Significantly large space of the outcome structure limits usage of the mentioned antenna for MIMO 5G system. One more distinctive example could be seen at the [18] paper, where two-element symmetrical multibranch monopole with dimensions 80 mm × 65 mm × 0,8 mm for LTE-42 frequency band. Such antenna construction has the outcome level that is higher than 25 dB. However, because each separate element has respectively large size that equals to 15 mm with long microband line, it limits possible usage of such construction for MIMO 5G.

There is infinity of constructive solutions for the MIMO 5G mobile antennas that are eliminating problems that were mentioned higher by different constructive solutions. Some of those constructions would be considered at this paper later.

Purpose of the paper is to discover good decoupling and carrying capacity securing in moderate dimensions of the antenna elements during the antenna designing for the 5G mobile apps. 5G system architecture depends on universal antenna design for the millimeter range tasks solving. One of such tasks is large losses overcome on the way of millimeter wave spreading at the free space that weaken signal power significantly.

DESIGN OF 5G ANTENNA SYSTEMS FOR BASE STATIONS

As were mentioned before, MIMO antenna configuration at 5G basic cellular station antenna systems is very important technology for wireless system carrying capacity improving and for support of large user's amount [13, 19–22].

A brand new working range and large amount of elements in the 5G antenna grade are needed additional space for installation on the base station cell tower. MIMO 5G antenna grates to 6 GHz level could be installed at the radiating aperture of the 2G, 3G and 4G antennas that already exist. There are many developments that are concentrated on the two linear antenna grates integration that are working in the different network generations, for example 2G/3G [23, 24], 2G/3G/4G [25–29] and 4G/5G [30]. An example of the antenna grate realization designed for work at two different ranges: LTE (2500-2690 MHz) and Sub-6 GHz 5 G (3300-3600 MHz) for base stations for frequencies that are lower than 6 GHz shown in the Figure 2 [30] (a — geometry of the suggested antenna element; b — antenna element prototype; c — S-indexes for the lower and upper frequency ranges; d — antenna grate prototype).

Built-in scheme is one of the most popular two-range antenna manufacturing technologies for base stations. This scheme has a simple design and effective decoupling for the high and low ranges. However, it is limited by the linear grate configuration and high and low frequency range correlation must be approximately equal to 2. But for the 5G high range similar built-in systems are so difficult to apply, because at this case antenna grates are planar and frequency correlation between two ranges are equal to 5. A solution for this task, could be, for example three-range double-polarized base station inner antenna for mobile communication system usage [31] that is designed for 2G, 3G, 4G and new 5G applications servicing at the range that is lower than 6 GHz. The design of such antenna consists of two orthogonal dipole antennas for the double polarization ensuring (Fig. 3.) and each dipole consists of three different emitters: elliptic arm dipole, bow-tie-arm dipole and cat-ear arm brackets dipole for different ranges.

By the [32] paper authors a drawback that was marked at the [31] antenna design has been considered. It is radiation pattern instability at the higher frequency ranges (from 3,3 to 3,8 GHz). For this task solving, a frequency-selective surface (FSS) adding into the antenna grate for the two-range low-profile structure with joint aperture [33] was suggested. At the topology, suggested in [32] MIMO 4 × 4 antenna grate of the upper band (UB) is situated under the FSS (Fig. 4). Interband and innerband reciprocate connections between LB and UB antennas are additionally suppressing by the usage of three decoupling methods including rectangular annular resonator, ferrite ring and new baffler structure.

At the previous examples, the MIMO 5G antenna systems for the range that is lower than 6 GHz with the antennas of the other cellular generations integration has been considered. But modern 5G networks are also initiated usage of the range that is higher than 24 GHz for the carrying capacity deficit problem solving [34]. Frequency spectrum transition at the millimeter wave side provides many benefits, such as: shorter wavelengths for the antenna element dimension reduction, channel width extension, spectrum extension possibility [35, 36].

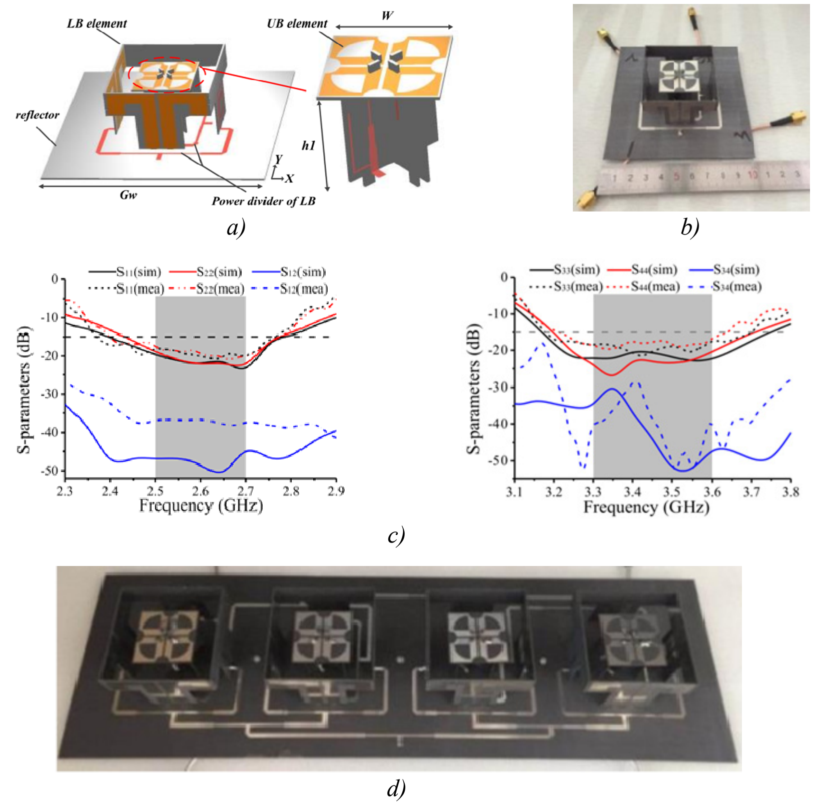

Fig. 2. Compact two-dimensional double polarized antenna with filter structures

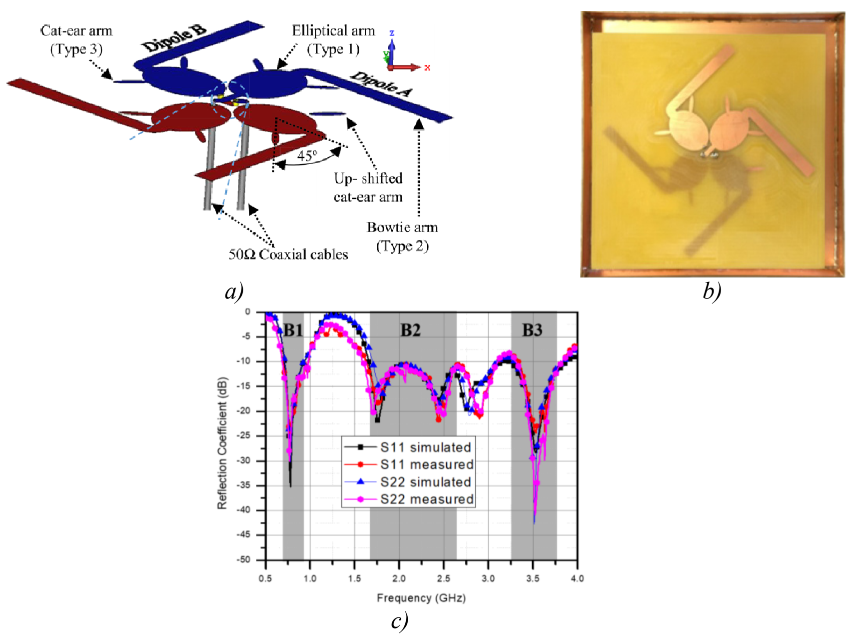

Fig. 3. Geometry of the three-range double polarized base station indoor antenna (a) [31] and suggested antenna prototype (b), graphs of the three-range double polarized base station indoor antenna reflection indexes (c- frequency)

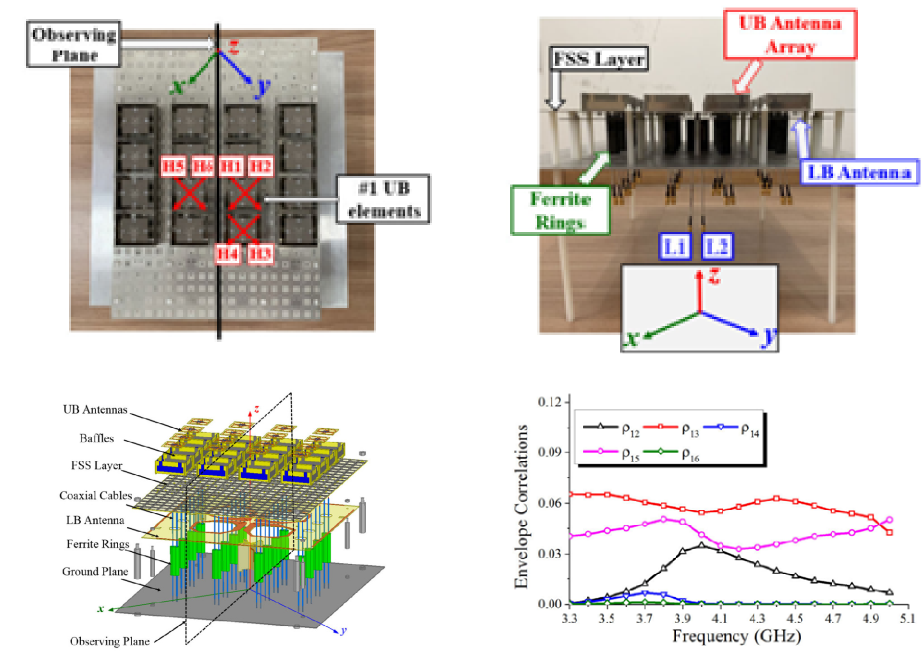

Fig. 4. Three-dimensional image of the two-range antenna grate [32], produced prototype and UB antenna grate correlation index graph

5G system architecture significantly depends on antenna universal structure for millimeter range critical task solving. One of such tasks is huge loss overcoming on the way of millimeter wave spreading at the free space that are weaken significantly the power of signal. To solve this task ultra-dense cellular network zone with the small working radius, where modern inner base stations with highly productive antenna systems are recommended.

MIMO compact antenna grates are giving the wise choice for the demand to high amplification maintaining that is necessary for the loss of millimeter wave on track compensation and for bandwidth expansion for high speed data transfer. Also, usage of broadband antenna elements at MIMO antenna grates is necessary for future cellular networks. It provides higher carrying capacity, possibility to alleviate fading through the multipath propagation, increasing of transfer quality and better network coverage. For example, at [37], MIMO antenna grate with T-shaped patch elements with waveguide feeding (Fig.5). On the back side of the dielectric substrate, two symmetric sets of round gaps as a grounding load are etched. Experimental results are demonstrating wide band of frequencies from 25,1 to 37,5 GHz and also peak amplification value that is equal to 10,6 dBi on 36 GHz.

Though ordinary patch-antenna geometries suggest planar integration and production and installation simplicity, they have limited strengthening and carrying capacity. Carrying capacity can be extended by the structural changes, such as gap, fractal and monopole geometry adding, things that are frequently associated with smaller amplification and effectiveness [38].

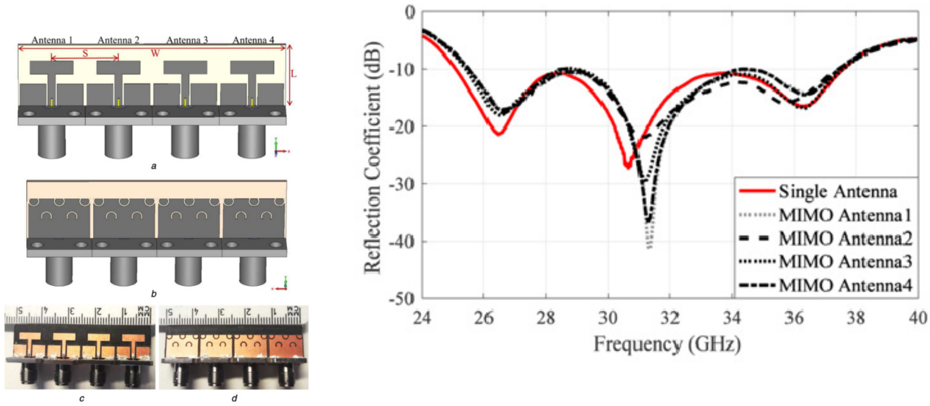

Fig. 5. T-like MIMO-antenna of the millimeter range with defect earth structures for 5G cellular networks [37] and S-parameter graphs

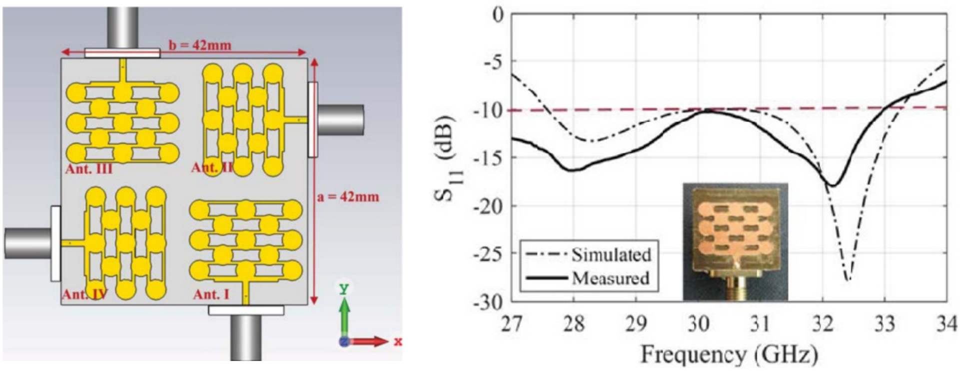

Fig. 6. Compact 4-element MIMO antenna grate [44] and graph of the modelled and measured S_{11} parameter with the produced prototype

On the other side, antenna amplification can be improved by the bigger radiation area, by adding of the parasite sections that, generally, decreasing compactness through the significant size and having limited bandwidth. For example, at the [39] antenna grate elements are distributed one from another for reciprocate connection and side lobe creation avoidance and also, they are made with good coordinated feeding network. It tends to extra construction area extension.

The latest developments at the 5G antenna sphere are solving these tasks. Several linear and two-dimensional antenna grates and 5G applications with high amplification and extended bandwidth that are keeping compactness at the same time [40–43]. For example, at the [44] MIMO antenna grate (Fig. 6) is represented, that have united high amplification advantages, wide bandwidth, high distribution level and compact structure. Flat and compact two-dimensional net of round patch-oscillators is developed as a single antenna for the 5G range on the 28 GHz frequency level and using in MIMO 4-element assemblage. Produced one-element grate antenna measurement results are showing 6 GHz bandwidth at the range from 27 to 33 GHz.

5G ANTENNA DESIGN FOR THE MOBILE APPS

Several MIMO antenna systems for mobile applications were developed at different scientific papers. At first, MIMO antenna systems were developed for WiMAX, WLAN and LTE ranges. For example, the two-element MIMO system of WiMAX apps [45] for 3,6 GHz frequency, LTE antenna [46] for 2,5-2,7 GHz band of frequencies, WLAN antenna [47] for 5 GHz. Also, multi-range MIMO antenna systems were described at the literature. For example, such as: he two-range antenna 2,4/5 GHz for WLAN [48], 2,1/2,4 GHz for UMTS and WLAN [49], 2,1/2,6 GHz for UMTS and LTE applications [50]. The [51] paper describes three-range MIMO antenna system for WLAN and WiMAX apps that can work at the frequency ranges from 2,07 to 2,52 GHz, from 4,28 to 4,50 GHz and from 5,67 to 7,27 GHz.

Also, many MIMO antenna system structure descriptions for the 5G apps of the [52–63] mobile terminals could be found at the literature sources [52–63]. Such systems have shown their advantages from the decoupling and channel carrying capacity point of view. Different methods for decoupling quality increasing between antenna elements were used. For example, such ordinary methods as spatial diversity [52] (structure of the suggested antenna is shown in Fig. 7) that could be used also at the notebooks or Wi-Fi blocks and polarization diversity [53, 54] (Fig. 8).

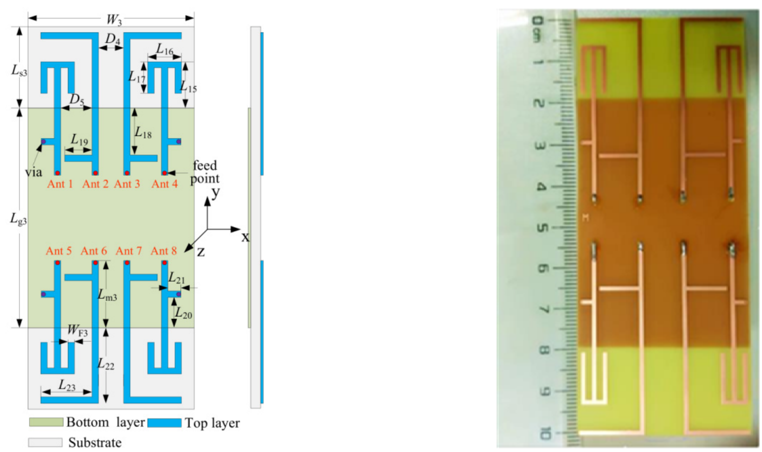

Fig. 7. Geometry and photography of the compact MIMO 8-element antenna [52]

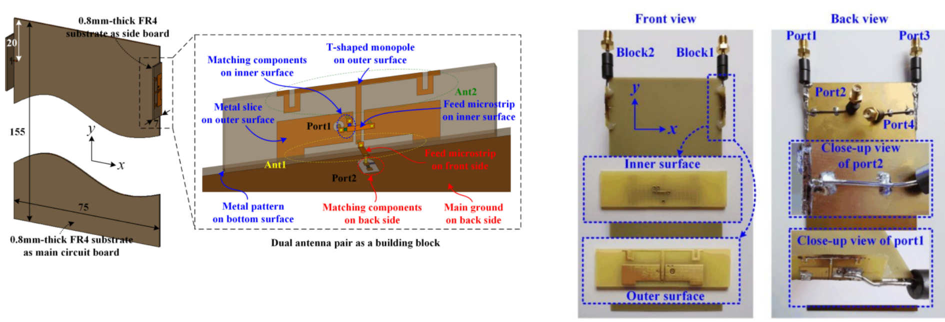

Fig. 8. Geometry and prototype of the four-element MIMO antenna grate MIMO [53]

Also, for the decoupling increasing, the inverted ground I-slots with neutralization line structure between antenna elements [55] (Fig. 9) were suggested to use. One more option to be the problem solving it is usage of the grate grounding plane for signal distribution protection from one port to another [56, 57] (Fig. 10). On the Fig. 11 ECC (envelope correlation coefficients) from frequency dependence for considered antenna examples are shown.

There are two different approaches at the MIMO antenna systems from the high channel carrying capacity receiving point of view. The first approach is based on the bandwidth improvement for the work on several frequency spectrums [58–60]. Antenna design suggested at works [58] and [59], and also dependencies of their S-parameters are represented in Figure 12 and Figure 13. In the second approach MIMO system order increases in the way of element quantity increasing at the antenna grate [61–63]. Antenna design proposed at works [61] and [62], so as dependencies of their S-parameters are represented in Figure 14 and Figure 15.

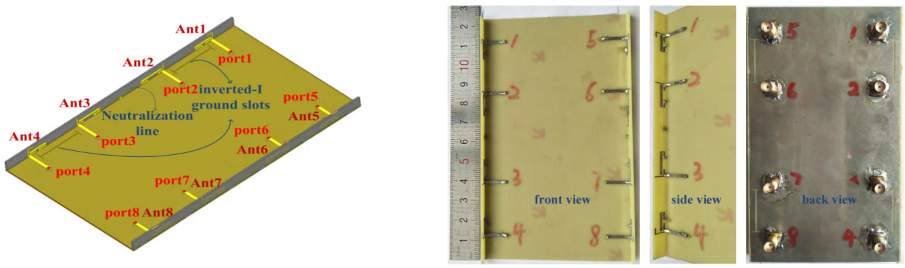

Fig. 9. Eight-element MIMO grate configuration and a photo of the produced grate [55]

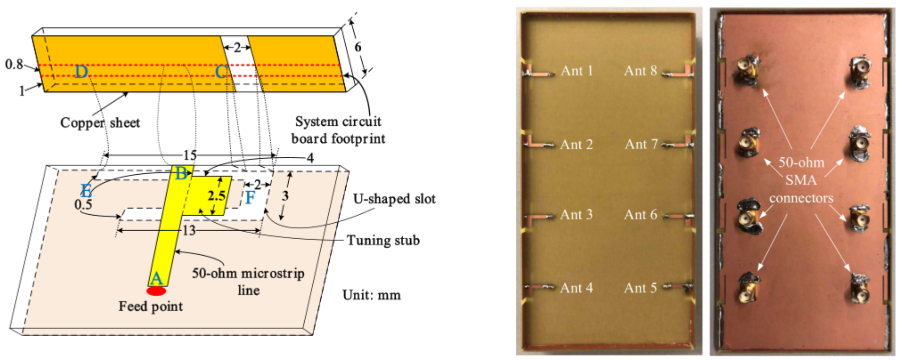

Fig. 10. Antenna element detailed structure and photos of the eight-element antenna grate [56]

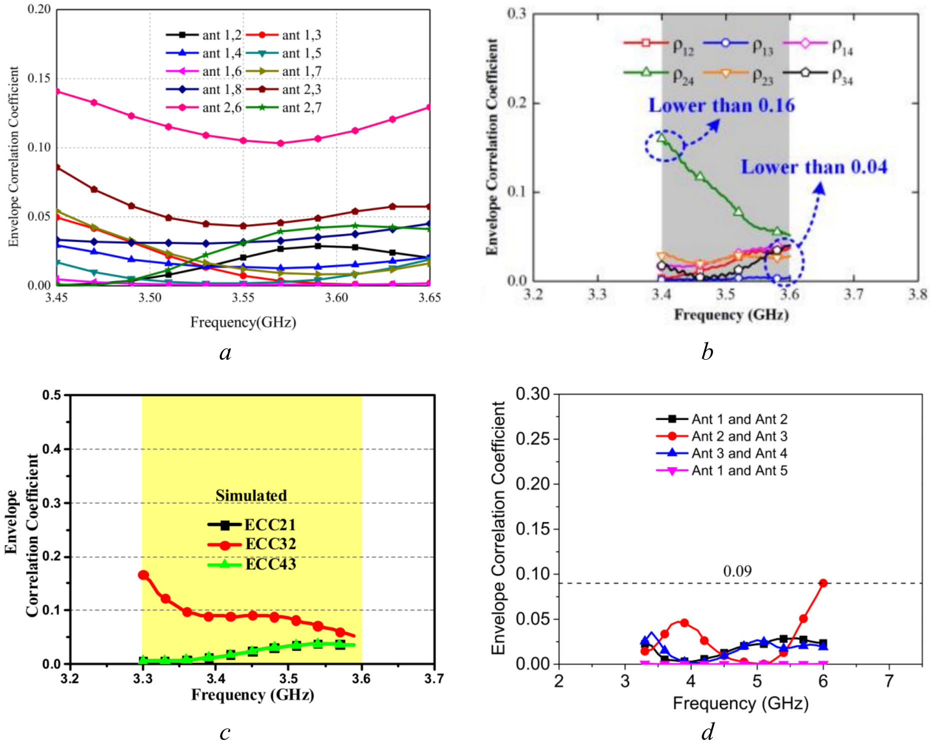

Fig. 11. Dependency of the correlation factor from frequency: *a* – for the antenna with [52]; *b* — [53]; *c* — [55]; *d* — [56]

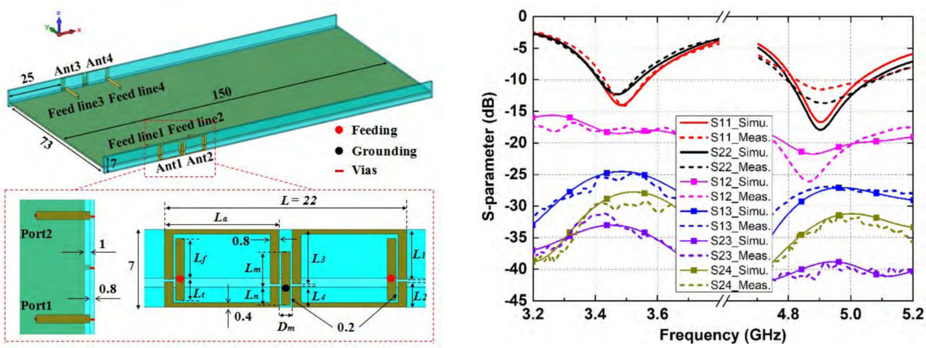

Fig. 12. Geometry of the two-range four-element MIMO antenna system that consists of two compact antenna pairs [58] and measured S-parameters

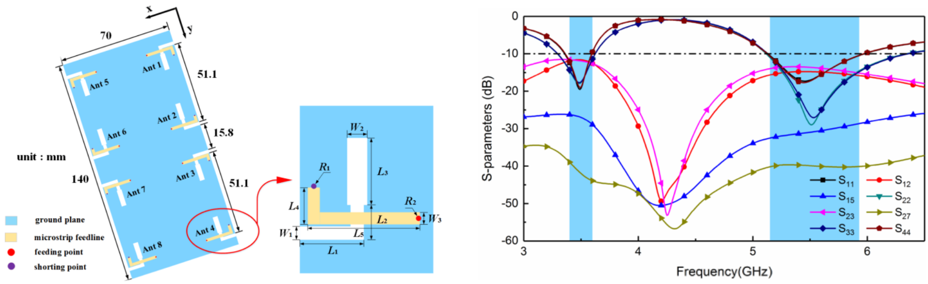

Fig. 13. MIMO 8-port two-range antenna grate geometry [59] and modelled S-parameters

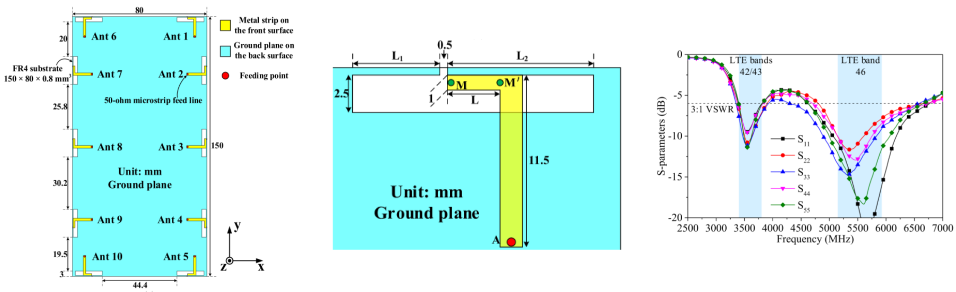

Fig. 14. Geometry and dimensions of the MIMO antenna grate [61] and measured S-parameters

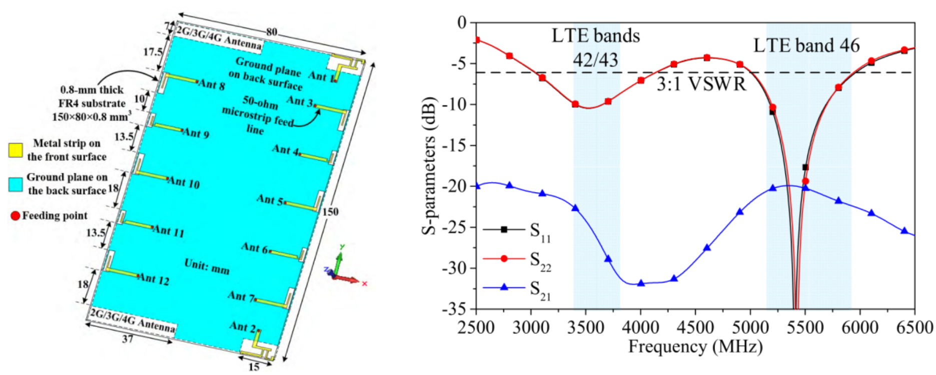

Fig. 15. Geometry and detailed dimensions of the suggested 12-element grate [62] and modelled S-parameters

One more task could be cancelled during the cellular network terminal creation. It is needed for frequent 5G support at the mm-range additionally to the existing 4G at the range that is lower than 3 GHz. However, it is well-known that mobile terminals have limited space, so big antenna amount adding is not advisable. So, the solving is in the way of the MIMO antenna system developing with antenna elements that are seizing different 5G and 4G ranges, using only one structure, but not two. So, need of multi-range antenna elements at the MIMO system usage that is a key factor for the antenna dimension reduction inside the mobile terminal [64], [65]. But, at the same time, 5G and 4G antenna integration at the same structure creates problems on the side of antenna dimensions, isolation between the antennas at different frequency ranges and antenna amplification factor.

There were designed many structures to satisfy 4G and 5G antenna demands for MIMO usage at the range that is lower than 6 GHz. For example, to realize 10 × 10 MIMO apps at the three LTE ranges, 10 T-like antenna elements with connected source gaps were used [66]. A simple MIMO antenna for work with LTE/WWAN for notebooks that consists of two open gap elements is represented at [67]. T-like gap is set into the display grounding plane and connected to the hinge groove. At the time of unification these two elements are behaving as radiator and T-like gap functions as isolator. 5G and 4G antenna models for the LTE 42/43 and LTE 46 ranges were suggested with radiating elements in the form of bended belt at [6] or turned over L-like antenna with an open gap [62].

There are some perspective MIMO 5G perspective systems (higher than 6 GHz) and MIMO 4G (lower than 3 GHz) that are using separate antenna structures for 5G and 4G. At [68] integrated design that consists of MIMO antenna system for 4G system (on the basis of 4-element turned over F-antenna) and planar connected antenna grate (on the basis of gap elements) for 5G apps are represented [68]. One more integrated antenna solution for wireless compact gadgets for 4G and 5G standards is shown at [69]. Such solution consists of combination of MIMO antenna system for microwave range (from 1870 to 2530 MHz for 4G) and antenna grate for millimeter range (from 1870 to 2530 MHz for 4G) and antenna grate for millimeter grate (28 GHz for 5G). MIMO antenna system consists of two monopoles with reactive loading and antenna grate for 5G consists of 2 × 4 gap elements.

There are scientific developments that are giving united antenna structure for 4G and 5G applications. For example, at [65] integrated MIMO antenna structure that includes two-element 4G gap antenna system and two-element system on the basis of connected antenna grate for the 5G range is represented (Fig. 16). Two rectangular loops engraved on the periphery of the grounded plane. Upper and lower parts of thin loops are acting like two 4G MIMO antennas and parts of their sides are acting like 5G arrays.

At [70] integrated 4-element 5G/4G MIMO antenna system that uses one antenna united structure is represented (Fig.17). It works at three ranges (28, 37 and 39 GHz) for 5G and at the wide range (from 1,8 to 2,6 GHz) for 4G. Each MIMO element consists of the gap at the grounding plane and two micro strip source ports at the upper lining layer. Low frequency filter for the isolation improvement is also integrated in the structure. Respectively linking one of two ports, antenna could work at two different work modes. One of source ports responds to the conical slotted antenna with an end radiation for 5G, when at the same time another port responds to the slotted antenna with omnidirectional radiation for 4G.

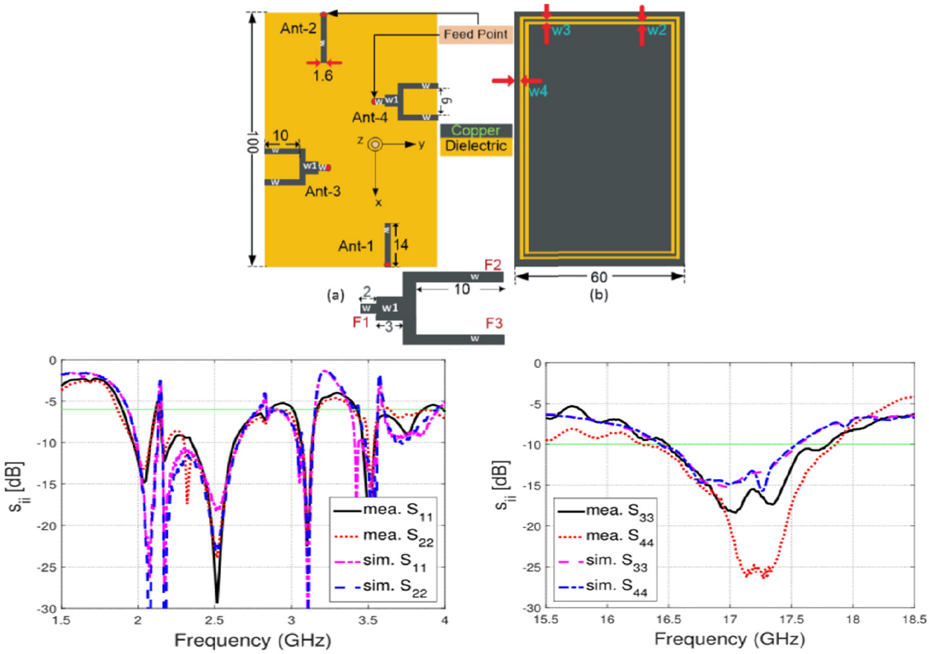

Fig. 16. Geometry of the MIMO antenna system for 4G/5G terminals and S-parameters [65]

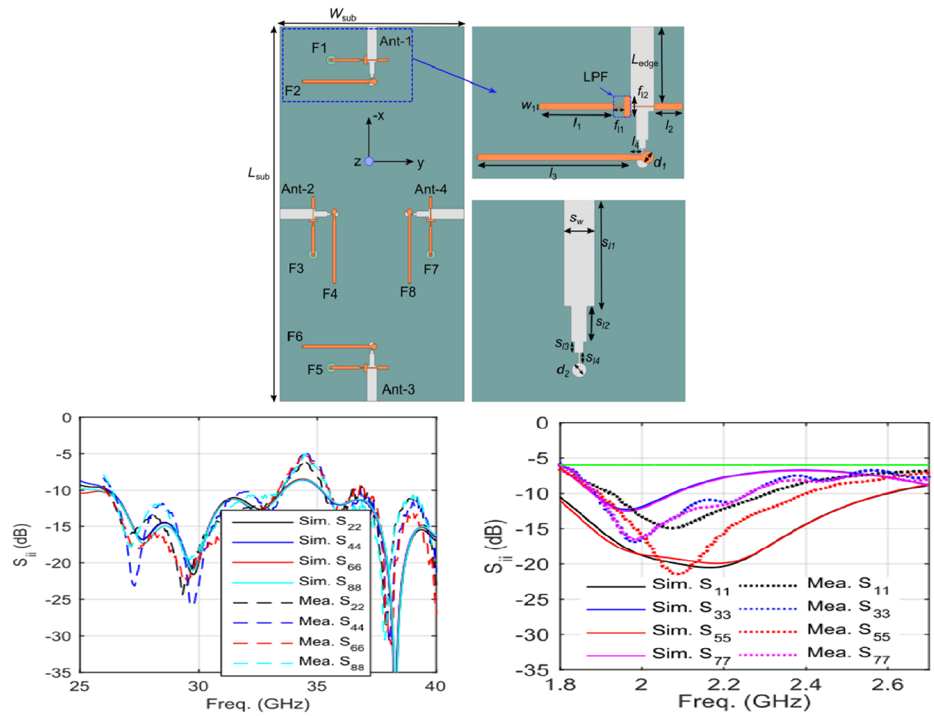

Fig. 17. Geometry of the four-element MIMO antenna system for multirange mobile connection of the 5G millimeter and 4G broadband ranges [70] and S-parameter graphs

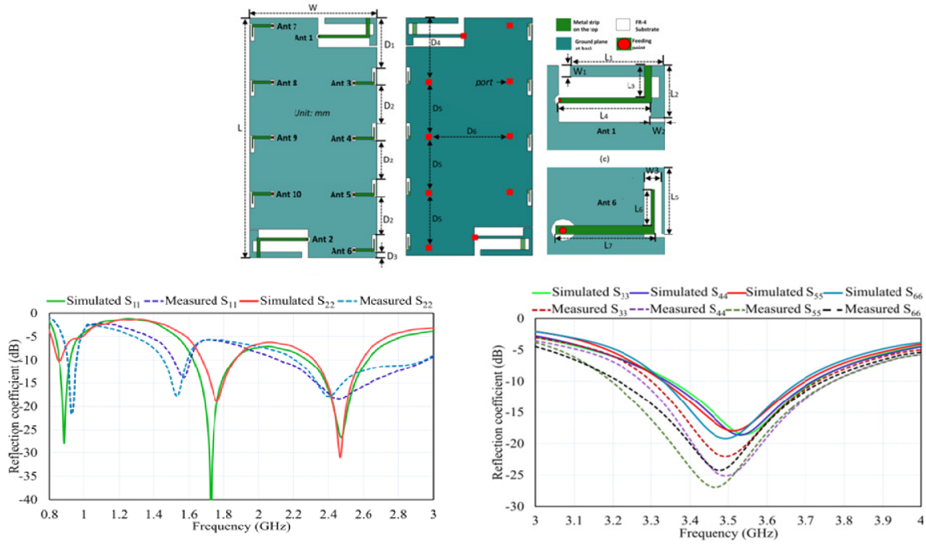

Fig. 18. Geometry and detailed physical dimensions of 10-port MIMO antenna system [11] and S-parameters graphs

At the previously considered works, large quantity of the MIMO antenna systems for 5G mobile apps that are showing good results at the defined frequency ranges. However, they have not considered such MIMO system that could cover all generation frequency bands including 2G, 3G, 4G and 5G. The scientific paper [11] presents 10-port MIMO hybrid antenna for 5G smartphone applications (Fig. 18).

Suggested antenna system consists of two antenna module types: the 1-st is a multi-range module consists of two identical multi-range antenna elements, each antenna element at this module covers 2G ranges (GSM 850/900/1800/1900 MHz), 3G range (UMTS 2100 MHz) and 4G range (LTE 2300/2500); the 2nd is a one-range module that consists of eight identical L-form elements, each antenna element at this module covers C-range (from 3400 to 3600 MHz) for 5G. Dimension measurements of the suggested antenna system are 150 × 80 mm^2. Experimental results are shown that reflection coefficients are exceeding -6 dB and -10 dB and ECC is significantly lower then 0,3 and 0,1 for suggested multiband and single band modules respectively. Separated antenna elements at both modules are demonstrating good radiation characteristics with maximal peak amplification value from 2 dBi to 4 dBi. Channel carrying capacity reaches 43 bit/s/Hz at the single band module. Suggested antenna system could be a quiet good candidate to the brand new modern mobile system with such characteristics.

CONCLUSION

Relatively free to use millimeter wave spectrum suggests different abilities for mobile network carrying capacity increasing because of big amount of available unprocessed bandwidth. Basic 5G antenna differences from adjacent 4G antennas are not only dimension measurements that are corresponding to shorter wavelengths but also narrow ray formation at the directional diagram on the mobile device, as well as at base stations.

The most typical modern developments at sphere of MIMO antenna systems for 5G mobile network system base stations and mobile applications have been considered at this paper. According to purpose all antenna systems for 5G mobile networks by the design specifics could be relatively divided into two types, such as base station antenna systems and antennas for mobile apps. Depending on frequency range each of the divided types includes two other subgroups: higher than 6 GHz and lower than 6 GHz. 5G base station MIMO antenna systems for the range that is lower than 6 GHz is frequently integrates to the 4G antenna systems that simplifies their realization and their placing on the cell towers. Good decoupling securing and carrying capacity in moderate dimensions of the antenna elements are being principal directions during the antenna designing for the 5G mobile apps. 5G system architecture depends on universal antenna design for the millimeter range tasks solving. One of such tasks is large losses overcome on the way of millimeter wave spreading at the free space that weaken signal power significantly.

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АНАЛІЗ КОНСТРУКЦІЙ АНТЕННИХ СИСТЕМ МНОЖИННОГО ВХОДУ
І МНОЖИННОГО ВИХОДУ ДЛЯ БАЗОВИХ СТАНЦІЙ
ТА МОБІЛЬНИХ ЗАСТОСУНКІВ БЕЗДРОТОВОГО ЗВ'ЯЗКУ 5G

Вступ. *Швидкий технологічний розвиток мереж стільникового зв'язку уможливив роботу систем зв'язку одразу в кількох стільникових частотних діапазонах різного покоління, що суттєво покращило ефективність прийому сигналів. У такому випадку, найбільш оптимальним типом антени, що підходить для роботи в стільникових мережах покоління 5G, було вибрано системи зв'язку з рознесеними передавальними і приймальними антенами.*

Особливу увагу можна приділити тому факту, що залежно від призначення всі антенні системи для мобільного зв'язку 5G за специфікою конструювання умовно можна поділити на два типи: антенні системи базових станцій та антени для мобільних застосунків. У свою чергу, залежно від частотного діапазону кожен з визначених типів має дві підгрупи — нижче 6 ГГц або вище 6 ГГц. Антенні системи MIMO (multiple input multiple output — множинний вхід і множинний вихід) базових станцій 5G для діапазону нижче 6 ГГц часто інтегруються з антенними системами 4G, що спрощує їхню реалізацію та розміщення на вишках зв'язку.

Мета. *Виявити під час проектування антени для мобільних застосунків 5G найбільш оптимальне розгалуження та надійне забезпечення пропускної здатності в помірних розмірах елементів антени. Одним з таких завдань є подолання великих втрат на шляху поширення міліметрової хвилі у вільному просторі, що значно послаблює потужність сигналу.*

Результати. *Визначено найбільш ефективне забезпечення конструкцію розгалуження та пропускної здатності антенної системи MIMO. Загальні розміри, компактне розташування та оптимальні робочі параметри також визначають найкращу конструкцію серед наявних антенних систем MIMO задля її використання для мобільних застосунків бездротової мережі 5G.*

Висновок. *Найоптимальніший дизайн структури антенної системи MIMO може стати справжнім кроком вперед у галузі стільникових технологій. Використовуючи переваги мереж усіх попередніх поколінь, нова бездротова антенна система MIMO має здатність працювати з мінімальними втратами та найбільш гнучким і оптимально-частотним способом. Розробка також демонструє вплив габаритів на розташування блоку базової станції та універсальність його використання в комплексі з антенами практично будь-якої конструкції.*

Ключові слова: *стільникова мережа, базові станції, множинний вхід і множинний вихід, 5G.*