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High technology in wireless communication

New generation microwave solutions

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1 Abstract

One of the main bases of the modern society is the need for fast flow of information. To ensure this, the countries need a reliable communication network. As the amount of information increases and needs to travel faster, the network must grow and develop as well. The telecommunications technology has a quite short history, but it is full with innovations, and creative solutions.

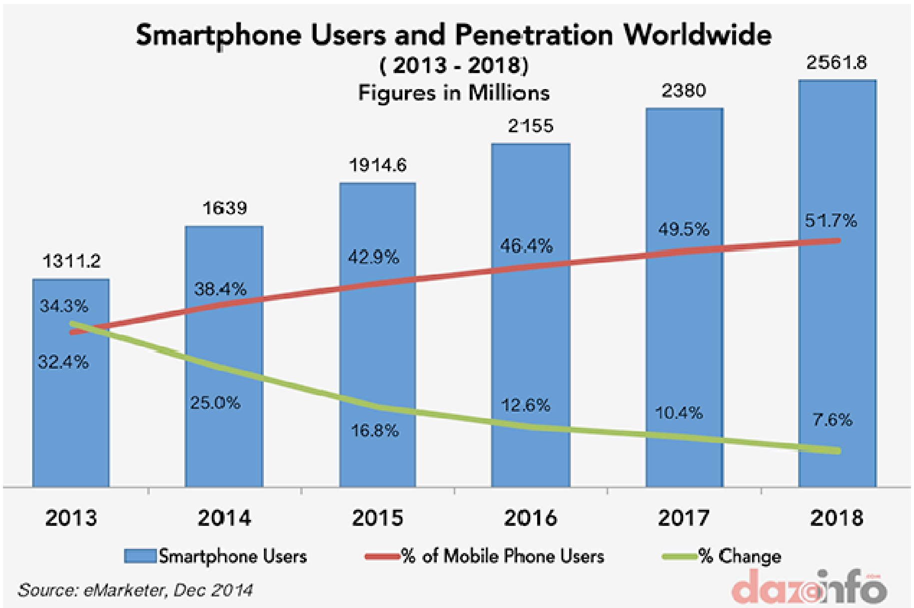
In this short summary I will write about past and present of the microwave communication. I will make a comparison between optical and wireless microwave communication, to see why it is so important to develop wireless systems. I want to introduce the HEMT, and how it is affecting the development of the state of the art microwave communication. In addition I want to summarize some technical properties of the HEMT manufacturing.

2 Contents

3 The short history of microwave communication

Communication always took an important part in people life, but it started to grow drastically only about 150-200 years ago. In the way to the present technology the first step were maybe the Morse coding followed by the invention of the telephone. As the number of connections grew the network were able to provide hundreds of telephone lines and television programs by using coaxial cable. At this time the engineers were faced the problem first, that many areas are difficult to reach with cable network, so they thought that the solution is the wireless communication. In 1930’s began the first tests with microwave communications chains. The experts saw the opportunity, in microwave data transmission, because of the centimeter range in wavelength. This enables to build very high directionality antennas to bridge great distances. The first microwave network was kind of experimental to recognize the modulation techniques and the microwave attributes. In the second world war the radar technology caused a huge improvement in microwave technology, so shortly after the world war, the developers were able to deploy the first public microwave communications chain.

The next big step in the progression of the microwave communication were the space programs. The satellites around the Earth could provide communication between continents. The new solutions created new problems like, great distance between satellites and the receivers, small electrical performance, and the need for a high durability. Nowadays the satellites must provide even GPS information for many devices.

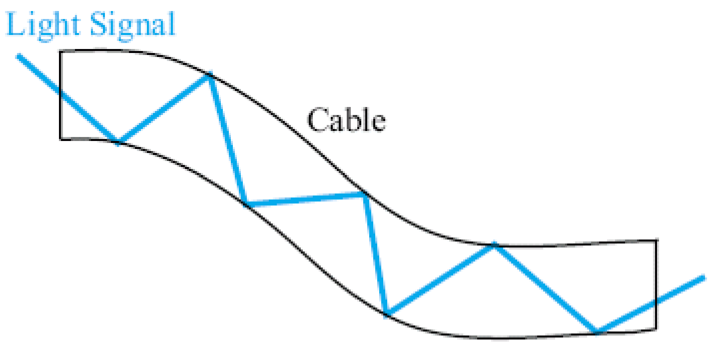


1. figure Number of smartphone users forecast

Nowadays the tendency shows growing in mobile communication. The telecommunication companies have to provide much more now, than a simple telephone line. The subscriptions includes mobile internet, telephone line, SMS, and MMS sending. On the 1. figure can be seen, that the number of smartphone users is still growing. Because of this growth, the wireless networks must develop as fast as possible, so there is a big need for the microwave innovations. One of these new technologies is the usage of the GaN HEMT.

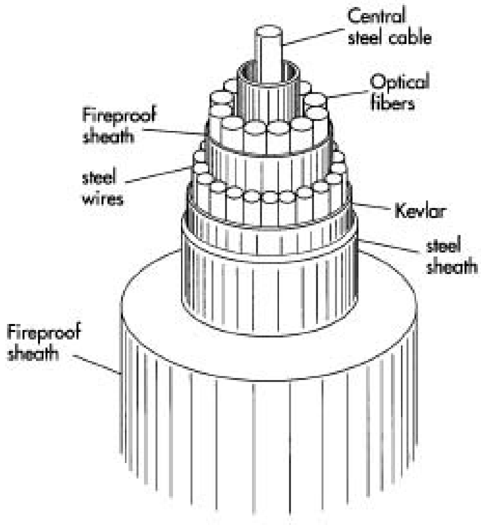
4 Optical cable and microwave communication

The optical fiber is a cylindrical, insulated, easy to bend thread. The theory behind the optical fiber is that it transfers light abusing the reflexion on the cable's edge, that can be seen on the 2. figure.



2. figure Light through the optical cable

The typical structure of the optical cable can be seen on the 3. figure.



3. figure Typical structure of the optical cable

The optical cable have many applications, such as telecommunication, or computer networks, because of its flexible usage, and it can provide wider bandwidth than the copper wires.

The main problem with the optical cable is not the attenuation, but the dispersion. This parameter defines the highest distance that can be bridged through the cable. At multimode dispersion the light travels ways with different lengths this defines the performance of the multimode cable. At great distances this effect causes shifts in the bits of the binary code that is transmitted. The maximal bandwidth of the transmission can be calculated from the dispersion, and from the distance.

4.1 Advantages and disadvantages of the optical fiber and the microwave communication

The optical fibers have a large capacity, it could transmit over two million simultaneous telephone conversation. An optical cable contains up to 200 optical fibers. This way the capacity can be increased by hundred times. Comparing to the microwave communication fiber optics having an advantage over microwave communication in capacity.

The optical cable is not sensitive to any electrical interferences, and it doesn't produces any electrical noise. In addition, there are no cross communication between two fibers. The optical fibers doesn't need any insulation.

The data loss rate is very low, and this loss is easy to track by monitoring the power of the received ray.

The optical cables have a high lifetime, up to 25-30 years. It doesn't need any maintenance, and it is useable

With these many advantages comes many disadvantages as well. Firstly the price of the optical cable is quite high. In many situation is a serious question, that this high-tech solution is even needed.

Despite the optical cable doesn't need any maintenance, it is quite fragile, and the glass can be affected by chemicals, such as hydrogen gas. If the optical cable is exposed to radiation it can become opaque. This effect occurs mainly in military usage.

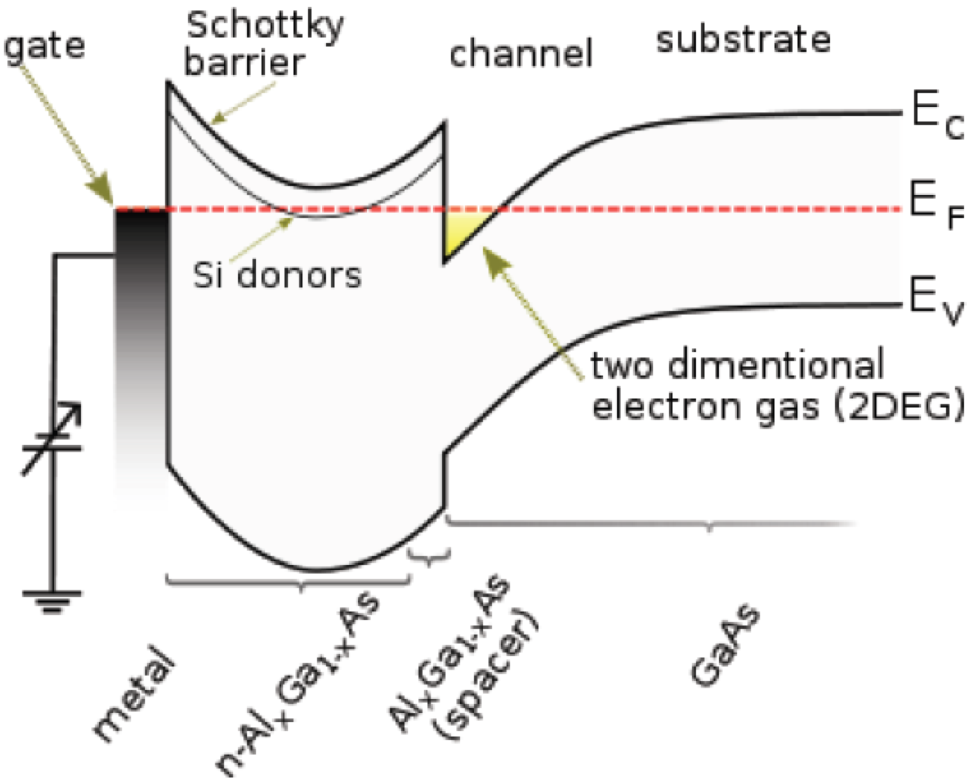
There is no direct compatibility between copper wired systems and optical cable, so to bridge this incompatibility it needs special solutions.

The newest innovations in microwave communication are about to increase the bandwidth of the transmission. Thanks to these new technologies the transmission rate of the microwave communication is catching up to the optical cable. Because of the wireless communication the microwaves don't have to rely on physical medium such as cables. This makes the microwave technology much cheaper than the optical cables. The microwave transmission towers are placed on rooftops, or on mountains, which is an inexpensive solution.

There are two main problems with the microwave communication: the solid objects, and the electromagnetic interference. The microwaves don't pass through solid objects. This can be a very serious problem at certain terrains. But the other side of this effect is, that the microwaves can bounce off the solid objects even the moon. This bounce off can be utilized to create connection between antennas. The electromagnetic interference can degrade or obstruct the performance of the signals. All electronic devices produces EMI, that can disturb the microwave communication. The microwave communication can be degraded also by heavy moisture in the atmosphere, so the factors must be kept in mind while designing a bit microwave communication system.

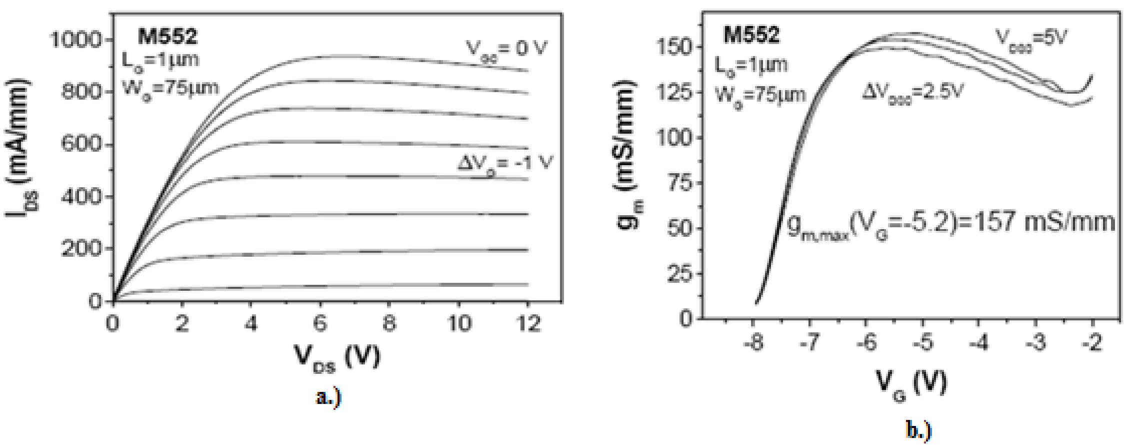
5 High-electron mobility transistor

The transistors are very versatile element of the electrical devices. Transistors are used example in switches, oscillators, and amplifiers. In microwave communication it is necessary, that the transistor switches fast, and has a low consumption. This is why the high-electron-mobility transistors are good for microwave technologies. The HEMT is also known as modulation-doped FET. The channel in these transistors are a junction between two material with different band gaps. The most common materials in the HEMTs are GaAs and AlGaAs, and this combination has also a decent high-frequency performance, but recent experiments shows that the GaN HEMTs is the way to improve microwave communication systems. On the 4. figure a band diagram can be seen of a HEMT.



4. figure Band diagram of GaAs and AlGaAs HEMT

The big advantage of the HEMTs over regular FETs is that the moving electrons aren't slowed by the impurities of the doped layers. In the HEMT the electrons move through a non-doped channel layer. On the 5. figure can be seen the characteristics of a HEMT.



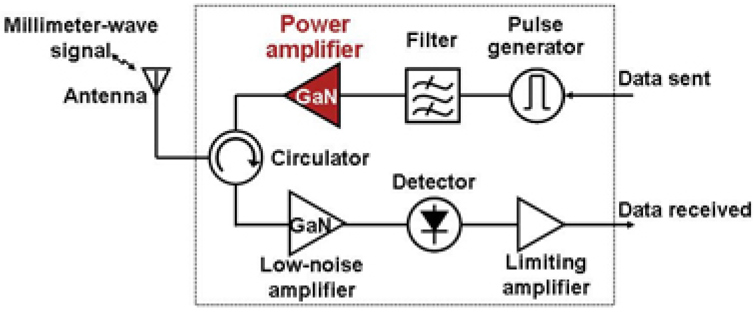
5. figure HEMT characteristics

On the 5/a figure can be seen the drain-source current depending on drain source tension. On the 5/b figure can be seen the transconductance depending on gate tension.

HEMT transistors applications are mainly in the microwave and millimeter wave communications, radars, astronomy, etc. These applications require high gain and low noise parameters in high frequencies.

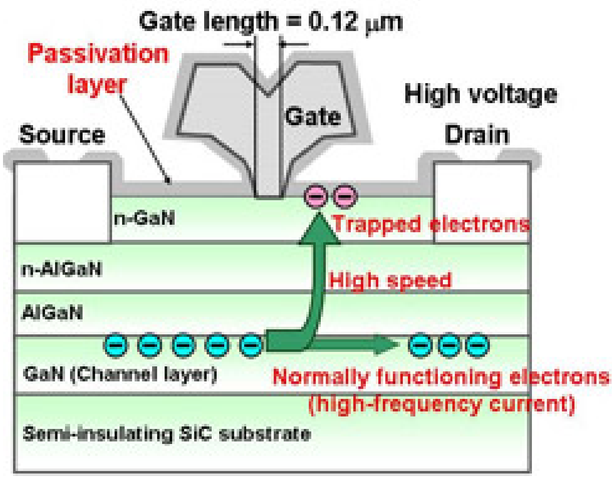
5.1 Gallium nitride HEMT

In order to produce microwaves that can reach the target antenna, the signal must be heavily amplified to be able to cross great distances. In this amplification take part the high-electron mobility transistors. On the 6. figure can be seen a microwave transceiver and the GaN HEMT amplifier.



6. figure Microwave transceiver

The gallium nitride HEMT was already in use for several application, but Fujitsu managed to improve its output performance. Gallium nitride has a wide band-gap, and it has stable breakdown voltage at high temperature, which makes it a more viable choice for high frequency application than the gallium arsenide and silicium arsenide transistors. The experts discovered that electrons pile up in the SiN passivation layer, which can be seen on the 7. figure. They explained this phenomena with the inadequate crystallization of the silicium nitride. Through experiments the experts managed to improve the passivation layer by modifying the composition of the SiN and its crystal structure. As result the improved transistor could amplify twice as much output performance than before.



7. figure The schematic figure of the GaN HEMT

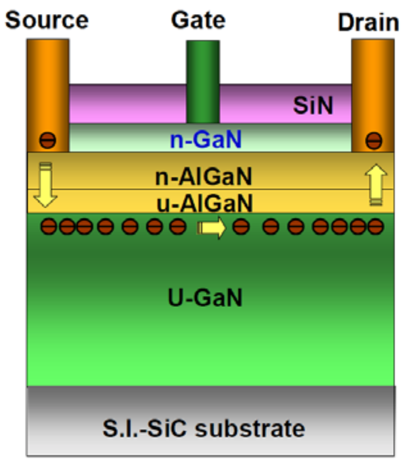
As on the 6. figure can be seen, the signal goes through the power amplifier, in order to be able cross great distances. To get the needed amplification there is a distribution circuit, which leads to parallel transistors. These transistors do the amplification, so a combining circuit can combines the signal, which is already able to cross great distances at this state. The engineers of Fujitsu as the second step of the development took a closer look in this process. They observed the electromagnetic behaviors of these distribution and combining circuit and successfully designed a circuit, which has minimal amplification loss at the distribution and combining circuits. With this solution the accuracy of the amplifying circuit increased by 15%.

This developments in GaN HEMT and the whole amplification circuit made a huge improvement in wireless technology. The W-band is radio range between 75 and 110 GHz. This is the range of the fast wireless communication, and car radars. These new devices achieved 1.3 W output performance in the W-band of millimeter range, which means new world record. Previously the highest available performance with GaN HEMT was 350 mW, so it can be clearly seen the improvement in the technology. This innovation allows the microwaves to cross six times greater distances in the W-band. In addition the communication provided by these new GaN HEMT solution is less sensitive to weather condition, and interferences.

5.2 Reliability and manufacturing of GaN HEMT

As the wireless networks are growing it is not enough to find solutions that can handle the increased bandwidth and the need for greater distances. It is important to assure, that the innovation is viable, reliable, and is compatible for mass production. Fujitsu laboratories made a study about the reliability of the GaN HEMT. In the "Recent Progress of High Reliable GaN-HEMT for Mass Production" study the experts examine the GaN HEMT, and its possible problem, and furthermore they suggest manufacturing method for cheap and reliable mass production. The following part of my report will summarize the main parts and results of the mentioned study.

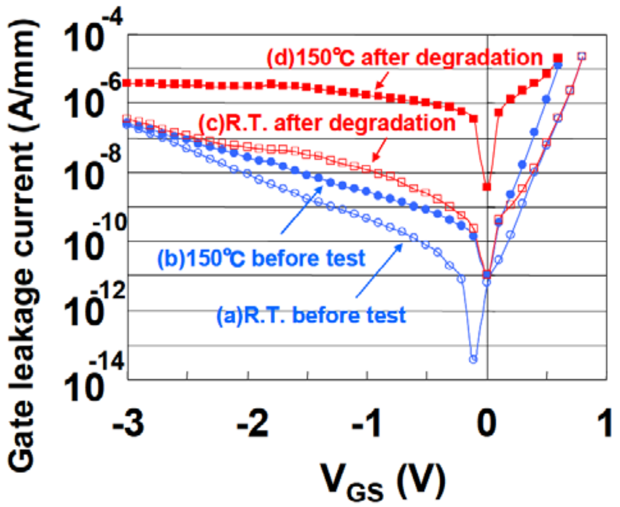
The laboratory developed a special GaN-MIS-HEMT, which can operate at 60 V with 110 W. The schematic of the examined transistor can be seen on the 8. figure.



8. figure GaN-MIS HEMT

This type of the GaN HEMT shows improved forward gate leakage current, in order to overstate the reliability and amplification problems caused by the forward gate leakage current.

During the test were three phenomenon observed, which might be important for high reliability. Rapid gradual gate degradation occurred within 10 seconds during high temperature stress test. The reason behind this phenomenon as the experts found out the stability between the electrode and the GaN surface. In the high temperature pitched-off DC stress test after 1-2 hours sudden degradation appeared. On the 9. figure can be seen the leakage current before and after the stress test. This degradation is possibly originated from gate leakage pass.



9. figure Gate leakage current before and after test

As last after 10 hours at room temperature a gradual degradation was observed, which was less than 0,5 dB of output power. Both process condition of surface layer and growth condition of a buffer layer are quite important to improve this degradation. This can be suppressed in the test structure.

The conductive substrate in the transistor caused some problems such as parasitic capacitance and isolation leakage. This problem can be solved by growing 10 µm thick AlN buffer layer between the n-SiC substrate and the GaN-HEMT structure. This layer also affects the performance.

To use this technology for manufacturing, it is suggested to use 3-inch substrate. The main issue that must be controlled during the manufacturing process is the bow of the wafer. As the study says, they measured 8.7 µm bow after the MOVPE (metalorganic vapour phase epitaxy) growth of GaN HEMT. The detailed description of the manufacturing parameters can be found in the "Recent Progress of High Reliable GaN-HEMT for Mass Production" study, which is a low-cost, high-gain technology and suitable for mass production.

6 Conclusion

Nowadays the communication technologies developing very fast. As an engineer it is really important to have knowledge about the key sectors of electrical engineering such as the telecommunication technologies. During this essay I got chance to take a closer look in to the microwave communication. As I learnt about the microwave communication, I also studied the optical fibers, so I could make a comparison between these two different technologies. Thanks to this comparison now I know, that it is true that optical cables can transmit enormous amount of data, but I think there is a lot more potential in microwave communication due to its cheapness and it is easy to build up these systems. To transmit data through microwaves the signals must be amplified. To do this amplifying most of the companies use high-electron mobility transistor. I studied these HEMTs, and found innovation around the GaN HEMT. As ending I looked for studies about the manufacturing of the GaN HEMT. I made a short summary about the reliability of the GaN HEMT, and about the possibilities of the GaN HEMT's mass production.

I think this research helped me to improve as an engineer, and I obtained decent knowledge about microwave communication, and about high-electron mobility transistors.

7 Sources

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