Internal Technical Report

Four Channel Correlated Noise Source with Variable Correlation Coefficient

D. Anish Roshi, A. Praveenkumar and M. Gopinathan
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1 Introduction

The basic measurement made in a radio interferometer (like the GMRT) is the cross correlation of signals from different antennas. The hardware unit which performs the correlation is called a correlator. Since the system noise (receiver + ground spillover + "resolved" sky background) of different antennas are independent, observation on a source produce a correlation coefficient less than unity. Typically for astronomical sources the correlation co-efficient varies over 3×10^{-3} to 0.4 in the frequency band of the GMRT. To test the GMRT correlator, we designed and built a correlated noise source with correlation coefficient varying in this range. From practical considerations, the number of outputs is restricted to four. Provision to feed an external correlated signal (for example a sine wave) also exists.

2 Principle of operation

Consider two signals v_1 and v_2. Let a common signal v_c be added to the two signals. The correlation coefficient of the two signal is defined as

$$\rho = \frac{< (v_1 + v_c) \times (v_2 + v_c)^* >}{\sqrt{< (v_1 + v_c)^2 >< (v_2 + v_c)^2 >}}, \qquad (1)$$

where the angle brackets indicate time average. If v_1, v_2 and v_c are independent Gaussian random noise then the above equation becomes

$$\rho = \frac{< v_c^2 >}{\sqrt{(< v_1^2 > + < v_c^2 >)(< v_2^2 > + < v_c^2 >)}} \qquad (2)$$

Let $P1$, $P2$ and Pc are the powers of noise v_1, v_2 and v_c respectively and let $P1 = P2 = P$, then

$$\rho = \frac{Pc}{P + Pc} \qquad (3)$$

The above equation shows that a variable correlation coefficient between two noise sources can be obtained by adding the noise power from a third source (Pc) and varying its power.

3 Block diagram

The basic block diagram of the designed system is given in Fig. 1. It consists of four independent noise sources and one common noise source all realized using reverse biased zener diodes. Compared with avalanche solid state noise diode, Zener diode offers a simple and low cost method of generating the noise. Moreover, in our application the bandwidth needed is not large (< 16 MHz) and "flat" spectral density over this bandwidth is not required (∼ 3dB). The output of the common noise source is fed to a four way power splitter and combined with the outputs of the four independent noise sources. The amplitude of the common noise source is controlled using a variable attenuator (0 to 15 dB and an external 10 dB fixed attenuator). In addition to this, the common noise source alone can be switched off. An external input can also be combined with all the four noise sources. Automatic level control (ALC) circuits (old GMRT ALC circuit) are introduced at the four outputs to maintain the power level to 0 dBm as required by the correlator. The output power can be further adjusted using a 0/2dB attenuator. The output bandwidth is restricted to 12 MHz using elliptic low pass filters.

4 Circuit Schematic

The schematic of the circuit is shown in Fig 2a,b. The noise generated by the zener diode is amplified using operational amplifier AD5539. The operational amplifiers are also configured to add the signal from the external input to the common noise source as well as to add the common noise to the four independent noise sources. The noise bandwidth is restricted to 12 MHz using elliptic low pass filters. A home made 4 way power splitter is used to divide the common noise source power for combining with the four independent noise sources. A 0/2 dB attenuator is implemented using reflective type GaAs FET MMIC switches (SW239).

5 System Characteristics

Fig. 3 shows the spectra at points (A) and (B) (marked in Fig. 1). For these measurements a 12 dB fixed attenuator was used. The output power spectra measured with a spectrum analyzer when the attenuator values are changed between 0 dB and 15 dB and also when the common noise source is switched off are shown in Fig. 4. Spectra of all the four outputs are shown in the same plot. The output power variation is about 3 dB.

The following measurements are made with 10 "good" multipliers of the GMRT correlator. The four channels of the noise source are connected to sampler inputs C00 to C03. The variation of correlation coefficient for different attenuator values is plotted in Fig. 5 for a narrow bandwidth of 125 KHz about 10 MHz. For these measurements a 10 dB external fixed attenuator is used along with the variable attenuator. The self spectra of all the four outputs are shown in Fig. 6. Fig. 7 and 8 are the 6 cross spectra obtained for 0 dB and 7 dB variable attenuator values. The cross coupling between the four outputs when the common noise source is switched off is shown in Fig. 9. The cross coupling measurements for channels 1, 2 and 3 are limited by the inherent coupling in the correlator. This limitation is checked

using two independent noise sources. Please note that channel 4 of the system seem to ha higher cross coupling, especially with channel 3.

6   Acknowledgment

Fig 1: Four Channel Correlated Noise Source

EXT.I/P
TNC-F

56E   56E
1M
10K pf
120E
51E   470E
150 pf
9.1V ZEENER
10K pf
220E
SW SPST
→ + 12 V

100K pf   220E
→ + 12 V
330 nH
100K pf

7   10
1   +   AD5539   8
14   −   3
470E
5.1K
100K pf
51E

100K pf   330 nH
220E
100K pf   → − 12 V

COMMON NOISE SOURCE + AMPLIFIER

75E
100E
100E

1Q dB PAD

VARIABLE ATTENUATOR
(0 to 15 dB in 1 dB steps)

2-22 pf   2-22 pf
56 pf   180 pf
100K pf   L2   L1   100K pf
220 PF   330 pf   120 pf   220 pf

12 MHz LPF

L1 : 26SWG, 6mm D, 12T
L2 : 26SWG, 6mm D, 19T
(Enamelled copper wire)
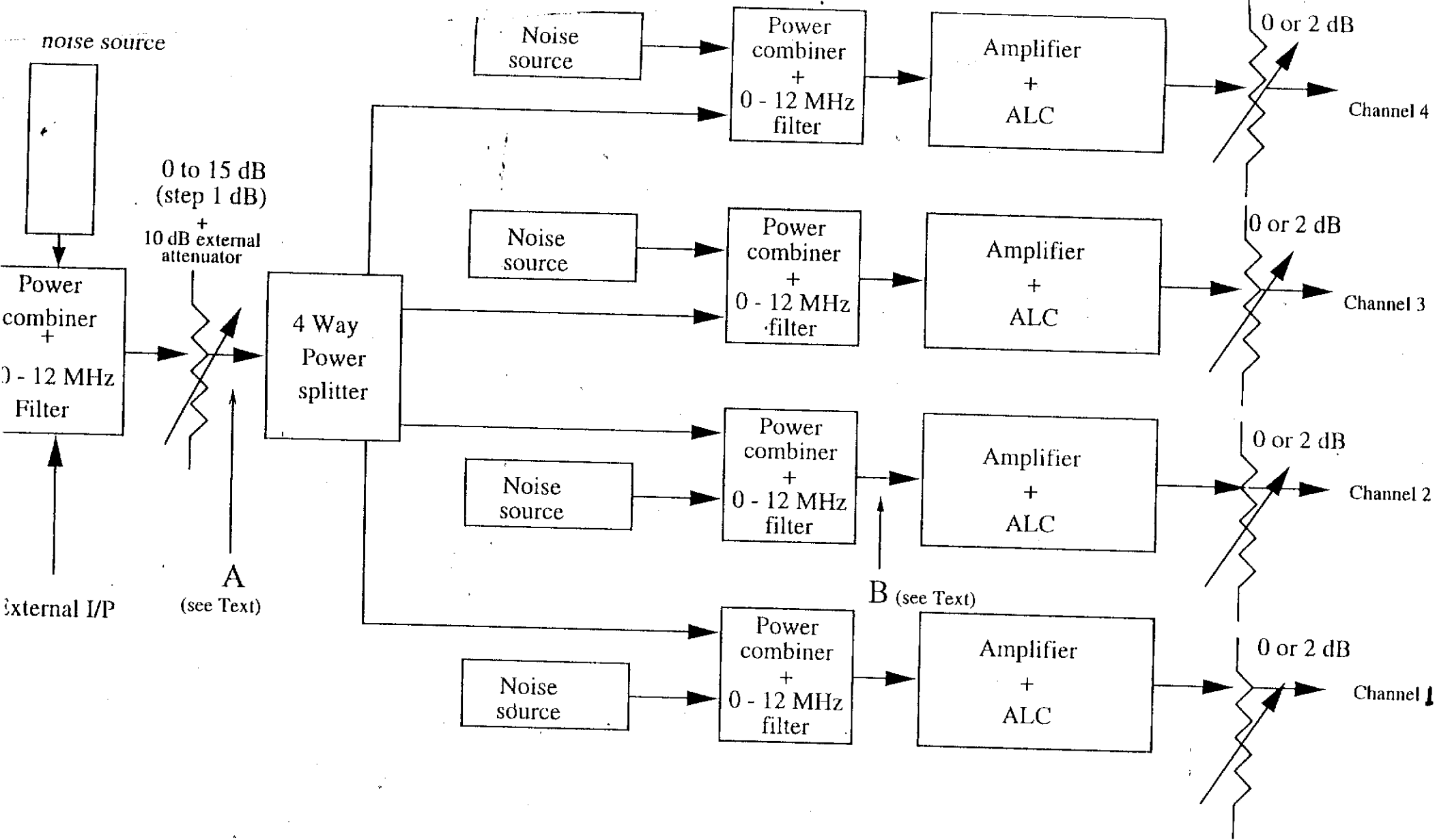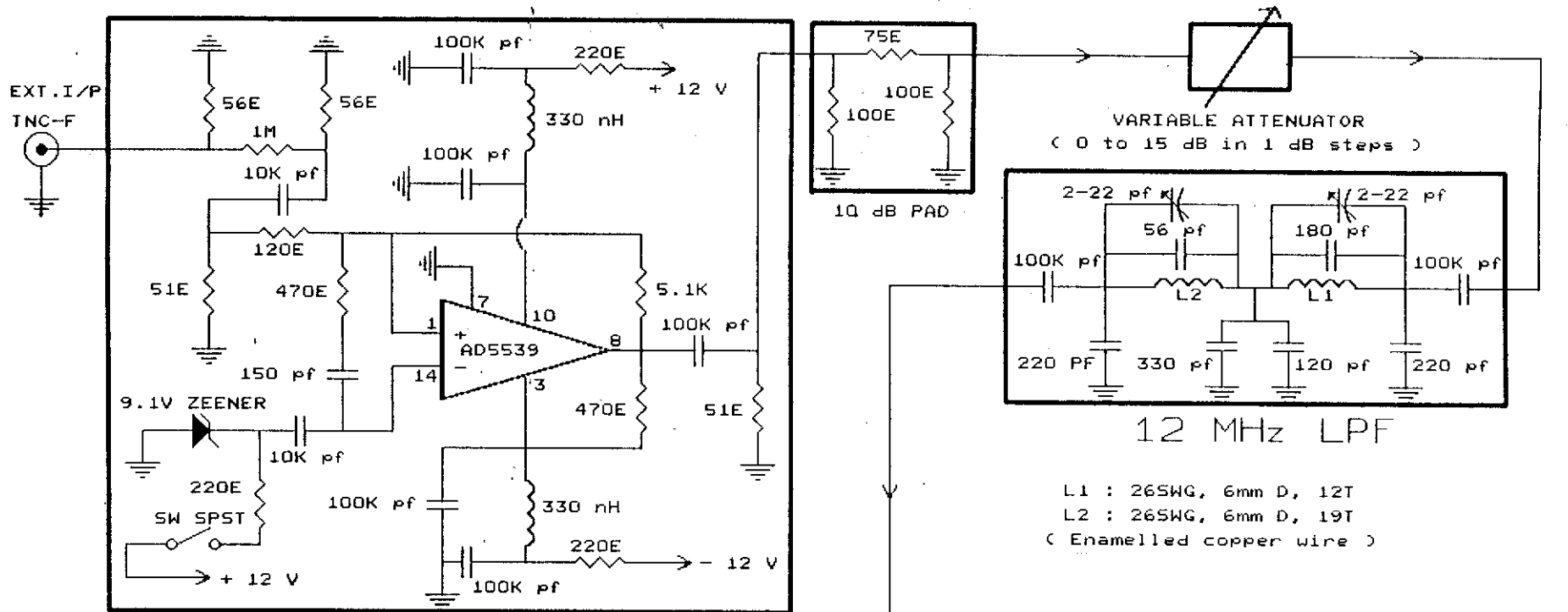
T1 to T4 : Toroidal
    Transformers
T1 : 24 T, 25 twists/"
T2, T3, T4 : 15 T,
    25 twist/"

All toroids wound with
32 SWG enamelled copper
    wire

33 pf
18 pf
T1   T2   51E

T3   100E   2-22 pf

2-22 pf

T4   100E   2-22 pf

2-22 pf

CH.1
CH.2
CH.3
CH.4
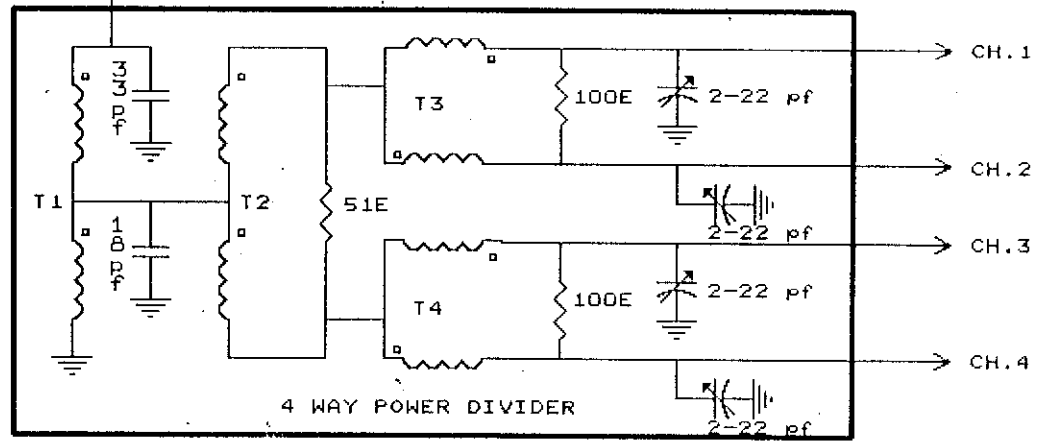
TO NOISE SOURCE
+ AMPLIFIER UNITS

4 WAY POWER DIVIDER

Fig. 2a : 4 CHANNEL CORRELATED NOISE SOURCE.

23-12-99
Drawn by M.Gopinathan

NOISE SOURCE + AMPLIFIER
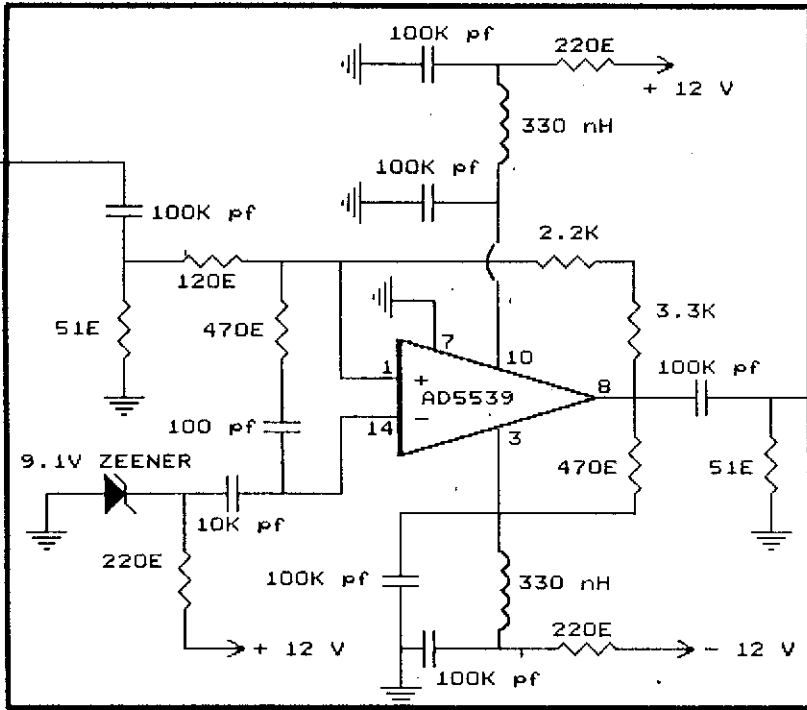
DC Power Supply Requirement
+ 12 V/ 2A
- 12 V/ 2A
- 07 V/100mA

100K pf   220E   → + 12 V
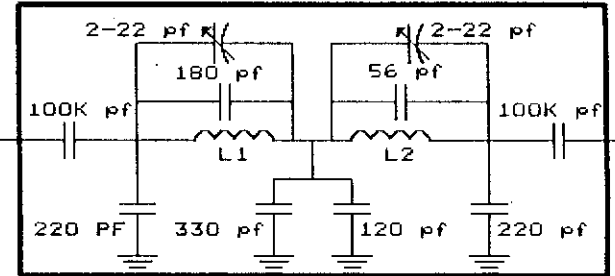
330 nH

100K pf

100K pf

2.2K

3.3K

120E

51E   470E

100K pf

7
1   +   10
AD5539   8
14   -   3

100 pf

470E   51E

9.1V ZEENER

10K pf

220E

100K pf   330 nH

→ + 12 V

220E   → - 12 V

100K pf

12 MHz LPF

2-22 pf

2-22 pf

180 pf   56 pf

100K pf   L1   L2   100K pf

220 PF   330 pf   120 pf   220 pf

L1 : 26SWG, 6mm D, 12T
L2 : 26SWG, 6mm D, 19T
(Enamelled copper wire)

CH. 1

FROM POWER DIVIDER

CH. 2

CH. 3

CH. 4

SAME AS CH. 1
CIRCUITRY

ALC CARD
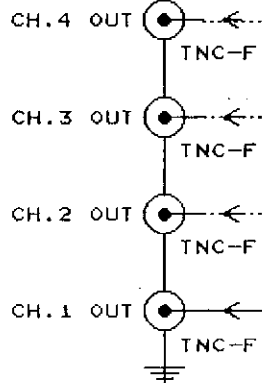
2 dB ATTEN.
(selectable)

CH.4 OUT
TNC-F

CH.3 OUT
TNC-F

CH.2 OUT
TNC-F

CH.1 OUT
TNC-F

12E

GaAs
Switch
SW 239

GaAs
Switch
SW 239

470E   470E

- 07 V
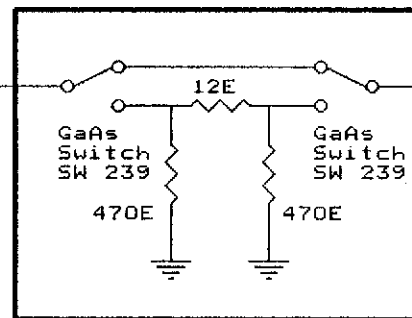
Drawn by M.Gopinathan
23-12-99

4 CHANNEL CORRELATED NOISE SOURCE.

Spectra at Point (A) and (B) (shown in Fig 1) measured with a Spectrum Analyzer

Fig 3

Output spectra of all 4 channels showing the power variation when Attenuators are varied from 0dB to 15dB.

"temp"

Power in dBm

Spectrum
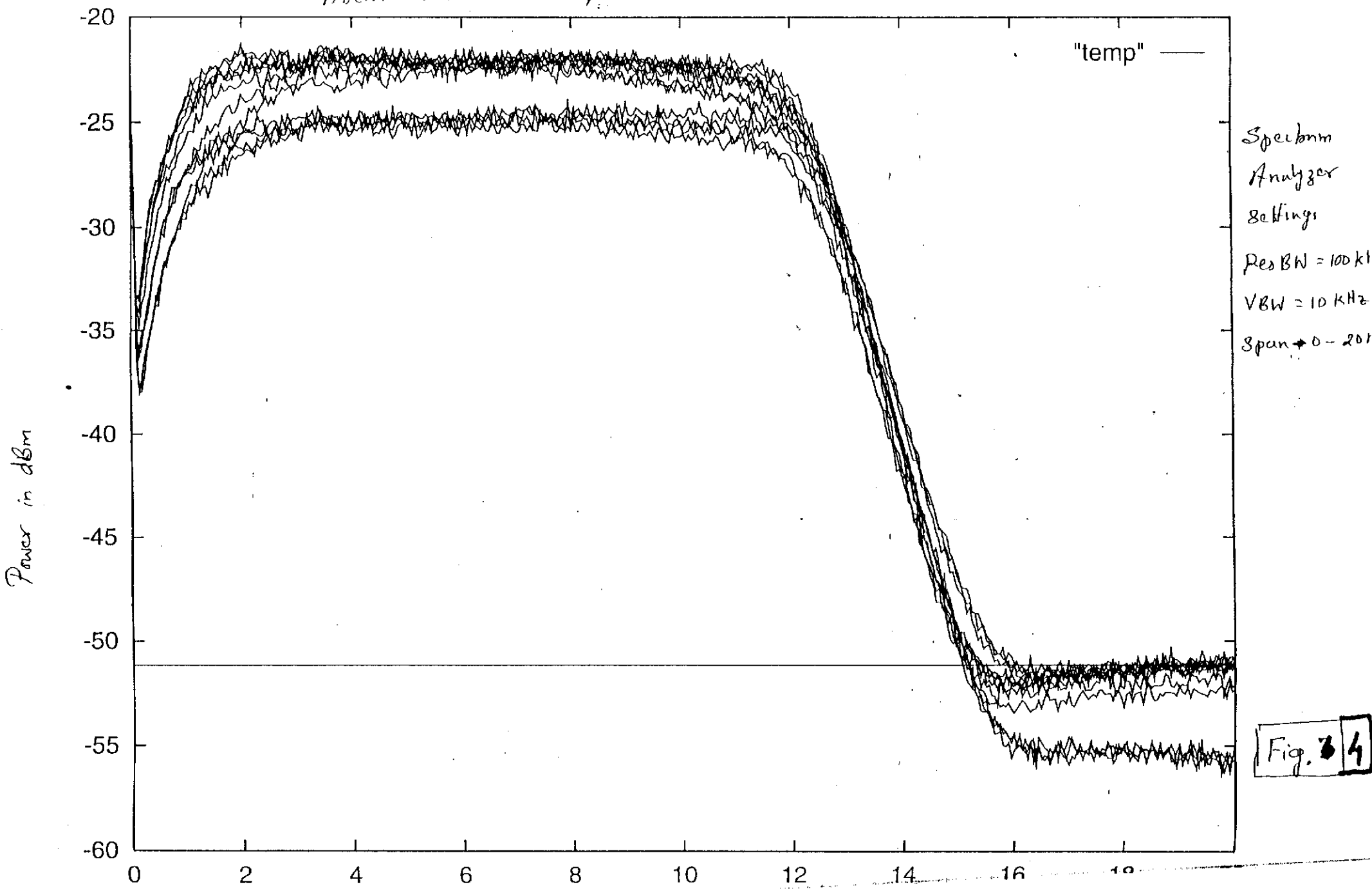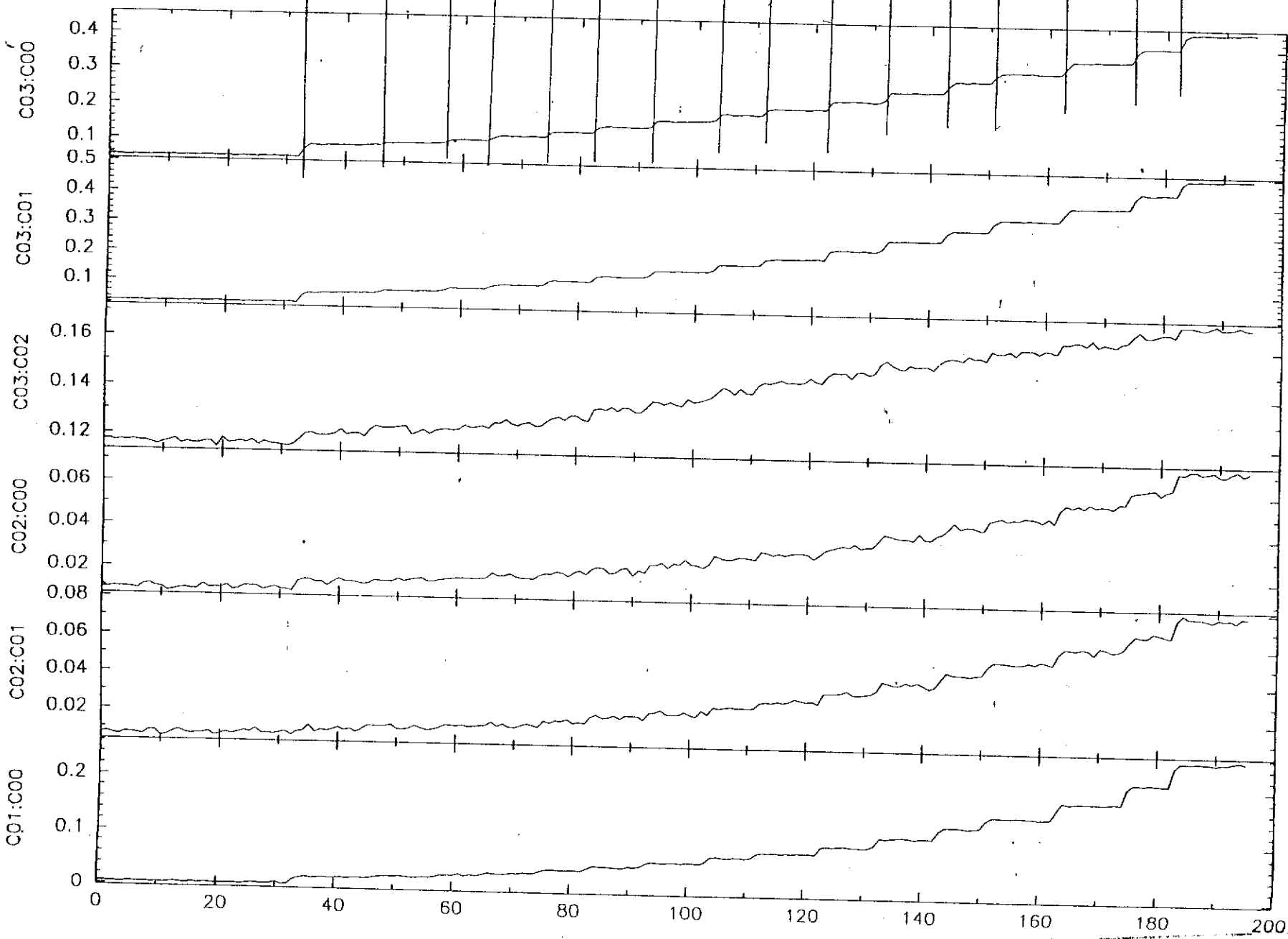Analyzer
Settings

Res BW = 100 kHz
VBW = 10 kHz
Span 0 – 20

Fig. 4

Fig. 5

With 10 dB extern...
fixed attenuator

C_{00} = channel 1
C_{01} = channel 2
C_{02} = channel 3
C_{03} = channel 4

For this plot
Spectral channel
80 was taken.
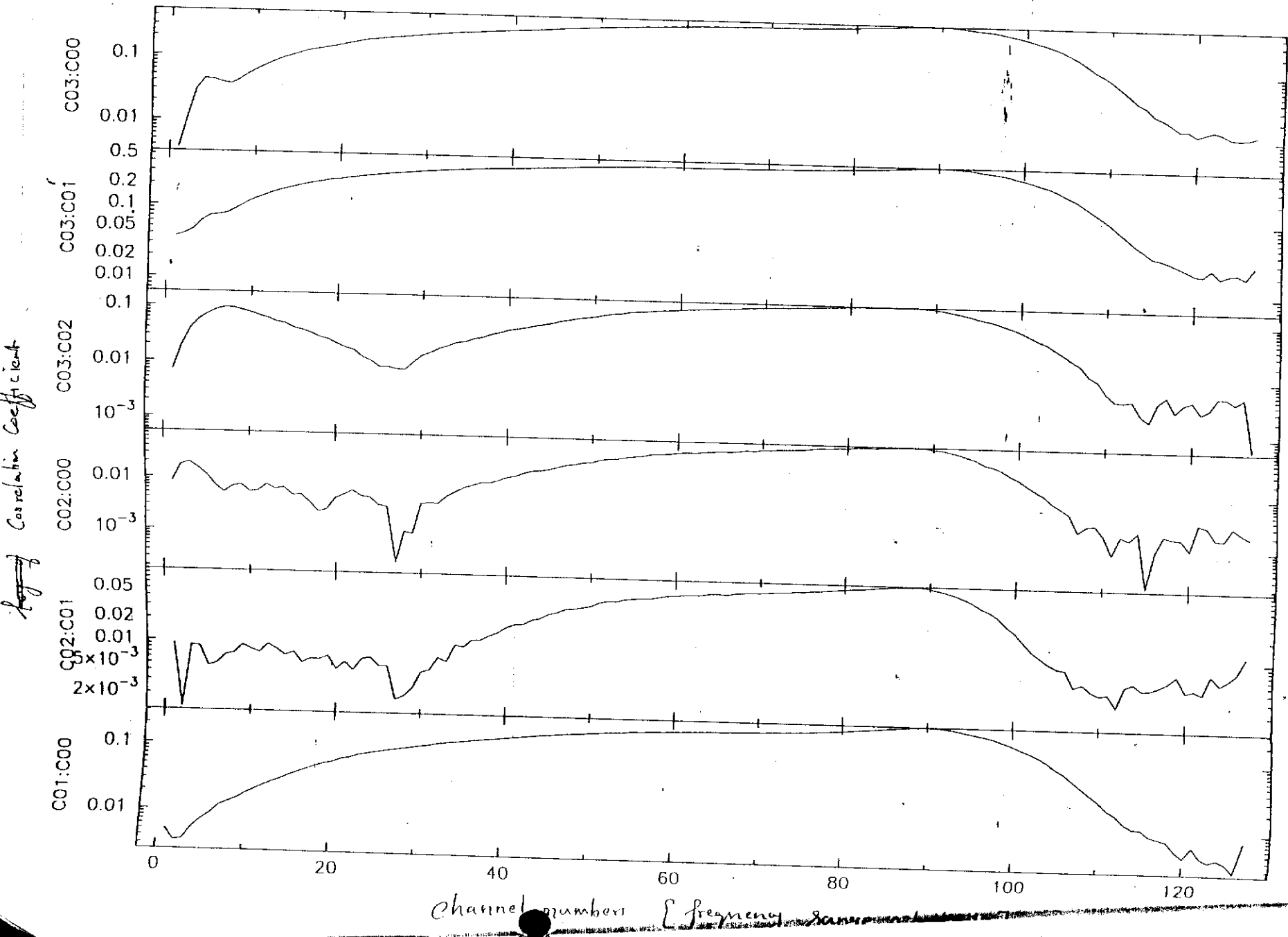This corresponds to
10 MHz and band
width 12$ kHz

Fig 6

C00 — Channel 1
C01 — channel 2
C02 — channel 3
C03 — channel 4

Channel number, [frequency sweep 0 to 14 MHz]

Cross power Spectrum for attenuation value 0 dB. +10dB fixed attenuator
variable

C00 – channel 1
C01 – channel 2
C02 – channel 3
C03 – channel 4

Fig 7

Log Correlation Coefficient

Channel numbers [frequency

Cross power Spectrum for attenuation value 7dB + 10dB fixed attenuator

Variable

C00 — channel 1
C01 — channel 2
C02 — channel 3
C03 — channel 4

Fig. 8

Average Correlation coefficient

Channel numbers [frequency range 0 to 16 MHz]
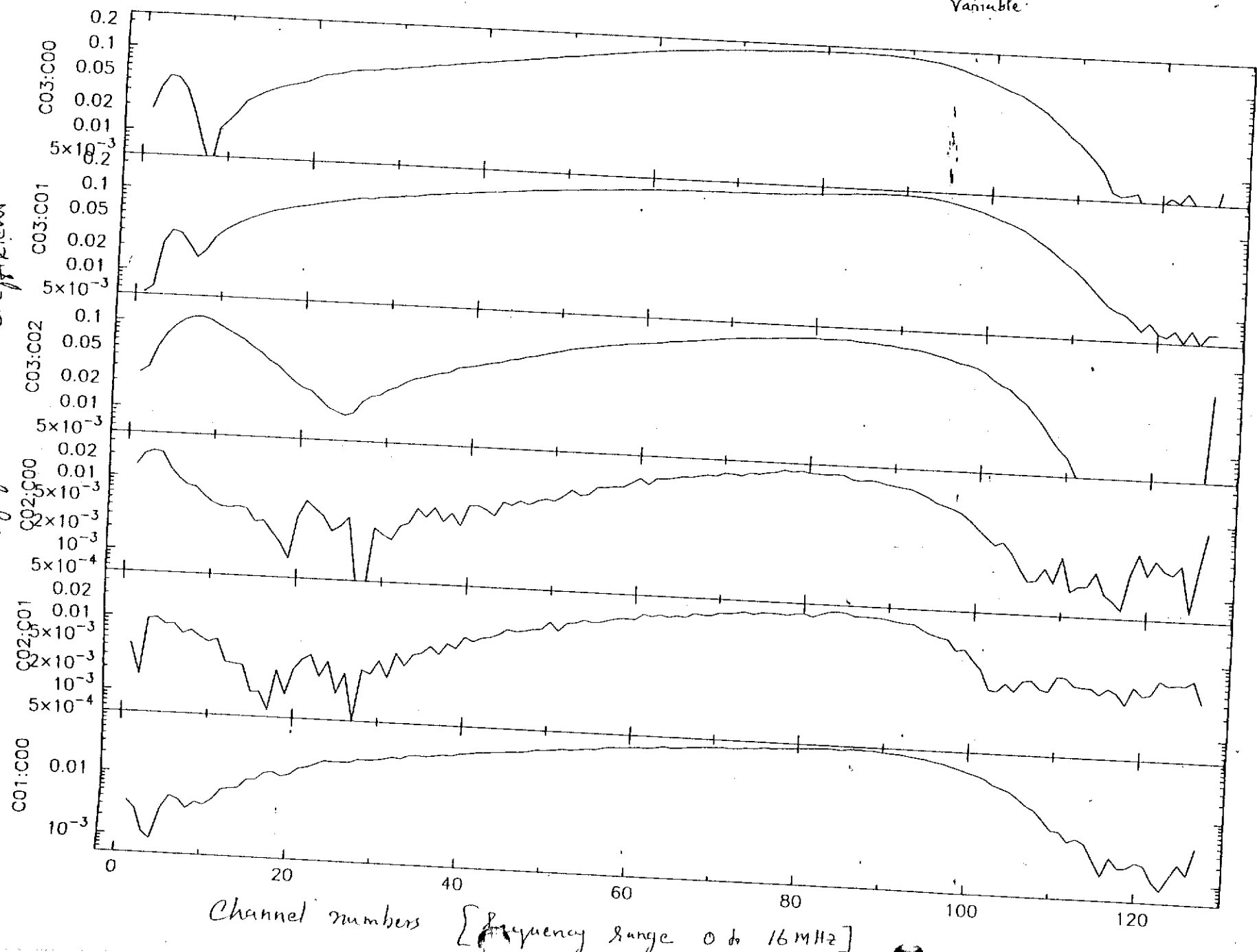
Cross power spectrum when the Common noise source is off.

Channel number [frequency range 0 to 16 MHz]

COO — Channel 1
CO1 — Channel 2
CO2 — Channel 3
CO3 — Channel 4

Channel 4
~~another~~
~~baseline~~
has more coupling
than ~~the antenna~~ due to
limitation due to
the coupling in the
GMRT Correlator.

Fig 9