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Developing of perimeter access guarding system based on sensitive optical fiber

This paper is a short summary of "Engineering of perimeter guard system made with sensible fiber" work, which was a specialist graduation thesis in Ural Federal University in 2010.

Many modern perimeter access guarding systems are using electrical cable as a sensor element. Although it has its advantages, its main disadvantage is susceptibility to electrical interference. On the other hand, light, passing in the optical fiber, does not have such weakness. Until 21st century optical fibers were expensive, and they had very high attenuation rate, so mass usage of optical fibers was ineffective, but now it costs sometimes even cheaper, than electrical cables, and has very good characteristics, so using it in perimeter guarding systems is a very promising idea. There are two ways of using it in such systems: first one is using optical fiber as a transport between sensors and controlling station, unaffected by electrical interference, and second one is using optical fiber as a sensor itself. This article deals with the research of using single-mode russian optical fiber "SMF-28" as a sensor in perimeter access guarding system.

SMF-28 is a single-mode fiber. Modern Russian perimeter guarding systems use multi-mode fibers, but their main disadvantage is modal dispersion, which single-mode fiber has not. Also, LEDs, which are used to generate source for multi-mode fiber are less stable, than laser diodes used for single-mode fiber. This can be problematic in detecting an intruder, because interference, caused by his actions. The goal of this research is to prove that the single-mode fiber can be successfully used as a sensor in perimeter guarding systems.

There are two approaches of using optical fiber as a sensor: measuring of reflected optical signal on the same end of the fiber (reflectometric method) and measuring pass-through optical signal on the other end of the fiber (direct measure method). First approach was looking more perspective, because it's actually a reflectometric method, widely used to find defects in optical fiber lines, and it was awaited, that this method could not only detect an intrusion, but also point its location. To test this hypothesis, a test stand was assembled (see figure 1).

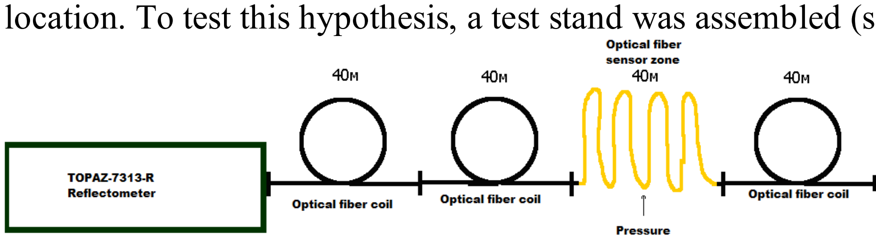
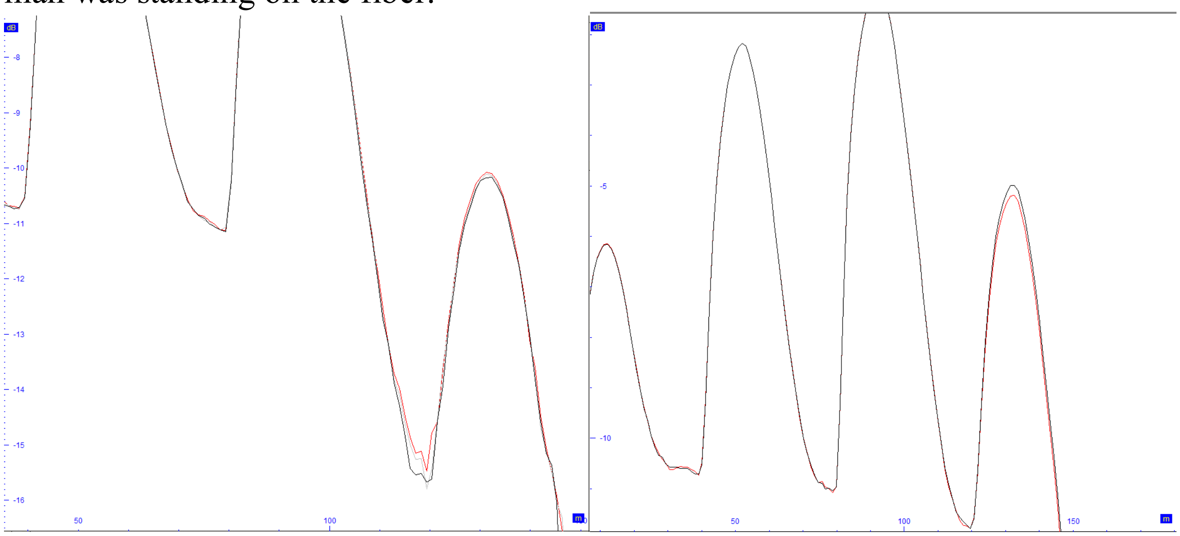


Fig 1. Test stand to measure interference, caused by pressure on the optical fiber, by using reflectometric method.

Test stand consists of Russian reflectometer TOPAZ-7313-R and four segments of optical fiber, each 40 meters. Third segment will act like a sensor. 7313-R reflectometer has resolution of 15 meters and maximum distance with this resolution is 2 kilometers. First two segments added because 7313-R, like most reflectometers, is actually “blind” first 60 meters, so two coils used to compensate this flaw. The main problem is that it takes 15 seconds to completely scan the trace. On the first series of tests pressure (standing man, weight 60 kilograms) was applied all time during reflectometric scan (all 15 seconds). Results was positive. As it can be seen on figure 2a, there is a significant difference between etalon reflectogram (without any external interference) and reflectogram, measured when man was standing on the fiber.



a. b.

Fig.2. a) Etalon reflectogram (black) and reflectogram in time of applying constant pressure to optical fiber (red).

b) Etalon reflectogram (black) and reflectogram in time of applying short pressure to optical fiber (red).

This experiment confirms, that the light in optical fiber is affected by applied pressure. Also, it shows the place where pressure was applied (of course with accuracy of 15 meters, but it’s a very acceptable accuracy in perimeter guarding systems). But there is a large problem. As it was said earlier, pressure was applied all the time trace was scanned, and it’s a 15 seconds – real intruder will not stop on sensor for such time, he will just pass by. Also, sensitivity is not good. In second experiment pressure time was lowered to 1 second (a man just stepped on the fiber). The difference between reflectograms in this experiment is not as obvious, and, actually, there were a lot of experiments, where it wasn’t any difference at all. Figure 2b shows the best experiment result. To sum up, these experiments have proved, that single-mode fiber can be used as a sensor, and using of reflectometric method is possible, but not to detect short interferences. For example, it is possible to use SMF fiber as a sensor in building, by merging it into the wall to control its structural integrity. As wall will deform with time, it will affect fiber, and by using reflectometric method it will be possible to find weak points and fix them. But using such method in perimeter guarding systems is not advised in most cases. Maybe if more advanced reflectometer was used in experiments, results would be better, TOPAZ-7313-R is actually the cheapest and easiest reflectometer on russian market.

Second method which was tried is measurement of pass-through light. Test stand was also assembled, and its scheme is presented on figure 3.

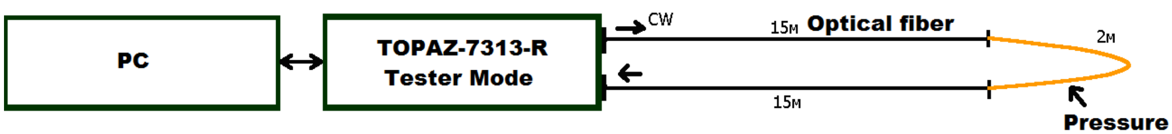


Fig.3. Test stand to measure interference, applied to optical fiber, by using direct measure method.

In this test stand, 7313-R reflectometer is acting in “tester mode”, so it just constantly emits stabilized light into optical fiber and measures the power of light after it passes the fiber.

It was awaited, that the external interference will affect power of light, and it was confirmed. Photodiode of 7313-R was registering power about 500-600 uW. When the interference was applied, the changes in light’s power were detected, about 10-30 uW. To detect intrusion, current indications of tester were compared with previous, with resolution about 0.2 seconds. Experiment showed, that differences of 2 or more uW were caused by external interferences. Differences lower than 2 uW were caused by instability of the light source and slow changes in surrounding temperature. Optical fiber successfully reacted to pressure, vibrations, and even loud sounds. Of course, experiment was held indoors in laboratory conditions, and outdoors various interference will be more significant, but lower, than interferences caused by intruder anyway. The best results were achieved by detecting fiber vibration.

Main disadvantage of this method is that it is not possible to determine exact location of interference. Figure 4 shows, how to build a perimeter access guarding system by using this method, and, with some limitation, detect location of an intrusion.

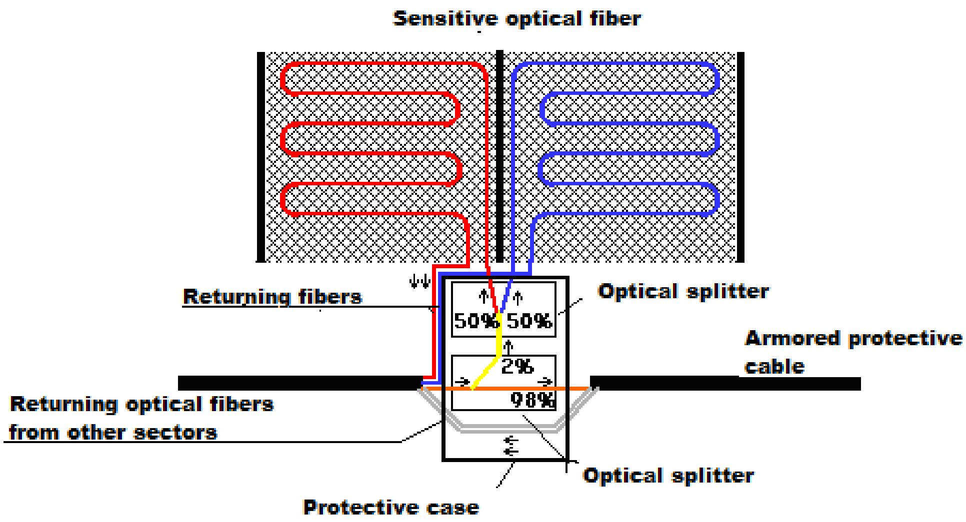


Fig.4. Schematic of one sector of the perimeter access guarding system.

Optical fiber is fixed on the fence, and is protected by armored cable all the way, except sensor part. By using optical splitters, it is possible to lower count of needed fiber and so, lower the price of the whole system itself, but each section of the fence must have its own returning fiber anyway. In figure 4, red and blue fibers are sensors, orange one is the fiber, which is used to supply “red” and “blue” with light. If intruder will try to climb over the fence, it will vibrate, and vibrations will be detected (as it was describer in direct measure method), and location will be estimated just by looking, which fiber caused intrusion detection. The price of such system is similar to systems, based on electrical cables, but this one, as already was said, have one main advantage – it is unaffected by electrical interference, only by physical. Other significant advantage is that there are no any power elements presenting on the perimeter, which can be sabotaged, and, of course, it needs less energy, than electrical-based guarding systems.

To sum up, results of research indicated that single-mode fiber can successfully be used in perimeter access guarding systems and other sensing applications.

Literature:

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