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Methods to reduce backscattering and reflection induced noises in GMRT fiber optic links

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Introduction:

In my earlier report on " Rayleigh Backscattering and Fresnel Reflection induced noises in GMRT " it has been found out experimentally that the periodic spikes that appear in the GMRT fiber optic system is due to the optical reflection between the laser diode and the VFO-DF connector and not due to any electrical interferences as suspected earlier. The optical reflection is due to the bad alignment between the plug and the adaptor of the VFO-DF optical connector. This bad alignment worsens the return loss performance of the connector. These noises were removed using better connectors having good locking system , such as FC/APC connectors. Connectors like E-2000 series provide very high and repeatable return loss.

The second part of the above report explains about the Random spikes that appear along with the above periodic noises. Experimentally it was concluded that these Random spikes were due to Rayleigh backscattering along the optical fiber link. To reduce these spikes and to further confirm that these random spikes were due to Rayleigh backscattering , optical Isolators and good return loss connectors were suggested to be included in the links.

With the above introduction to the reflection induced noises, this article discusses about the noise supression techniques for the GMRT optical fiber links. Also describes the solution provided to the W4 antenna, where the PLL of the Receiver system failed to lock due to poor SNR at the antenna base.

Rayleigh Backscattering and Double Rayleigh backscattering induced noises:

When Laser is coupled to the Optical fiber link the light propagates along the length of the fiber, but some part of the light is reflected back along the length of the fiber, which is inherent reflection caused by impurities in the fiber. This inherent reflection is called Rayleigh backscattering in the fiber. Optical Time domain Reflectometer (OTDR) uses these backscattered light to estimate the link loss and fiber length. Rayleigh backscattering gives - excess noise at the fiber optic receiver output , these noises are random in time and has a flat frequency spectrum.

The other type of backscattering is double Rayleigh backscattering, which occur between every pair of reflective components as well as between every reflective component and the fiber Rayleigh backscatter.

In longer fiber optic links Rayleigh backscattered and double Rayleigh backscattered light is large and produce very strong random spikes in the receiver, and thus reducing the over all SNR. Thus at faraway antennas like W4 had more of these random spikes generated by the Rayleigh backscattered light when compared with the nearby central square antenna links. This increase in the noise level is very random in time and this makes a random change in the signal to noise ratio of the link.

Noise supression techniques:

1. Reducing Single Rayleigh Backscattering induced noises:

The Rayleigh backscattered light can be prevented from interfering with the Laser diode by inserting an optical isolator. Optical isolators are passive optical devices which allows the light to travel in only one direction , and it prevents the reflected light to re-enter the Laser diode. The commercial devices offer an isolation of minimum 40 dB between the input and output port. The isolator uses Faraday rotator and polarizers to provide the above isolation. The important thing to be noted is to have low reflection at the isolator input, because they may generate multiple reflection between isolator and the laser diode giving periodic pulses.

Also it is wise to avoid connectors between the laser source and the isolator. The isolator should be connected nearer to the laser source. The splice used between the laser source and the optical isolator should be free from reflection. To avoid these reflections some of the laser sources are made with the built in optical isolators, in particular the DFB single mode lasers are very sensitive to reflection and hence they are built with optical isolators.

2. Reducing reflection induced noises:

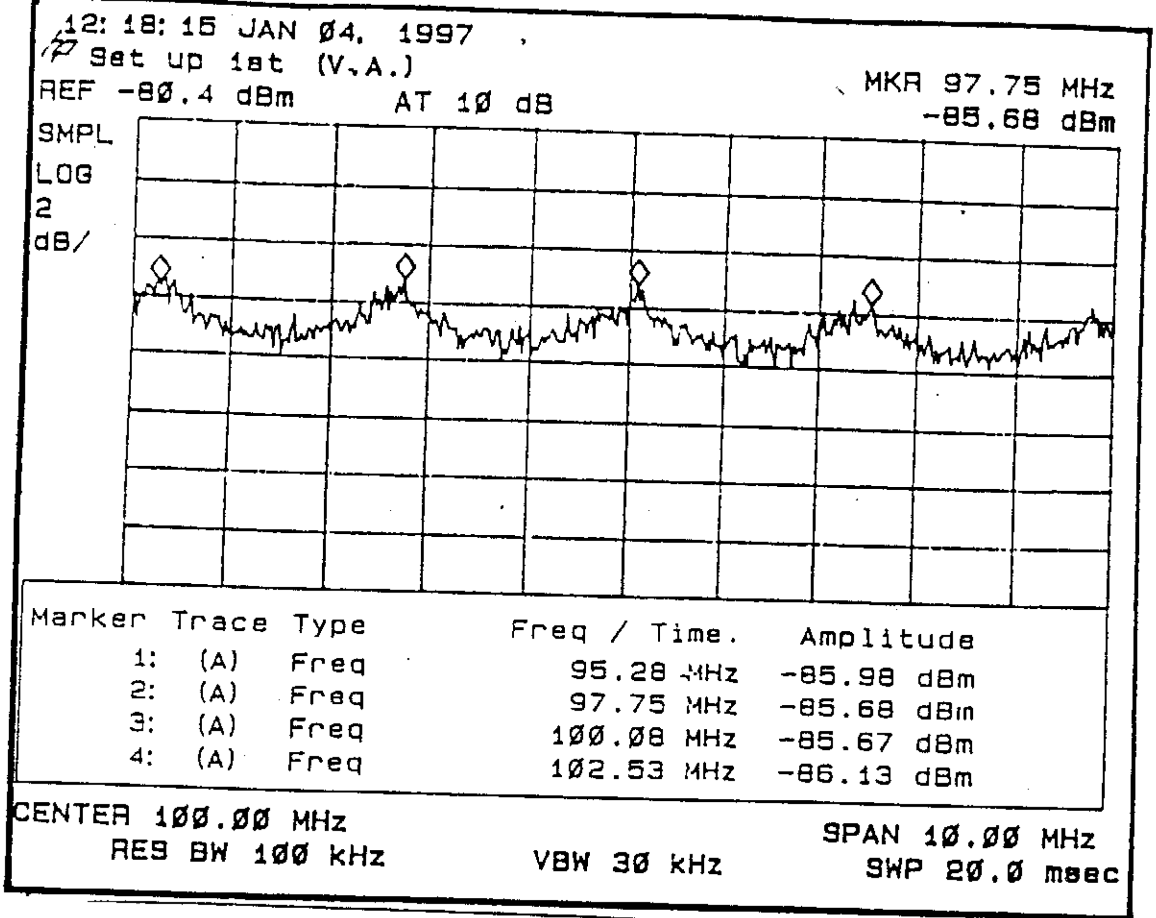
The optical reflections from connectors, splices, devices like Photodiode etc. moving towards the laser diode is also prevented by the isolator connected next to the Laser diode. There will be no periodic noises due to the reflections in the link. These reflection induced noises are prominant only in the short links and they get attenuated and produce very weak pulses in the longer links. The interesting phenomenon noticed in the GMRT link is these periodic pulses not only attenuated in long links but also show pulse spreading like a transmitted digital signal. Pulse spreading is a common phenomenon in a digital links, which limit the over all bandwidth of the system and it is due to dispersion in the fiber links.

Thus introducing optical isolator near the laser diode helps in preventing the reflected and backscattered light from interfering with the laser source. This has helped in clearing the periodic and random spikes earlier appeared at W4 antenna shell.

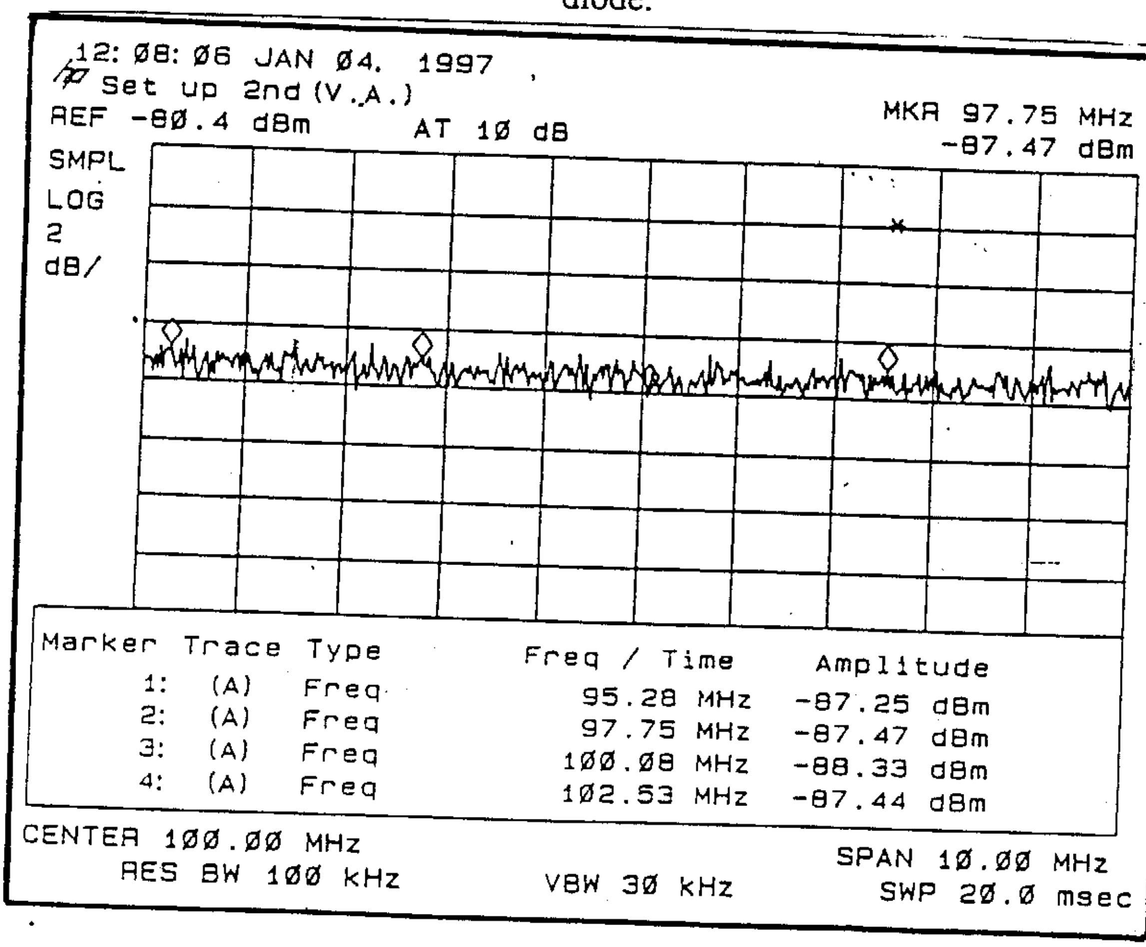
3. <u>Reducing Double Rayleigh backscattering induced noises:</u>

The optical isolators can prevent only the reflected light that re-enters the source, but double reflections and double Rayleigh backscattered light travel towards the optical detector giving spikes and their by degrading the signal to noise ratio. The double Rayleigh backscattering occurs due to reflection of the backscattered light at splices, connectors, reflective isolator output ports, WDM devices etc. Thus the reflections at the above places should be reduced by reflection free splices and by using low return loss connectors and devices. In GMRT we use splices, optical connectors and optical isolators in the link. To prevent the above double backscattered noises, the over all reflectance should be kept minimum by using ultra low return loss connectors, giving minimum 70 dB return loss. The splices should be done using arc fusion splicing machines with no air bubbles at the splicing joint.

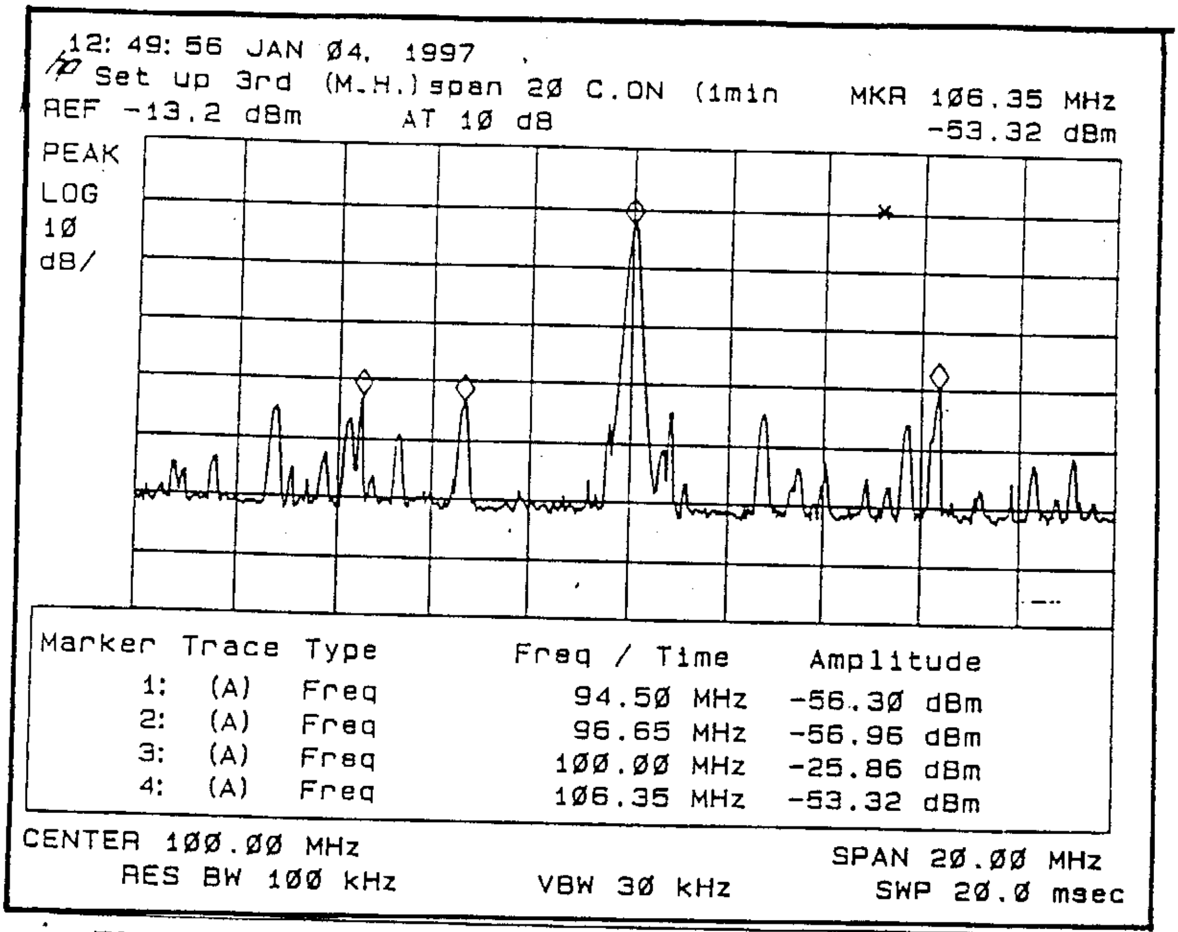
From literature it is understood that for a distance of 20 km (the longest link in GMRT) , the Single Rayleigh Backscattering level of the fiber is - 32 dB and Double Rayleigh Backscatter of the fiber is - 65 dB.



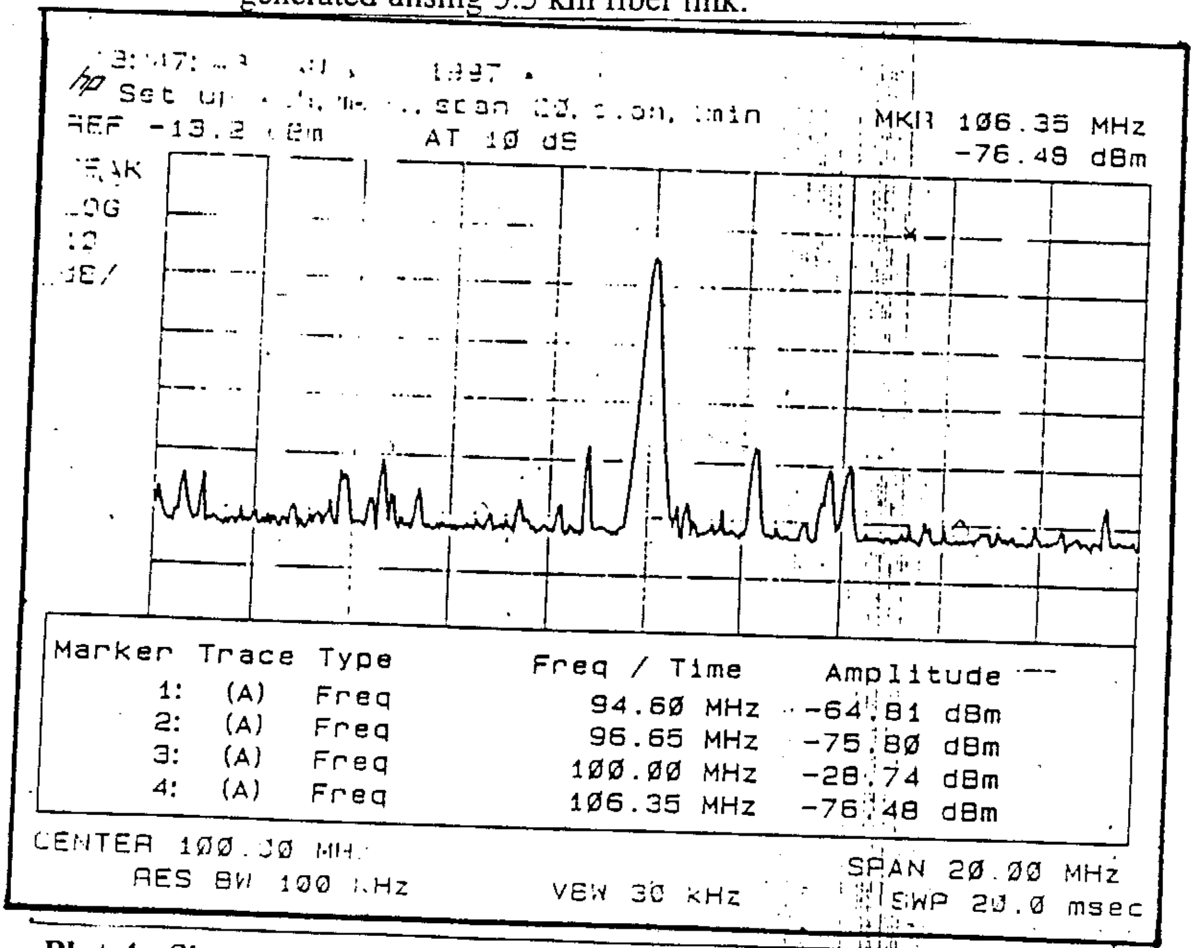
Plot 1. Shows the Periodic pulses between an optical connector and laser diode.



Plot 2. Shows the periodic pulses removed when an Optical Isolator inserted between the Laser diode and the optical connector.



Plot 3. Shows the Rayleigh Backscattering induced random spikes generated unsing 3.5 km fiber link.



Plot 4. Shows the Random spikes reduced when an ultra low return loss optical connector inserted in the link , thus reduced double Rayleigh Backscattering.

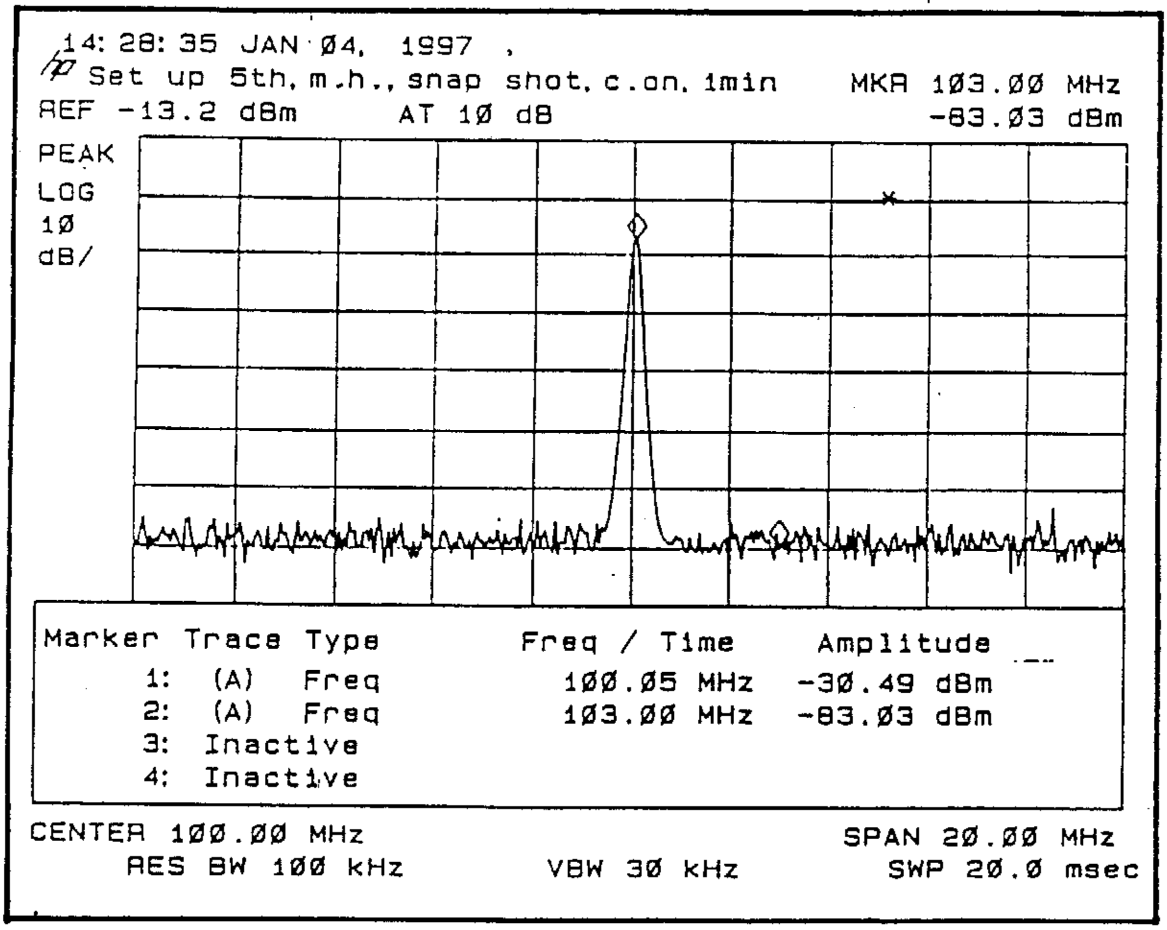
Thus it is better to use connectors having optical return loss of 70 dB for the GMRT fiber optic link.

Experimental results :

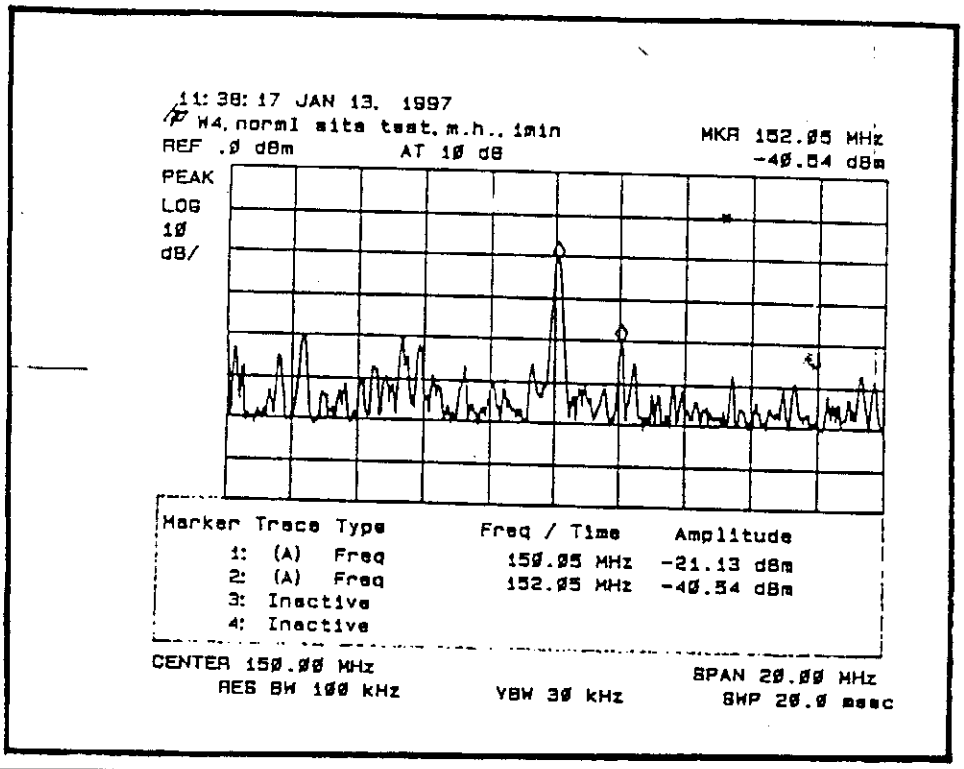
1. Plots 1 shows the periodic pulses generated by misaligning the VFO-DF optical connector, generated due to reflection between the connector and the laser diode. We can the pulses are placed with equal separation.

Plot 2 shows that the periodic pulses removed using an optical isolator inserted next to the laser diode and hence the reflected light from the connector do not interfere with the laser diode. This shows that any reflection towards the laser diode can be removed using isolator. The best is to use low reflection connectors, splices and high return loss devices in the links.

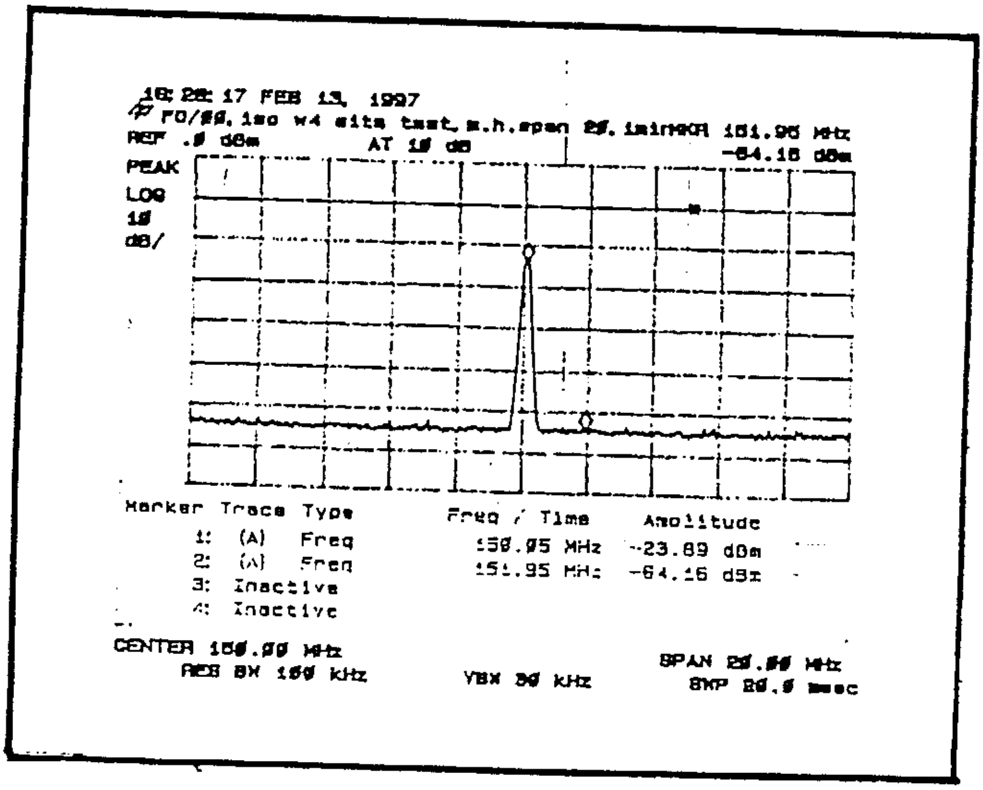
2. Plot 3 shows Rayleigh backscattering induced random spikes. These spikes were generated using 3.5 km fiber link between the laser transmitter and the photodiode receiver. We can see that the spikes are not periodic and strong enough to suppress the signal (100 MHz carier) . Thus the signal to noise ratio drops down and they vary randomly.



Plot 5. Shows the Optical isolator inserted next to the laser diode remove the remaining random spikes generated by single Rayleigh backscattering.



Plot 6. Shows poor condition of the W4 antenna filled with strong spikes giving SNR of 19 dB only.



Plot 7. Shows clean spectrum at W4 antenna free from all Spikes when optical isolator inserted in the link, thus giving SNR of 40 dB.

Plot 4 shows the Random spikes reduced when compared with plot 3. This is because a set of FC-APC connectors were introduced in the link at the laser diode and the photodiode connecting the 3.5 km fiber link. This ultra low return loss connector reduced the double Rayleigh backscattering towards the photodiode and hence less number of spikes. The spikes seen is more due to single Rayleigh backscattering towards the laser source.

3. Plot 5 shows the remaining Single Rayleigh backscattering induced spikes removed by introducing an optical isolator next the laser diode. We see the noise level comes down when the random spikes are removed and hence the signal to noise ratio improvement in the link.

4. Plot 6 shows the poor condition of the western arm antenna filled with strong spikes reducing the signal to noise ratio to 19 dB. This poor signal to noise ratio resulted in locking and unlocking of the signal with the receiver at W4 antenna base.

Plot 7 shows the clean spectrum at Western arm antenna W4, free from all spikes. This is obtained by introducing optical isolator in the link i.e the forward link. This solved the above signal to noise ratio requirement of the receiver system. We can see the signal to noise ratio has improved from the worst 19 dB to 40 dB i.e. an over all 20 dB improvement in the SNR is obtained..

Conclusion:

The above analysis and the experimental results indicate that the GMRT fiber optic link should use ultra loss return loss connectors and the long links should use optical isolators along with the above connectors. Also the over all reflection in the link should be kept minimum by avoiding reflections at splice joints.

References:

1. S.SureshKumar, " Rayleigh Backscattering and Fresnel Reflection induced noises in GMRT " , NCRA - TIFR Technical Reports, Fiber optic group - June 1996.

2. Barbara Birrell , " Effects of Reflections on Carrier to Noise Ratio in Fiber Optic Analog CATV VSB systems " , 3M

3. Product News - Angle Polished Connectors from DIAMOND, Littleton, MA 01460