NCRA - TIFR Technical Reports

Fiber optics group

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Rayleigh Backscattering and Fresnel reflection induced noises in GMRT

By

S.SureshKumar, TIFR - Pune.

Experimental setup and measurements by R.V.Panchal & S.Ramesh

Report No. : SSK/01/june-1996

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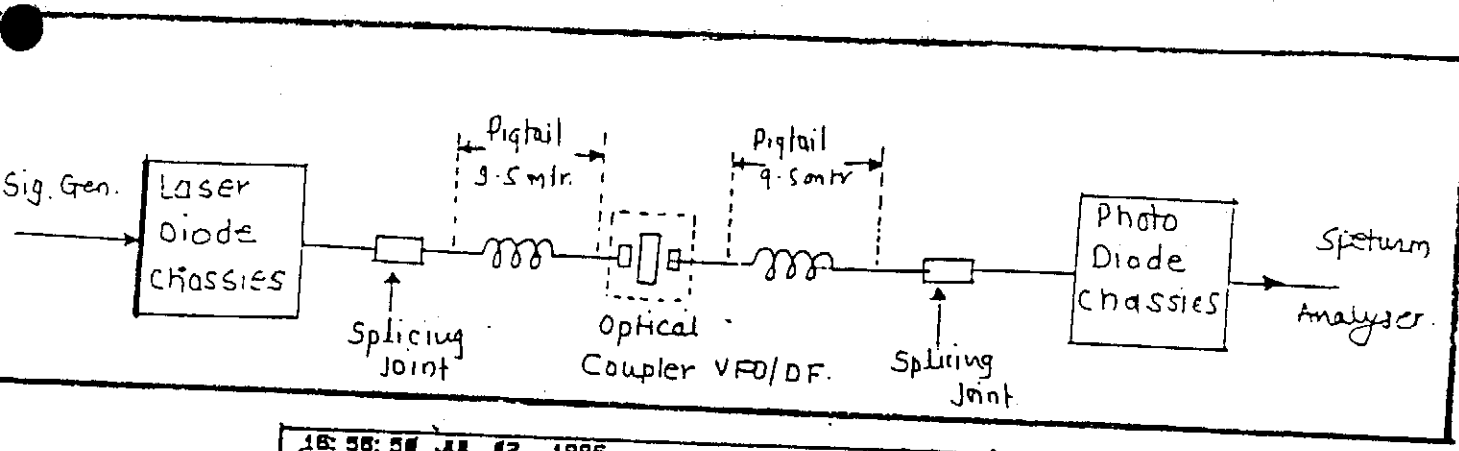
Introduction:

In the year 1995 it was reported that the noise floor of the fiber optic system installed in GMRT show a sinusoidal pattern or ripple with 8 MHz spacing fig. 1. While studying the periodic pattern it is observed some random spikes also appear in the link.

A clear study has been made to identify its origin and methods of removing these noises.



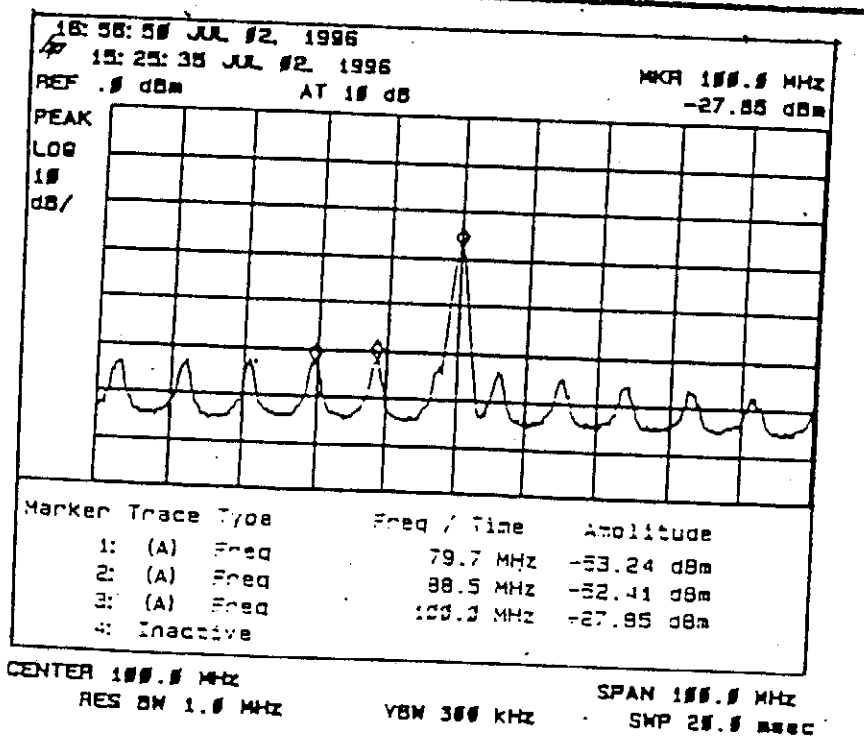


Fig 1. Plot showing Periodic spikes due to reflection at VFO-DF optical connector observed using the above experimental setup.

Periodic Spikes:

After many experiments it is found that it is due to reflection in the link and it is between Laser diode and the VFO-DF optical connector and not between the following ports:

i. VFO-DF connector and Photodiode

ii. Splicing joint and Laser diode

iii. Splicing joint and Photodiode

iv. Splicing joint and VFO-DF connector

Experimenting with various test setup it is found that the 8 MHz periodic spikes disappear when the VFO-DF adaptor between the Transmitter pigtail and link fiber pigtail is adjusted. It is seen that the connector and adaptor found to have certain amount of play. Because of this misalignment the return loss worsens i.e. the quoted value of -55 dB is never achieved. This can be corrected to some extent by monitoring the 8 MHz ripple on a RF-Spectrun Analyzer by proper alignment . This is effective only when the optical connector nearer to the Optical Transmitter is adjusted. It is to be noted that the ripple spacing depends on the distance between the reflecting point and the laser diode. The relation between the distance and the ripple spacing seen in the frequency spectrum analyzer is

$$f = \frac{c}{2nl}$$

where f = ripple spacing of frequency of separation

c = velocity of light

n = refrative index of the fiber

l = distance of reflecting point from the source

Random Spikes:

While Experimenting the above to remove the 8 MHz periodic spikes it is found that some random spikes also appear in the link throughout the workable band of the system. Initially these spikes were found only at GMRT Project site and not when tested in the lab. It was suspected to be due to poor grounding at project site, but later by simulating a fiber optic link of ~ 1.5 km length at lab in Pune with good earthing and power isolation it is found the random spikes do appear along with the periodic spikes (later removed by proper connector alignment) which may be due to some reflection in the link and not due to poor earthing. Under same conditions the random spikes appear only when link fiber is introduced between the transmitter and the receiver and not when transmitter and receiver connected back to back using optical connectors.

Types of Reflection induced Noises:

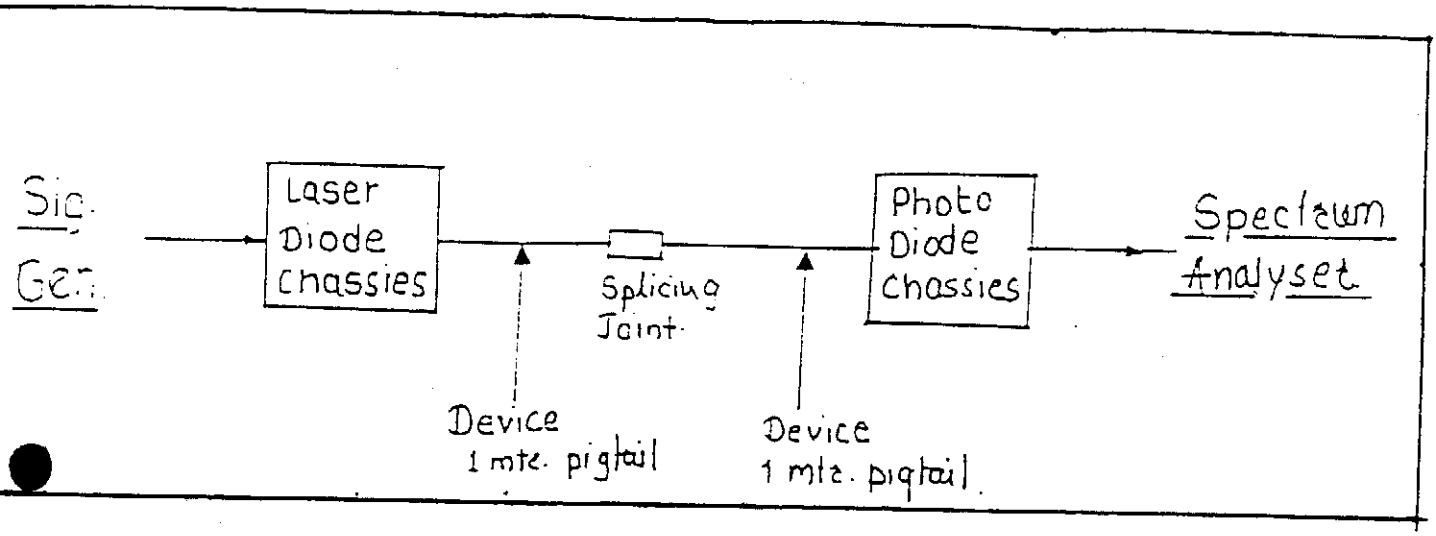
Reflection induced noises can be of three major types

a. Optical Reflection due to poor device-fiber-coupling

b. Optical Reflection due to optical devices,optical connectors, bad splicing joints or mismatched fiber coupling (fibers having different refractive index or core size are connected together)

c. Rayleigh backscattering

These reflection induced noises are studied independently as follows



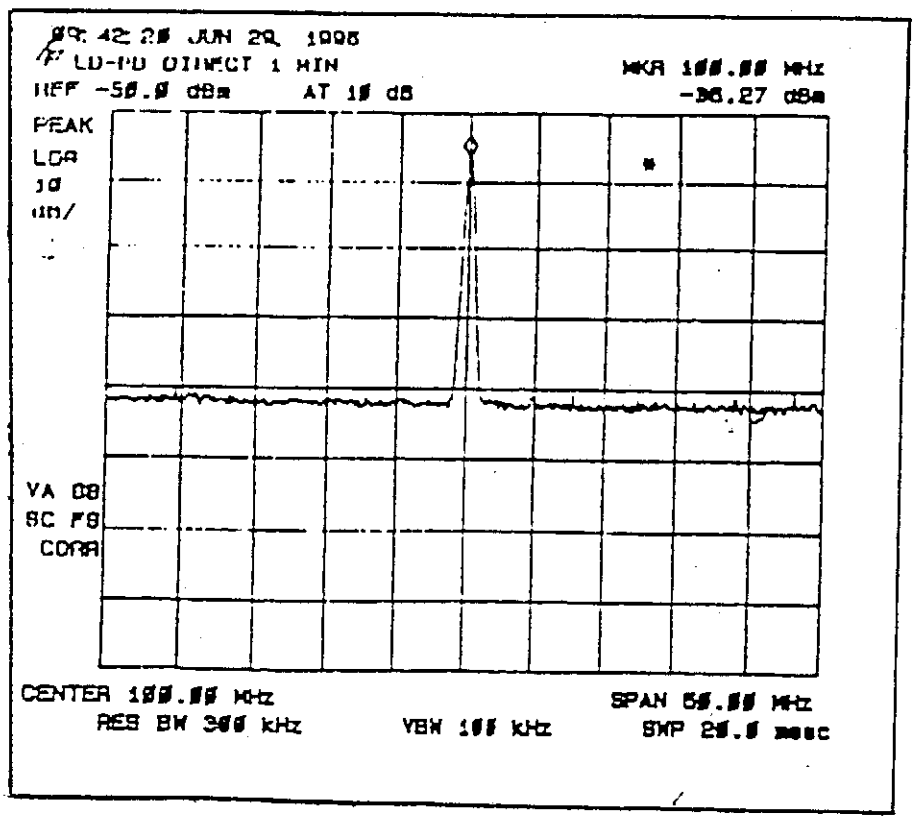
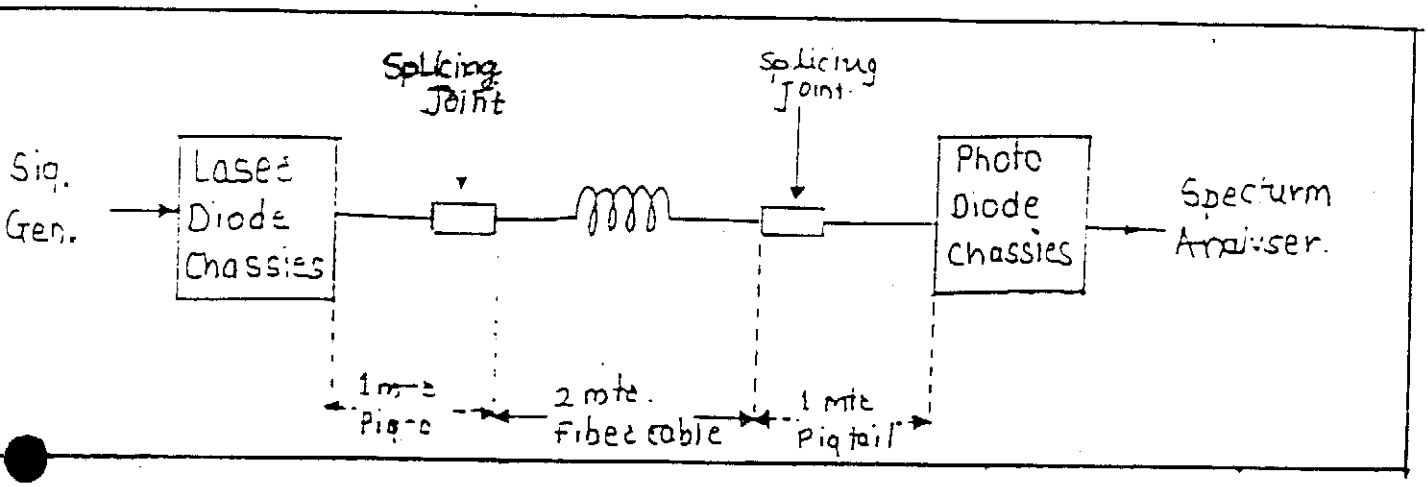


Fig 2. Plot showing clean spectrum i.e free from periodic and random spikes when laser diode and photodiode unit connected as shown in the above experimental setup.



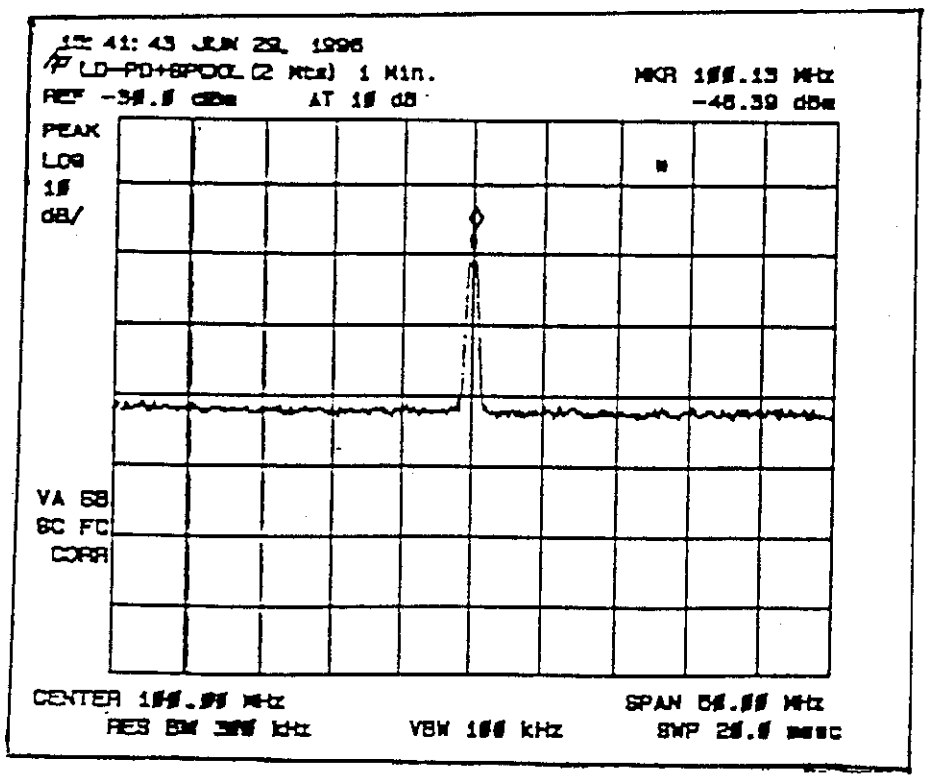
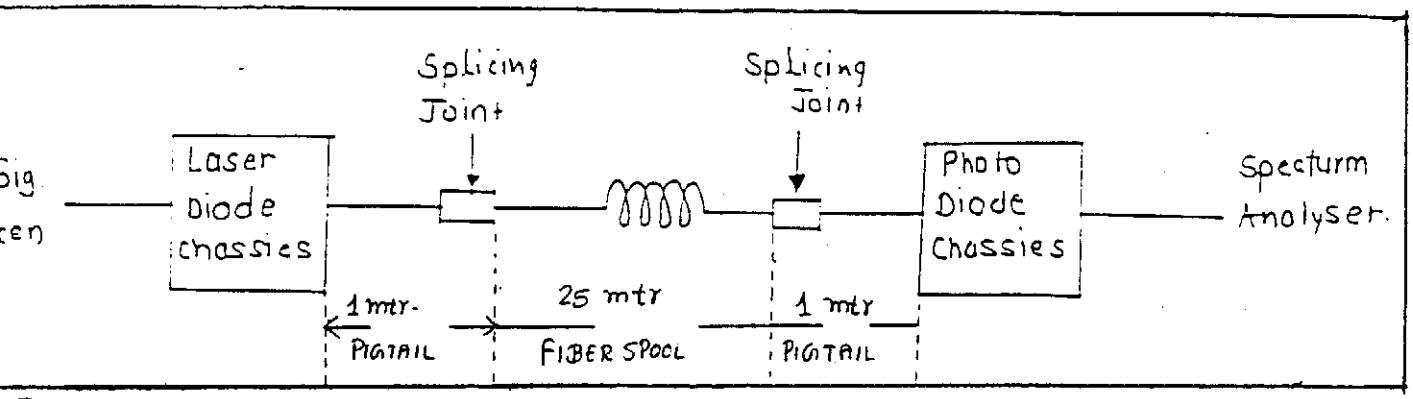


Fig 3. Plot showing clean spectrum with 2 meters optical fiber inserted between the laser diode and photodiode unit as shown in the above experimental setup.



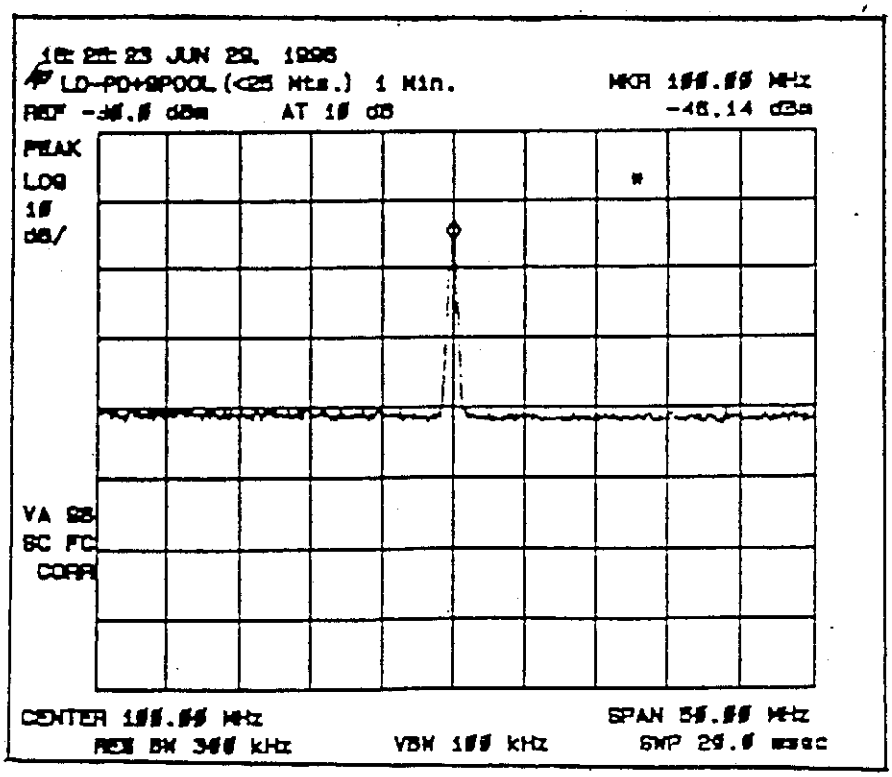


Fig 4. Plot showing clean spectrum with 25 meters optical fiber inserted between the laser diode and photodiode unit as shown in the above experimental setup.

Possibility of having reflection at Laser-Fiber coupling:

The possibility of having reflection induced noises due to Laser-Fiber coupling giving random spikes does not exists because the reflection induced noises due to poor Laser-Fiber coupling is periodic . Above all the laser diode used in GMRT Fiber Optic link is a pigtailed device i.e. the Laser-Fiber coupling is done by the manufacturer using proper lensing arrangement .

Possibility of having reflection at optical connectors, splicing joints, optical devices, fiber mismatch etc:

The possibility of having reflection induced noises do exists but they are periodic and it is found that these reflections occur at optical connectors which is removed by proper alignment of the optical connectors or by using better connector types which do not introduce any mechanical misalignment . Reflection due to splicing is avoided using arc fusion splicing methods and adopting fiber core alignment during splicing. This is also inspected using OTDR test setups and checking core offsets for each and every splicing which is provided by the arc fusion splicing machine. Reflection due to Photodiode is verified by directly splicing the Laser-diode to the Photodiode and no Reflection induced noise was present producing periodic and random spikes see fig 2. Finally fiber mismatch is verified by introducing a fiber of length 2 mts. and 25 mts between the laser diode and the photodiode and verified using the RF spetrum analyzer . It did not show any reflection induced noises including periodic and random spikes. This is shown in fig 3 and 4. So the possibility of getting random spikes due to optical connectors, optical devices, splicing joints and fiber type mismatch does not exists.

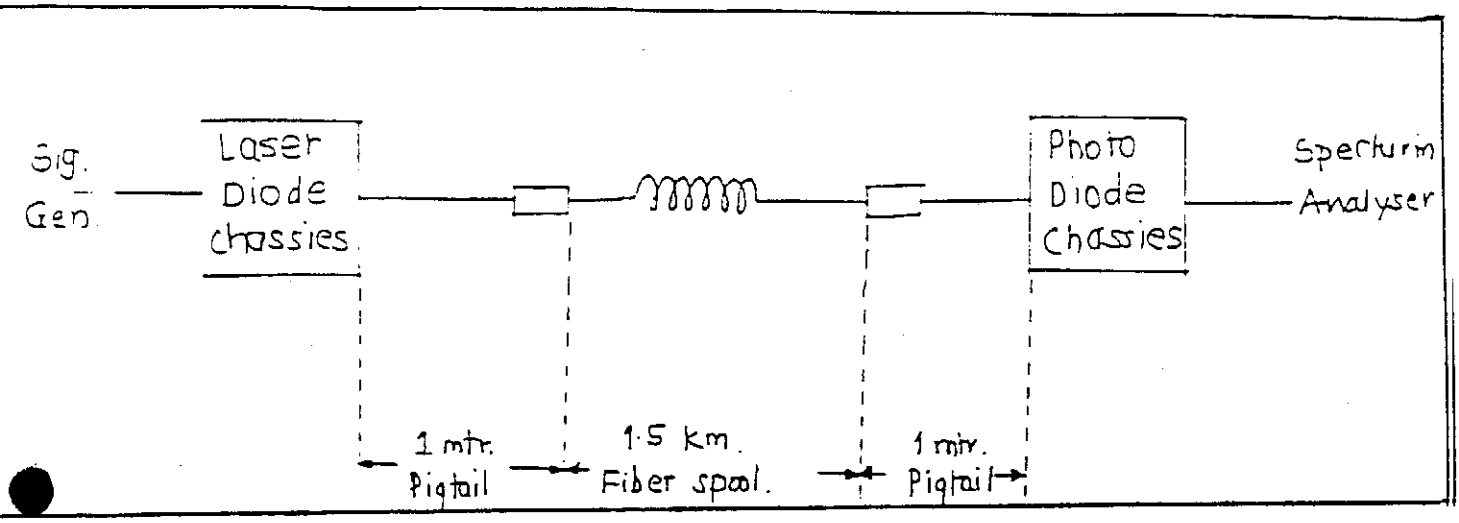
Possibility of having random spikes due to Rayleigh Backscattering:

During the above said experiments the random spikes do not appear , but it appeared when the link distance is increased to approx. 1.5 km optical fiber inserted between the Laser diode and the Photodiode fig. 5. When Pigtails are introduced in the link to connect the link fiber with the laser diode and photodiode the random spikes got reduced fig 6. This is further reduced when FC/APC connectors are tried having 60 dB return loss compared to VFO-DF connectors having 55 dB return loss. It is understood that the random spikes appear only when fiber of large length is inserted in the link and they get reduced when optical connectors of good return loss is used for connections.

This explains that the random noise is not due to any electrical source but optical which is Rayleigh Backscattering which becomes dominant in analog applications.

Noise supression techniques for fiber optic links:

1. Periodic noise peaks are due to poor connectoralighments. So connectors like FC/APC should be used which has superior connector locking system.
2. Reflective splicing joints should be avoided atleast nearer to the devices in the links.
3. Matched fiber should be used for fiber coupling.
4. Rayleigh Backscattering can be avoided using optical isolators or by using ultra low reflection connectors i.e. connectors having return loss from -65 dB to -70 dB or still lesser. It is to be noted that Micro-Bends also help these backscattered light by guiding them in to the fiber. So micro-bends should be avoided in the links.



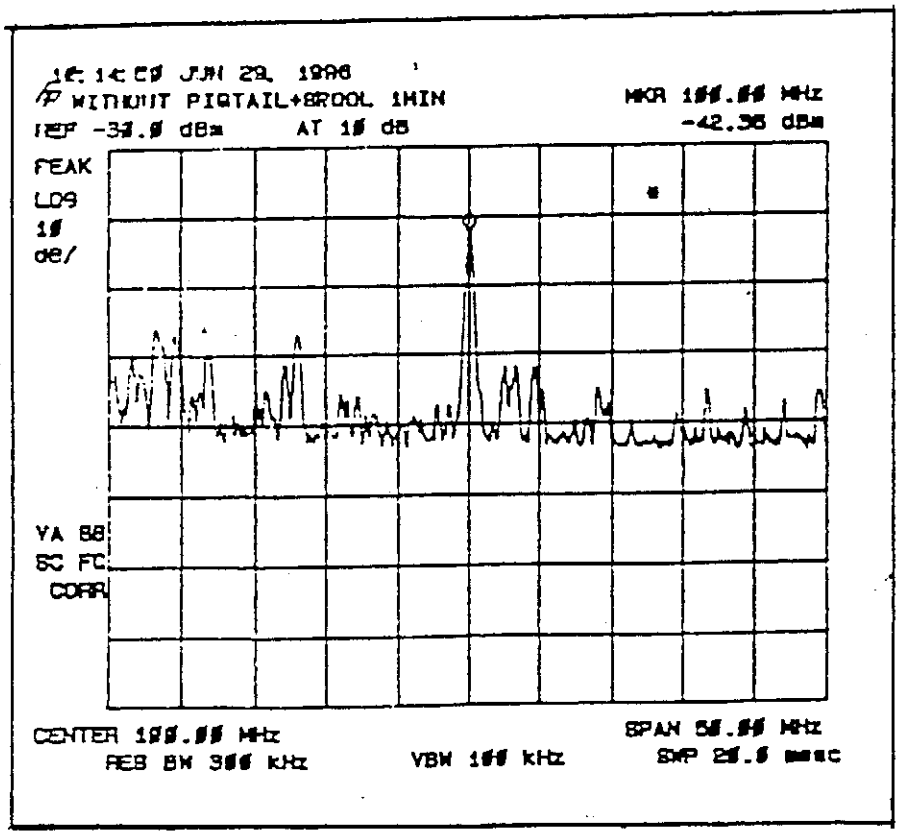
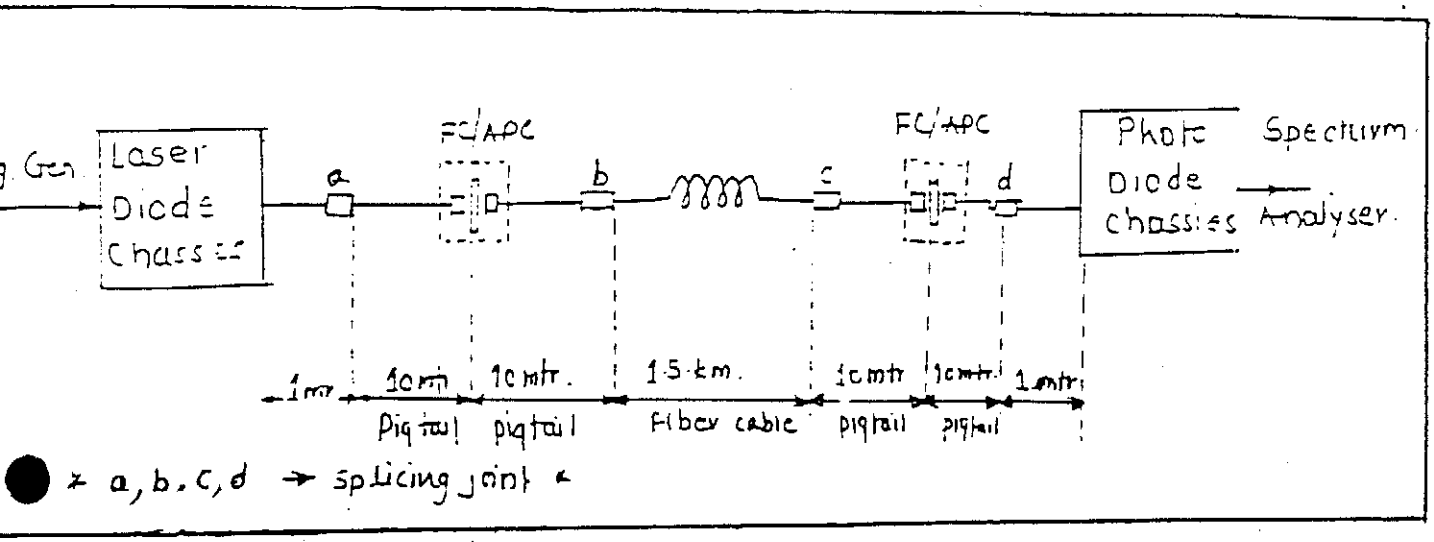


Fig 5. Plot showing Random Spikes with 1500 meters fiber inserted between the laser diode and photodiode unit as shown in the above experimental setup.



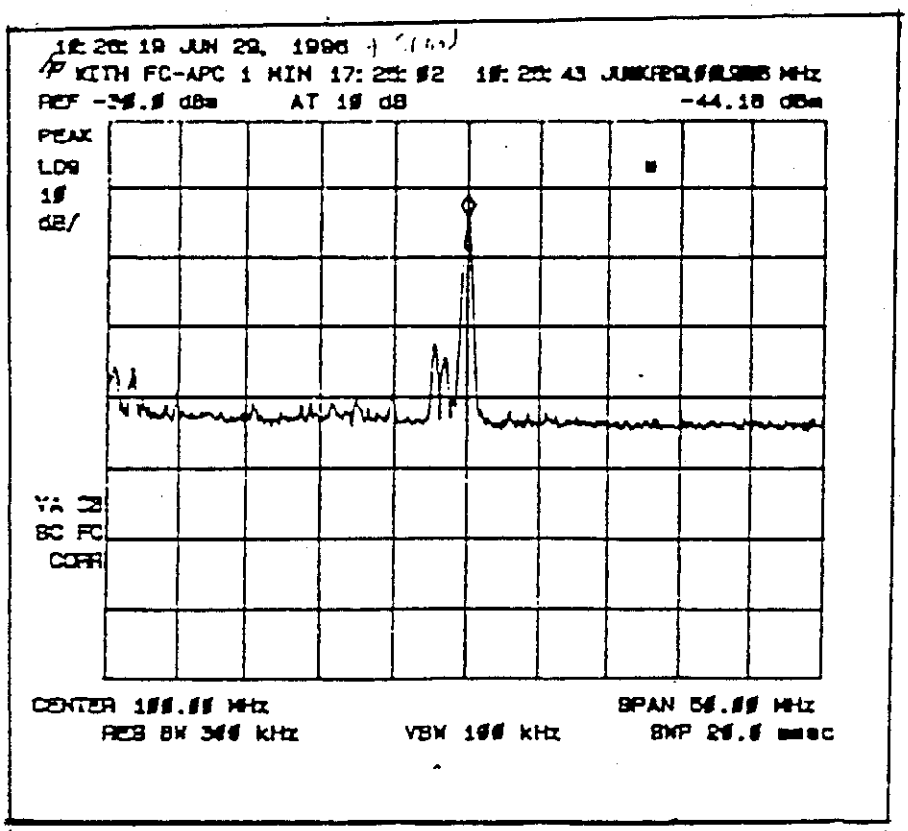


Fig 6. Plot showing Random Spikes reduced when FC-APC connectors introduced in the 1500 meter fiber optic link as shown in the above experimental setup.

Conclusion:

The Periodic spikes seen in the GMRT Analog fiber optic link is due to reflection at the VFO-DF connector and occur due to bad alignment between plug and adaptor. This can be removed by having FC/APC connectors which has better locking system.

The Random spikes are due to Rayleigh backscattering and can be avoided by having good return loss connectors having 65 dB and above. Presently connectors having return loss greater than 80 dB is available in the market which can be adopted.

Reference:

1. Optoelectronic Technology and Lightwave Communication Systems , by Chinlon Lin.
2. Optical Fiber Communications - Principles and Practice , by John M. Senior.