LB-1068

GALACTIC NOISE - AN IMPORTANT DESIGN CONSIDERATION OF VHF TELEVISION TUNERS

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Approved

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Owing to the presence of galactic or cosmic noise, the effective signal-to-noise performance of a VHF television receiver is not determined solely by receiver noise-factor measurements. This is particularly true for channels 2 to 6, where the galactic noise is an important factor. With increasing frequency the galactic noise falls off at a rate of approximately 7 db per octave, reaching thermal equivalent at about 180 Mc.

In view of galactic noise, it is necessary to re-evaluate the question of whether to design the tuner input to mismatch the source for improved noise factor or to match it for good passband characteristics. The latter approach may be advisable.

Introduction

In the design of a VHF television tuner, noise factor has been taken as one of the most important criteria. A typical VHF television tuner may exhibit a noise factor of 4.5 db at channel 2 and 8.5 db at channel 13 when measured in the laboratory. From the measurements, it might be assumed that a similar difference in signal-to-noise ratios would be expected in actual operation of the receiver with equal signal strength at these two channels. This is not true, however, since the receiver is subject to external influences when connected to an outdoor antenna. Under this condition, the 'system noise factor' must be used, which is defined as the equivalent noise factor of the entire receiving system including the antenna, transmission line, and the VHF receiver. The most important component of such external influences for VHF television tuners is the galactic or cosmic noise.

Effective System Noise Factor[1]

The entire receiving system may also be considered as consisting of four parts.

1. A loss-free antenna – receives a noise power resulting exclusively from external noise sources, primarily the galactic noise at VHF. This noise exceeds the value (kT_0B) by a factor f_a, where k = Boltzmann's constant, T_0 = reference room temperature, and B = effective noise bandwidth.
2. An antenna circuit – has a noise factor f_c. For high efficiency horizontally polarized VHF antennas, f_c may well approach unity.
3. A transmission line – has a loss f_t which is directly equivalent to the noise factor of the transmission line.
4. A VHF receiver – exhibits a noise factor f_r measured in the laboratory.

Using a generalization of Friis' definition and assuming the temperatures of the various parts of the entire receiving system to be equal to the reference room temperature, the effective system noise factor f becomes[2]

$$f = f_a - 1 + f_c f_t f_r$$

The average value of the galactic noise in excess of the quantity (kT_0B) as a function of frequency observed by the Bureau of Standards using a vertically polarized dipole antenna, is produced in Fig. 1.

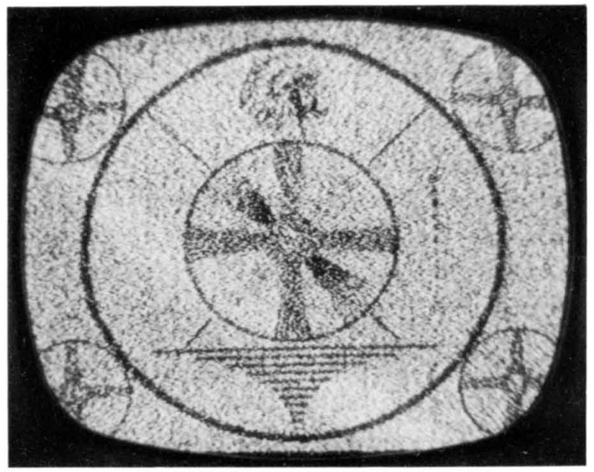
Effect Of Galactic Noise On Television Reception

To verify the effect of galactic noise on television reception, an experiment was made to evaluate the magnitude of f_a in a typical television receiving system. A home in Haddon Heights, New Jersey, a representative surburban area, was selected as the test site using a rotatable Winegard outdoor antenna and an RCA KCS-96 television receiver. The experiment was conducted after

[1] W. Q. Crichlow, D. F. Smith, R. N. Morton, and W. R. Corliss, 'Worldwide Radio Noise Levels Expected in the Frequency Band 10KC to 100MC' *NBS Circular 557,* August 25, 1955.

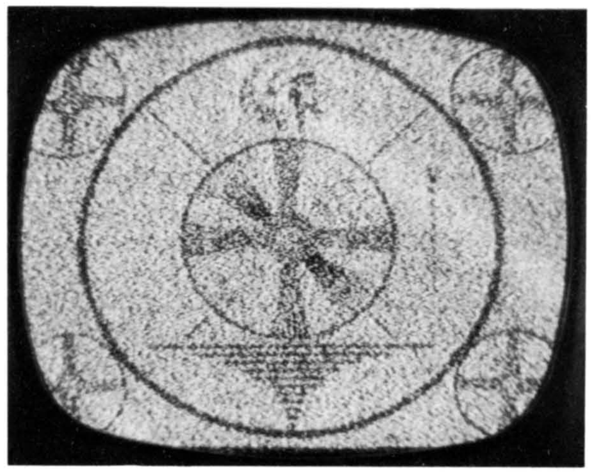
[2] H. F. Friis, *PROCEEDINGS IRE,* vol. 32, p. 419, 1944.

COMPARISON OF PICTURE QUALITIES

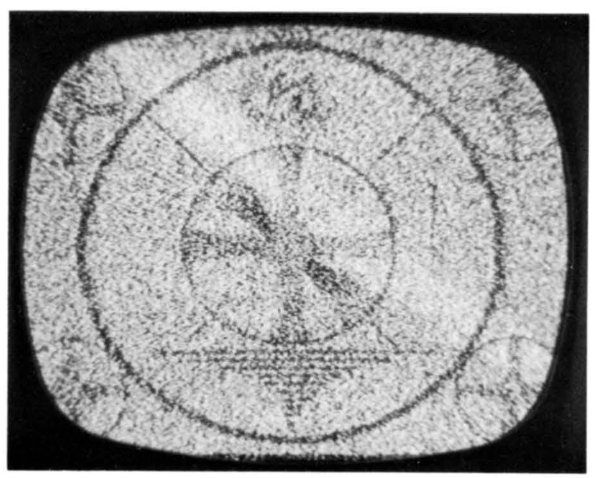


Fa = 11.7 db FR = 4.5 db F = 12.2 db
(1)

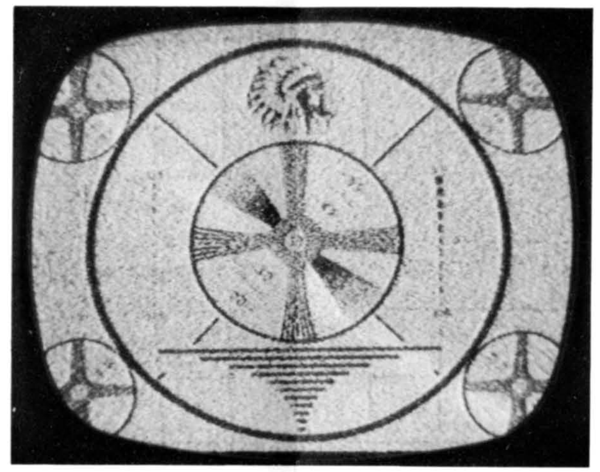
← A. PICTURE QUALITY AT CHANNEL 2, 65 μV SIGNAL WITH GALACTIC NOISE.



Fa = 11.7 db FR = 8.5 db F = 13.2 db
(2)

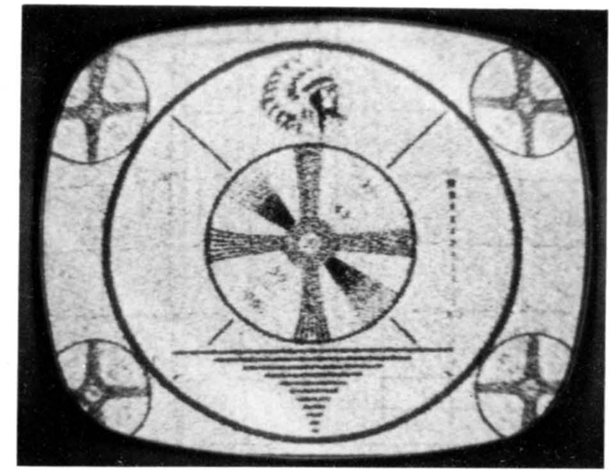


Fa = 11.7 db FR = 12.5 db F = 15 db
(3)

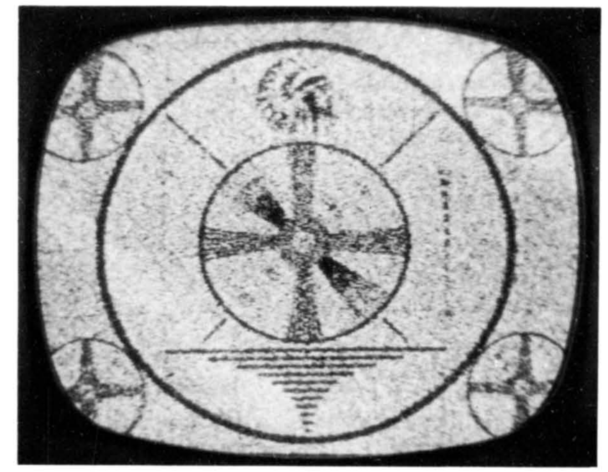


↑ B. PICTURE QUALITY AT CHANNEL 2, 65 μV SIGNAL.
Fa = 0 FR = 4.5 db
(4)

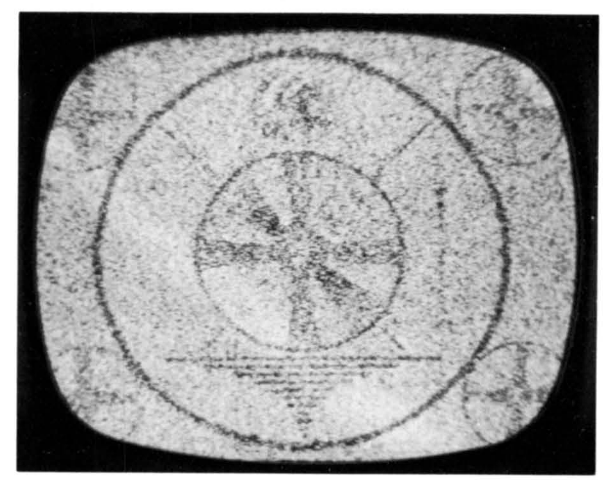
C. THE PICTURES AT THE RIGHT SHOW THE PICTURE QUALITY AT CHANNEL 10, WHERE THE GALACTIC NOISE IS ZERO, 65 μV SIGNAL. →



Fa = 0 FR = 6 db F = 6 db
(5)



Fa = 0 FR = 10 db F = 10 db
(6)



Fa = 0 FR = 14 db F = 14 db
(7)

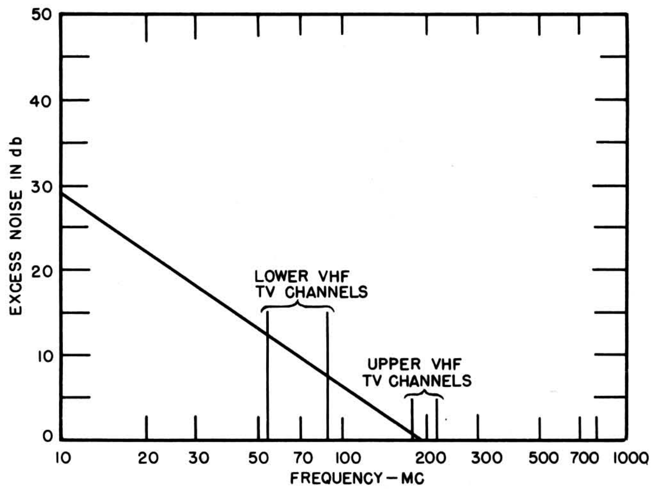


Fig. 1 – Galactic noise component from NBS circular 557.

station sign-off, 0200 EST on Septemper 1, 1956, according to the following procedure.

1. The test receiver was first terminated with a pure resistance of 300 + j0 ohms. The developed d-c voltage at the second detector resulting from the noise present in the receiver was measured with a vacuum-tube voltmeter.
2. The resistive termination was then replaced with the outdoor antenna and the transmission line, and the developed d-c voltage at the second detector was again measured. Eight readings were taken at every television channel corresponding to eight antenna positions, approximately 45 degrees between adjacent positions.
3. Finally, a noise diode was substituted for the antenna. The output of the noise diode was adjusted to produce the same d-c voltages at the second detector as those observed under #2. The excess noise denoted by f_a could then be calculated.

These calculated values of f_a are plotted along the Y-ordinate in Fig. 2. For instance, f_a = 10.5 db at channel 2 and 5.0 db at channel 6 as compared to 11.7 db and 6.8 db respectively of the results observed by the Bureau of Standards. The discrepancies are believed to be within the normal variations of the galactic noise.

It is now possible to determine the system noise factor using the f_a values just established on the basis of a typical television receiving system. For convenience, the relationship between the system noise factor and the receiver noise factor is presented in Fig. 2, assuming that both the transmission line loss f_t and the antenna circuit loss f_c are equal to unity or 0 db. If f_t and f_c are to be considered, they may be added directly to the receiver noise factor so that the curves of Fig. 2 are still applicable. These curves are significant to tuner designers. A certain amount of improvement in noise factor of the present commercial television receivers at the lower VHF channels produces a much smaller improvement in the system noise factor. A 1 to 1 improvement ratio is found only at the higher VHF television channels, e.g., frequencies above 180 Mc.

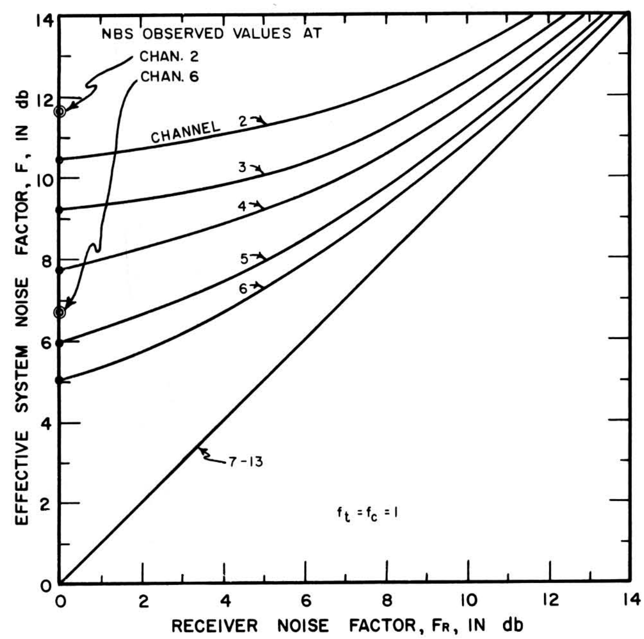


Fig. 2 – Effect of galactic noise on television reception.

Comparison Of Picture Qualities

A further verification of the effect of galactic noise on video transmission was performed in the laboratory (shown in Fig, 3) by comparing picture qualities under various noise levels to simulate the actual operating conditions of television receivers.

The megapix was used as the station and the noise diode as the external or galactic noise source. These two signal sources were fed simultaneously into the receiver under test by means of a matching device having an insertion loss of 6 db for either signal and an isolation between the signal sources of greater than 30 db. The comparison photographs are illustrated in the centerfold section of this bulletin.

Photographs #1 to #3 inclusive in area 'A' on the left are those taken at channel 2 in the presence of 11.7-db noise from the noise diode with a progressively increasing receiver noise factor by means of attenuation pads as indicated in Fig. 3. These photographs represent the equivalent system noise factor f under typical operating conditions of television receivers. The difference in picture qualities between photographs #1 and #4 is the effect of galactic noise on television reception at channel 2 for receivers exhibiting a receiver noise factor of 4.5 db.

If the receiver noise factor is degraded to 8.5 db, a difference of 4.0 db in receiver noise factor, the picture

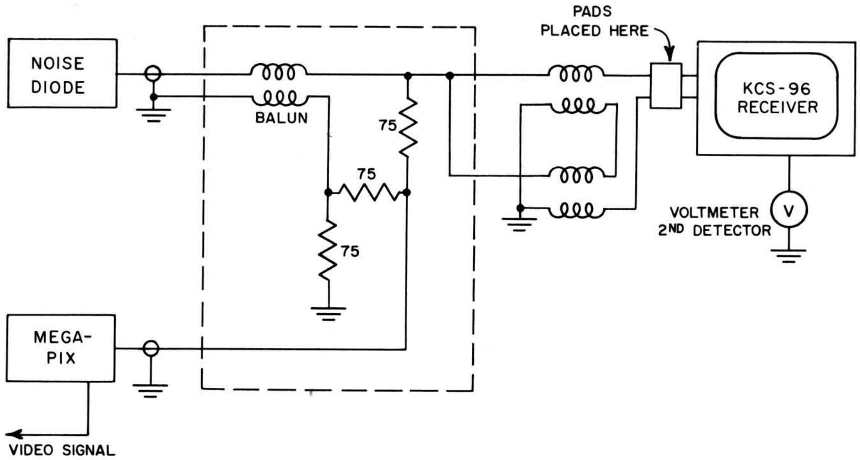


Fig. 3 – Laboratory setup for comparing picture qualities.

quality is displayed in photograph #2 which is to be compared to the picture quality of #1. For all practical purposes, these two television receivers are quite comparable insofar as signal-to-noise ratio is concerned. The degradation of picture quality at channel 2 is definitely discernible if the receiver noise factor is raised to 12.5 db, as evidenced by photograph #3.

Photographs #5 to #7 inclusive in area 'C' on the right are taken at channel 10 with zero galactic noise contribution, but also with a progressively increasing noise factor of the test receiver. It is noted that at the upper VHF television channels the receiver noise factor substantially determines the signal-to-noise ratio of the video picture.

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